ABSTRACT

Title of Document:	THE PERCEIVED UNDERGRADUATE CLASSROOM EXPERIENCES OF AFRICAN AMERICAN WOMEN IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM)
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The purpose of this dissertation study was to explore African American women's perceptions of undergraduate STEM classroom experiences, and the ways in which those experiences have supported or hindered their persistence in physics majors. The major research question guiding this study was: How do African-American women perceive the climate and interactions with peers and faculty in undergraduate STEM classrooms? Using qualitative methods and a multiple case study design, a sample of 11 women were interviewed. This study was also informed by data from 31 African-American women who participated in focus group interviews at annual meetings of the National Society of Black and Hispanic Physicists. Findings indicated that the women excelled in small courses with faculty who took a personal interest in their success. They also perceived that there was a

pervasive culture in physics and other STEM departments that often conflicted with their own worldviews. Findings also indicated that the women's perceptions of classroom experiences varied widely depending on professors' behaviors, institution types, and the level of courses. It is anticipated that through a better understanding of their perceptions of STEM learning environments and factors in their persistence, STEM faculty and departments can better retain and support this population of students.

THE PERCEIVED UNDERGRADUATE CLASSROOM EXPERIENCES OF AFRICAN AMERICAN WOMEN IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM)

By

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Dedication

This dissertation is dedicated to my grandparents. Your lives have been a testament to the power of faith and perseverance. I know the sacrifices you made for me to have this opportunity, and I know the importance you placed on ensuring a bright future for your family. Your sacrifices and prayers were never in vain. I know that you all watch over me, and your spirits will continue to live on through me. Thank you for being my light.

In loving memory of John A. Holmes, James C. Wright and Annie S. Wright

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I have always believed that no accomplishment is achieved alone. Instead, I believe that the grace of God, along with support from family, mentors, and friends have played a major role in my success thus far. With this in mind, I owe a number of individuals a great deal of gratitude for their support, encouragement, and patience during this process.

To my parents, Thomas and Jacqueline - you have been a constant source of strength throughout this process. You have been a listening ear, and helped however you could. I know the sacrifices you have made to ensure that I could pursue my education, and I do not take them for granted. I hope to continue making you proud. To my sister, Christal, no one knows me like you do! You have been an incredible motivator, and you always give me honest feedback, even when I may not want to hear it. For that, I am thankful.

Aside from my immediate family, I have been blessed with an incredibly supportive group of friends, confidants and colleagues. Whether it was discussing ideas with me, meeting up for writing sessions, calling to check on me, or making sure that I kept some balance in my life, you all have helped me achieve this goal. I am constantly in awe of the people who have been placed in my life, and all of your accomplishments. You all inspire me.

I have also been fortunate to have a number of mentors who have invested their time and energy in me. To my mentors past and present – Thank you for believing in me, and thank you for the great examples you set for me.

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opportunity to work with you and get to know you. I thank you for inviting me into your home and family, and I look forward to more opportunities to work together.

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Finally, I believe there has been a divine influence on my life. Last but certainly not least, I thank God daily for the opportunities I have had, the people in my life, and even my struggles. I thank God for this accomplishment.

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Chapter 1: Introduction and Context

In recent years, there have been numerous calls for greater degree production in undergraduate and graduate Science, Technology, Engineering, and Mathematics (STEM) majors in the United States. Government agencies, corporations, and educators have all identified disturbing trends in STEM disciplines. Specifically, these trends include decreased STEM degree production among United States citizens, limited enrollment and degree completion among women and racial/ethnic minorities, and the United States' decreased global competitiveness in these fields (Fouad & Singh, 2011; Hill et al., 2010; National Research Council, 2007, 2010). Each of these groups of stakeholders has called for increased research, funding, and other initiatives to support and sustain individuals who study and work in these disciplines. Special attention has been given to STEM degree completion, as STEM talent is linked to national security, innovation, sustainability, health care, and maintaining vital infrastructures on a national and local level (National Research Council, 2007, 2010).

Societal changes have also increased the demand for STEM majors. The American workforce has become increasingly knowledge-based, and a college education has become an increasingly desirable quality for job applicants (OECD, 1996). There have been a number of local, state and national initiatives intended to increase college enrollments and degree attainment, including a national campaign from President Obama to encourage a year of postsecondary education for all Americans (Bowen et al., 2009; Field, 2009). Subsequently, college enrollments have steadily increased over time. From 1999 to 2009, undergraduate enrollments in degree-granting programs increased by 38 percent, from 14.8 million to 20.4 million students (NCES, 2010). Although college enrollments have increased, a lesser percentage of degrees have been awarded in STEM majors, and STEM degree attainment of women and minorities has remained relatively low. In 2008, underrepresented minorities earned 18.2 percent of all Bachelor's degrees awarded in STEM, and women earned 15.7 percent (NCES, 2010).

In physics, there has been a particularly disturbing trend of declining enrollment and degree completion among African American students across institution types (Mulvey & Nicholson, 2012). Between the years of 1996 and 2010, the proportion of physics degrees awarded to African Americans has fallen by half, from approximately 5% in 1996, to 2.5% in 2010 (Mulvey & Nicholson, 2012). Between 2008 and 2010, of the 5,899 Bachelor's degrees earned in physics, only 157 were awarded to African American students (Mulvey & Nicholson, 2012).

Simultaneously, there has been rapid growth among minority populations in the United States. Between 2000 and 2010, Hispanic/Latino, Black, and American Indian populations grew 43, 12.3, and 18.4 percent, respectively (US Census Bureau, 2011). Although roughly 30 percent of the U.S. Population is comprised of African-Americans, Hispanics/Latinos, and Native Americans, these groups represent only 23.4 percent of enrollments in STEM, and 18.2 percent of Bachelor's degrees earned in these majors (NCES, 2010). The United States 2010 Census Bureau projects that racial/ethnic minorities will outnumber the White population in the United States by the year 2050. Investing in the education of racial/ethnic minorities is in the best interest of the country and ensures that we are tapping the full talent available in the nation.

Within each of the aforementioned racial/ethnic groups, women's enrollment in postsecondary education has grown over time. Specifically, between the years 1999 and 2009, women's undergraduate enrollment grew by 40 percent (NCES, 2010). In spite of this increased representation in American colleges and universities, percentages of Asian, Black, Hispanic/Latina, Native American, and White women in STEM majors at four-year colleges and universities have remained disproportionately low (NCES, 2010). Given their population growth and increased enrollment in postsecondary education, women of color represent a potential large untapped talent pool in STEM. Insight into factors that shape their academic and professional interests, as well as experiences that affect their interest in science and engineering could lead to their increased presence in STEM disciplines and careers. Thus, it is important that we gain a greater understanding of the experiences of minorities who are successful in these majors.

Role of the Classroom among Current Trends in Higher Education

With the increased interest in higher education, many institutions strive to stand out among others to attract the best and brightest students (O'Meara, 2007; Winston, 2000). Many institutions seek to appeal to students through campus enhancements related to student life outside of the classroom such as residence halls, gyms, technology, and dining services (Winston, 2000). Attracting prestigious faculty with strong records of research (or pushing other faculty to research and publish) is another way to attract students and achieve higher standings in rankings (Gamson, 1994; O'Meara, 2007). Though faculty research can benefit students if they are involved in the research process or new concepts are taught in classes, the presence of faculty with name recognition is not always associated with learning gains or positive classroom climates (Astin & Chang, 1995; Wawrzynski, 2004; Massy & Zemsky, 1994). When faculty are pressured to spend more time working on their own research over teaching and advising, they are more likely to spend less time focused on teaching, and out of class contact with students (Milem et al., 2000). In other words, the best-known researchers are not always the most effective teachers, and the overly competitive research environment of colleges and universities striving for prestige can strain faculty in ways that disadvantage students. These types of environments can lead to negative classroom environments as faculty may spend less time on instruction and more time on research.

Remaining competitive in terms of student life and faculty salaries is also costly for institutions, and the expenses of colleges and universities continue to increase (NCES, 2011, Morphew & Baker, 2004; Zemsky et al., 2005). Colleges and universities seek additional revenue from students' tuition and fees, lobbying for increases in state funding, and development campaigns. Given their larger investments in higher education, students, families, and legislators are interested in outcomes directly attributable to the college experience: what students have learned, what new skills they have as a result of a college education, and what percentage of students actually graduate with their desired degrees. These outcomes are largely centered in the classroom environment.

Despite increased enrollments and investments in higher education, college graduation rates in the United States have remained stagnant, and only about half of students who begin an undergraduate degree complete it within six years (Bowen et al., 2009). Classroom experiences play a key role in college retention and degree completion (Astin, 1993; Cabrera et al., 2001; Nora & Cabrera, 1996; Pascarella & Terenzini, 2005; Tinto, 1997; Volkwein, 1991). The classroom environment is directly related to the aforementioned outcomes through faculty contact, institutional commitment, and degree aspirations (Braxton, 2008; Braxton et al., 2008; Kinzie et al., 2008; Nelson Laird et al., 2008; Nora & Cabrera, 1996; Pascarella et al., 2008). Therefore, the classroom experience and subsequent academic outcomes are some of the primary determinants of students' success and persistence in their chosen major and college overall.

Overview of the Study

This particular study is centered on the experiences of African American women in STEM. African American women are a prime group of minority women to study, as they have outpaced African American men in postsecondary enrollment and degree attainment (Kim, 2011), and existing literature provides insight into their pre-college preparation and satisfaction, socialization, and the intersections of race and gender in their college experiences (Collins, 2000; Fries-Britt & Holmes, 2012; Howard-Hamilton, 2003; Winkle-Wagner, 2009). The gender gap in educational attainment is more pronounced between Black men and women than any other racial or ethnic group, yet African American women still earn fewer STEM degrees than women of other races/ethnicities and their male counterparts in a number of STEM majors.

Through this study, I sought to explore the undergraduate classroom experiences of African American women in STEM majors. The purpose of this multi-case study is to explore African American women's perceptions of interactions and practices in formal learning environments that contributed to or hindered their persistence in their chosen undergraduate discipline. Knowledge generated from this inquiry will afford new insights about this population's experiences in STEM and inform higher education practice. The experiences of 31 African American women enrolled (or recently enrolled) in STEM majors informed this study, however I conducted in-depth follow-up interviews with 11 of these participants. I utilized qualitative, case study methodology, and each of the 11 women with whom follow up interviews were conducted represents a case.

This chapter begins with an overview and context that frames the study. Following this is the problem statement, statement of purpose, and research questions. Also included in this chapter is discussion around research approach, and researcher perspective and assumptions. The chapter concludes with a discussion of the rationale and significance of this research, and definitions of key terms to be used throughout the study.

Statement of the Problem

Despite African-American women's increased presence in postsecondary education in the United States, their enrollment and degree completion in STEM majors remains disturbingly low (NSF, 2012, 2013). Research indicates that up until the first year of college, African-American women have an interest in STEM disciplines and careers, yet their interest does not translate to presence in undergraduate STEM majors (Hanson, 2004, 2007, 2008; Hill et al., 2010). The classroom plays a major role in knowledge gains and degree attainment, yet little is known about African-American women's experiences in these environments.

Statement of Purpose and Research Questions

The purpose of this dissertation research is to explore a sample of 11 African American women's perceptions of undergraduate STEM classroom experiences, and the ways in which those experiences supported or hindered their persistence in STEM. This study is guided by the following research question and sub-questions:

How do African-American women perceive the climate and interactions with peers and faculty in undergraduate STEM classrooms?

a. How did they attempt to succeed in these environments?
b. What classroom interactions and experiences did African American women perceive supported their persistence in their majors?
c. How do they perceive that classroom experiences and interactions influenced their identities as scientists?

d. How did classroom interactions compare with interactions with faculty and peers outside of the classroom? (i.e. social settings, office hours)

From this work, I will also identify key factors in persistence and degree attainment among African American women in STEM. It is anticipated that through a better understanding of their perceptions of STEM learning environments and factors in their persistence, STEM faculty and departments can better retain and support this population of students.

Research Approach

With the approval of the University's Institutional Review Board, a team of researchers led by Dr. Sharon Fries-Britt interviewed minority students in STEM majors at joint annual meetings of the National Society of Black Physicists and the National Society of Hispanic Physicists over a five-year period (2005-2009). These participants were enrolled in undergraduate and graduate STEM programs across the United States, and all participants had persisted beyond their first year. Transcripts of focus group interviews from each of the five years of the study have been compiled to form a database replete with information about the lived experiences of minority undergraduate and graduate students in STEM majors. Specifically, analyses have included information about their precollege preparation, parent involvement, faculty and peer interactions, and classroom experiences (Fries-Britt et al., 2010, 2012; Fries-Britt & Holmes, 2012).

A multiple-case study design was used to address the research questions. Creswell (2007) defines case study research as

> …a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of data collection, and reports a case description and case-based themes. (p. 73).

Each individual interview represented a case, focus group interviews, and field notes were used as additional sources of data about the women's experiences. Data were collected and analyzed in two phases: (1) Members of the research team conducted focus groups at annual meetings of the National Society of Black and Hispanic Physicists between 2005-2009, and coded focus group transcripts using themes developed from literature and theoretical frameworks (2) I interviewed self-identified African-American women who participated in the 2005-2009 focus groups, and coded the focus group transcripts and individual follow-up interviews using themes relevant to African American women's classroom experiences.

A comprehensive review of the literature relevant to the experience of minority students in STEM shaped the interview protocols for the larger study and the initial data analyses. As a member of the research team, I recoded the data and analyzed findings specifically from the African American women in the NSBP study, and led follow-up contact with participants. Guided by conceptual frameworks and literature relevant to the experiences of African American women and participants' responses, I developed new coding categories and re-coded transcriptions for new themes (Appendix G). I also arranged follow-up communications with African American women who participated in the study. These follow up interviews served as a primary source of data to inform my dissertation research. In the follow up interviews, I asked questions about their experiences after the NSBP meetings, undergraduate degrees, graduate studies, careers, and any other reflections on their classroom experiences in undergraduate STEM majors (Appendix F).

In-depth interviews were the primary method of data collection, and the information obtained through focus groups involving African American women informed the overall findings of this study. All interviews were recorded and transcribed verbatim, and each participant was identified by a pseudonym during data analysis. To support the findings from the interviews and focus groups, participants were asked to complete demographic forms with information about their race, gender, academic year, major, degree(s) earned, and post-graduate degrees (Appendix C).

Of the 162 participants in the NSBP study, 31 were African American women. Their comments and lived experiences are the basis of this study. I contacted these 31 women to arrange follow-up interviews. Eleven participants participated in individual interviews.

An integrated framework developed based on three theoretical frameworks representative of Black women's experiences in undergraduate STEM courses informed this study. The three frameworks included Carlone & Johnson's (2007) Grounded Science Identity Model for Women of Color, Cabrera et al.'s (2001) Teaching for Professional Competence Model, and Bandura's (1977) Self-Efficacy. Each framework helped identify factors that aid in persistence and degree completion among African American women in STEM majors. Carlone & Johnson's (2007) model outlines a process of science identity development among women of color. Competence, Performance, and Recognition from meaningful others in science contribute to the development of one of three types of science identities. Altruistic scientists utilize science to serve society or communities, research scientists align more closely with prototypical science practices such as lab research, and disrupted scientists have an interest in science, but are unable to reconcile their individual interests and negative experiences in their respective fields. Cabrera et al.'s (2001) Teaching for Professional Competence Model situates students' classroom experiences at the center of development of competencies necessary to be successful in STEM majors and the workforce. Finally, Bandura's (1977) self-efficacy examines the ways in which students' experiences and exposure to role models affect their perceptions of their abilities. More detailed information about the theoretical frameworks and research methodology will be provided in chapters two and three.

Rationale and Significance

This study has direct implications for teaching practices and learning in STEM classrooms and the college environment broadly. It will provide insight into the teaching practices that resonate most with African American women and their unique interests and perceptions of undergraduate STEM learning environments. Several researchers have made connections between classroom experiences and cognitive and affective gains (Braxton et al., 2008; Cabrera et al., 2001; Kinzie et al., 2008; Lambert et al., 2007; Nelson Laird et al., 2008; Nora & Cabrera, 1996; Pascarella et al., 2008; Strauss & Volkwein, 2004; Volkwein et al., 2007), and this study will provide specific, tangible practices that can maximize African-American women's engagement in, commitment to, and subsequent success in STEM majors.

On a broader level, this study includes participants who have been successful in undergraduate STEM coursework and persisted to become upperclassmen. Thus, I approached the issue from an achievement perspective, seeking to gain a greater understanding of factors in the success of African American women who persist in STEM, rather than focusing on those who do not successfully complete STEM degree programs. Although the participants were primarily physics majors, they took a range of STEM courses to fulfill requirements for their majors and minors. Therefore, findings from this study may be relevant to other minority groups in STEM, and may provide greater insight into ways to broaden the participation of these groups in STEM majors and careers. This increased presence of minorities in STEM may lead to greater innovation in these disciplines and reduce our nation's shortfall of students and professionals in STEM majors and careers.

Definitions of Key Terms Used in This Study

The following terms are germane to the conversation about the experiences of African-American women in STEM, but may be either unfamiliar to readers, or may warrant clarification, as they may be defined differently by varying readers.

African-American women[1] - Self-identified women who also self identify as African-American, Black, or descendents of Africans, and are United States citizens or permanent residents. The terms "Black" and "African-American" are used interchangeably.

STEM – Science, Technology, Engineering, and Mathematics majors. The National Science Foundation (NSF) defines STEM majors broadly (Appendix A), however for the purposes of this study, I will focus on natural, physical, and mathematical sciences. In Appendix A, these fields of study are subtitled "Chemistry", "Computer and Information Science and Engineering (CISE)", "Engineering", "Geosciences", "Life Sciences", "Materials Research", "Mathematical Sciences", and "Physics and Astronomy". The participants in this study are heavily concentrated in physics majors.

Classroom Experiences – Classroom experiencs include interactions between students and faculty or peers in academic settings including lectures, discussion groups and laboratory settings. Classroom interactions also include students' exposure to teaching practices, curricular material, and ways of knowing. Cabrera et al. (2001) define classroom experiences as "a complex phenomenon embracing teaching practices, the delivered curriculum as perceived by the students, and the climate permeating interactions among students and between the instructor and the students" (p.332).

[1] One participant in this study (Myriam) does not identify as African-American. She self-identifies as a Black woman of Caribbean descent.

First-Generation College Students - First-generation students are defined as "those whose parents' highest level of education is a high school diploma or less. In cases where parents have different levels of education, the maximum education level of either parent determines how the student is categorized" (Nuñez & Cuccaro-Alamin, 1998). "These students are compared with two groups of students whose parents went to college: those with at least one parent who had some college education, but neither attained a bachelor's degree; and those with at least one parent who earned a bachelor's or advanced degree" (Chen & Carrol, 2005, p. 2).

Historically Black Colleges and Universities (HBCUs) - HBCUs are academic institutions on the list maintained by the White House Initiative on Historically Black Colleges or Universities. The Higher Education Act of 1965 defines an HBCU as: "any historically black college or university that was established prior to 1964, whose principal mission was, and is, the education of black Americans, and that is accredited by a nationally recognized accrediting agency or association determined by the Secretary [of Education] to be a reliable authority as to the quality of training offered or is, according to such an agency or association, making reasonable progress toward accreditation." [2]

Pedagogical Practices – Teaching styles, development of curricula and other classroom activities intended to engage students in intellectual development. Specific pedagogical practices include the use of lecturing, group work, and real-world applications of course material.

Traditionally White Institutions (TWIs) - Colleges and Universities that were founded to serve the White population in the United States, and historically excluded African Americans and other ethnic minorities. The classroom climate for underrepresented minorities in STEM

[2] See http://www2.ed.gov/about/inits/list/whhbcu/edlite-list.html.

within TWIs has been documented as particularly problematic (Seymour & Hewitt, 1997; Johnson, 2007).

Underrepresented Minorities – Three racial/ethnic minority groups (Blacks/African-Americans, Hispanics, and American Indians) whose representation in science and engineering majors is smaller than their representation in the U.S. population (National Academy of Sciences, 2011).

Chapter 2: Review of the Literature

This study is informed by several bodies of scholarship, starting with education and sociology literature to examine the culture of STEM disciplines. This work will provide a context related to the values, norms, practices, and subject matter within STEM majors. Next, I will review empirical studies that have involved African American women and other women of color in STEM to elucidate ways in which these groups of women experience STEM disciplines. I will also examine the role of the classroom in undergraduate student experiences, as well as classroom interactions and their effect on cognitive and affective outcomes. Next, I will outline existing literature on the social and cultural perspectives of African-American women. I will then juxtapose these two bodies of literature to consider the ways in which STEM culture may support or deter African American women, and the ways in which this culture may conflict with the expectations or interests of African American women. Finally, I will identify theoretical frameworks relevant to this topic, which will inform my own research.

Culture of STEM Disciplines

Several researchers have sought to identify and describe the disciplinary culture of STEM by examining the norms, expectations, practices, and widely accepted beliefs within STEM disciplines (Bleier, 1986; Conefrey, 2001; Kuhn, 1962; Museus et al., 2011; Ong et al., 2011; Seymour & Hewitt, 1997; Tradweek, 1988; Varma, 2002). These studies were all developed from educational, feminist, and sociological perspectives. There is very limited discussion of STEM culture in literature from individuals who are researchers and educators in STEM disciplines themselves. In fact, several researchers have noted avoidance of discussions about social issues as a common practice in STEM departments (Johnson, 2007; Ong et al., 2011; Varma, 2002).

Sociologist Thomas Kuhn (1962) identified characteristics and fundamental beliefs commonly propagated by teachers in STEM disciplines. Kuhn asserts that science is influenced by societies at a given time, as certain laws, theories, and ways of knowing are accepted to be true. Kuhn also asserts that scientists often engage in the promotion of "normal science", and have a tendency to seek knowledge within a set process: the scientific method. When discoveries are made that challenge accepted knowledge or traditional ways of knowing, Kuhn suggests that they are frequently met with skepticism and rejection from the science community. The scientists who challenge norms are often ostracized and isolated by colleagues in science. Based on Kuhn's work, it seems that STEM scholars and departments often have set expectations about approaches to research and other scientific problems, and there is little room for different approaches and perspectives in these spaces.

A number of researchers have found that STEM majors have departmental climates, academic expectations and faculty demographics unlike those of other disciplines in the humanities, arts, or behavioral and social sciences (Johnson, 2007; Seymour & Hewitt, 1997). Specifically, many departments and faculty in STEM fields reinforce traditionally white male norms and interactions as part of an "institutionalized national (possibly international) teaching and learning system which has evolved over a long time period as an approved way to induct men in to the adult fraternities of science, mathematics, and engineering" (Seymour & Hewitt, 1997). Johnson (2007) identified behaviors rewarded in science:

> Success in the science settings I have described demands drawing attention to oneself in public; knowledge of how to succeed in a predominantly white, male-dominated competitive environment without encouragement; enjoyment of personal interactions

centered on information rather than relationships; and obliviousness or callousness toward a lack of acknowledgement of race, ethnicity, and gender. (p. 818)

Each of the aforementioned behaviors can disadvantage students from underrepresented groups (such as African American women) whose interests in science are often fueled by a desire to serve larger societal goals (Hanson, 2004; Johnson, 2007). For African American women in particular, encouragement and recognition are factors directly correlated with success in STEM (Carlone & Johnson, 2007).

In several studies, researchers have examined the perspectives of women and women of color as they pertain to departmental cultures in physics and STEM (Carlone & Johnson, 2007; Conefrey, 2001; Johnson, 2007; Justin-Johnson, 2004; Ong 2002, 2005; Ong et al., 2011). These groups of students have consistently described experiencing discrimination from peers and faculty based on their gender and race in STEM departments (Carlone & Johnson, 2007; Conefrey, 2001; Crawford & MacLeod, 1990; Justin-Johnson, 2004; Malone & Barabino, 2008; Ong, 2005; Sosnowski, 2002; Valenzuela, 2006). These incidences are particularly common among students who attended Traditionally White Institutions, and include invisibility, isolation, marginalization, and negative perceptions from peers and faculty (Conefrey, 2001; Johnson, 2007; Malone & Barabino, 2008; Seymour & Hewitt, 1997; VanLangen & Dekkers, 2005). This exclusion may lead to a lack of exposure to resources, networks, and heuristic knowledge in the field for female and minority students (Malone & Barabino, 2008). Furthermore, being ignored and overlooked equates to a lack of recognition, and may hinder the development of a positive science identity among women of color in STEM (Carlone & Johnson, 2007).

Based on a two year ethnographic study on women in STEM, individual interviews, and a review of literature examining women’s experiences in STEM majors, Theresa Conefrey (2001) identified 12 myths sustained by many STEM departments in the United States. These myths included assumptions that science is a "gender-neutral" and "value-free" meritocracy, no changes are needed in STEM curricula or pedagogy, challenge and competition are essential to science, and failure is students' own fault. She asserts that the STEM community's continual acceptance of these beliefs contributes to women's continued marginalization in these fields.

Research on women of color's perspectives on STEM culture alludes to tensions between this culture and the women's experiences. In a meta-analysis of literature on the experiences of women in STEM, Ong and associates (2011) described the apparent tension between the cultures of STEM departments, and women's experiences therein. The authors noted that STEM departments "…include a structure that is supposedly meritocratic in nature and focus on grades, classroom performance, and research results, which nevertheless ignores the social realities of racism and sexism in science environments." Sharon Traweek (1988) also described science as inhabiting a "culture of no culture", in which scientists gain authority and prestige from portraying their work as "objective, universal, and context free" (Haraway, 1991; Harding, 1991; Ong, 2005; Traweek, 1988). In another report on minority students' perspectives in STEM, Museus et al. (2011) characterized STEM departments as individualistic and competitive; noting that these type of environments "conflict with the cultural orientations from which many minority students come" (p. 70).

Seymour & Hewitt (1997) conducted a major qualitative study involving 460 students majoring in science and engineering at seven different colleges and universities. In their subsequent book titled *Thinking About Leaving: Why undergraduates leave the sciences*, Seymour & Hewitt (1997) interviewed students who left science majors, yet had strong grades in their coursework. The authors identified a number of key factors related to departmental cultures, faculty behaviors, and expectations of students that often reflected white male norms and isolated students from other backgrounds. These practices included 'weed out' classroom cultures, overly competitive peer interactions, and faculty dependence on lectures and textbooks instead of interactive teaching practices.

Students in the study also felt that material was often designed to be unnecessarily difficult to perpetuate the idea of the sciences as "hard majors" and "weed out" academically weak students. They perceived competitive environments wherein the progress of peers was often perceived as a threat to one's own success. Large classes, demanding work loads, fast-paced coverage of material, emphasis on individual over collective achievement, and poor pedagogy were also themes reported by many participants in the study (Seymour & Hewitt, 1997). One of Seymour & Hewitt's (1997) most interesting findings was that students who left the sciences did not leave because they failed to comprehend the material and earned poor grades. In fact, their grades were strikingly similar to those of students who persisted in science. Therefore, Seymour & Hewitt (1997) asserted that the negative climates and social norms of many science departments ultimately cause many students to leave these majors.

Johnson (2007) delved deeper into many of the issues addressed in Seymour & Hewitt's (1997) study. By interviewing women of color in STEM fields, Johnson was able to ascertain the ways in which specific faculty behaviors in STEM discourage this group of students underrepresented in their respective fields. Participants reported that faculty in their departments seemed to believe that a meritocracy existed within their departments, and knowledge and academic talent were the sole determinants of success in the field (Johnson, 2007). These individuals often believed that race, gender, and ethnicity had no place in research and dialogues about science. The students found this façade of a meritocratic science culture stifled discussion about the realities of biases and racism that they often experienced in their departments: “This match between whiteness, maleness, and the characteristics need for success in science was hidden in this setting by the silence about race, ethnicity, and gender, which was in turn hidden by the rhetoric of meritocracy” (Johnson, 2007). Ong (2005) also summarized this experience, stating “to claim membership in the context of science, women of color must maintain the appearance of belonging to a culture of no culture” (p.598).

Students in a study by Johnson (2007) identified more specific classroom practices that made them feel discouraged in STEM courses. They reported that the large class sizes, answering questions in class, and negative experiences with faculty in research settings were particularly discouraging. Johnson (2007) found that faculty in their departments tended to teach about specific aspects of science without situating them in a larger context. This decontextualization of science created distance between science and the women’s identities, and caused them to feel disconnected from the course material (Johnson, 2007). Large class sizes prevented participants from being able to connect with their professors and made them feel invisible among the masses of other students. Participants in the study felt that faculty often presented questions to their classes as a challenge wherein students had to prove that they understood the material, rather than asking questions to provide engaging learning opportunities (Johnson, 2007). To hesitate or ask follow-up questions would signify a lack of knowledge rather than an intent to learn more about the topic (Johnson, 2007). Students interviewed by Carlone & Johnson (2007), echoed sentiments about the intimidating nature of professors’ communication styles in STEM lectures:

> Merima: Whenever I go talk to molecular biology professors…they make me feel stupid.
> Chris & Monica: Uh-huh

> Merima: I couldn't even divide ten thousand by ten- I was so nervous. One time he said, "Did you understand what I just said?" I said "Uh-huh," so he said "Repeat in your own words," and I couldn't….
> Angela: What are they doing that makes you feel stupid?
> Monica: They put you on the spot.
> Merima: And they're not too friendly. If you don't know the answer, they just wait.
> Chris: It's like they expect you to know the answer. And then, if you don't, they just wait. They don't tell you the answer. (p.1205)

The observations of women of color in STEM provide insight into the culture and norms that pervade science and math departments. These norms can intimidate and marginalize groups underrepresented in STEM such as African American women.

In 2010, over 75% of STEM faculty members at 4-year colleges and universities were white men, and approximately 6% were underrepresented minorities (NSF, 2010). In that same year, only 7% of doctoral degrees in STEM were awarded to underrepresented minorities (NSF, 2010). Students graduating with doctoral degrees serve as the pipeline of future faculty, therefore the limited number of minority students with terminal degrees in STEM indicates that the demographics of the STEM professoriate are unlikely to change drastically in the near future. Therefore, improving the culture of STEM departments must be a combination of grooming more future faculty from minority and majority backgrounds capable of connecting with diverse student populations, and changing the practices of current STEM faculty and departments.

Role of Classroom Experiences in Cognitive and Affective Development

The classroom experience is defined as a "complex phenomenon embracing teaching practices, the delivered curriculum as perceived by the students, and the climate permeating interactions among students and between the instructor and students" (Cabrera et al., 2001). A number of researchers have focused on the classroom experience and its unique role in engaging and retaining students from a wide range of backgrounds (Astin, 1993; Cabrera et al., 2001; Nora & Cabrera, 1996; Pascarella & Terenzini, 2005; Tinto, 1997; Volkwein, 1991; Volkwein et al., 1986). Most of the academic discourse about classroom-based outcomes has been interwoven in student development and retention theories (Astin, 1993; Nora & Cabrera, 1996; Tinto, 1993, 1997). In these theories, classroom experiences are mentioned as one of a variety of interactions affecting student development and degree commitment. However, classroom and social interactions do not occur in isolation from one another. Several studies note that academic and social experiences are linked to one another, in the sense that positive or negative experiences in one domain, can result in similar experiences in the other (Cabrera et al., 1999; Nora & Cabrera, 1996; Tinto 1993, 1997)

Overall, these studies provide compelling evidence that interactions between faculty and students in the classroom learning environment lead to cognitive and affective gains. Cognitive gains involve students' knowledge of subject matter and approaches to making meaning of complex topics. Cognitive development extends beyond a particular course of study and includes improvements in critical thinking, problem solving, and epistemological development (Astin, 1993; Pascarella & Terenzini, 2005). Affective gains include predispositions toward learning such as academic or intellectual self-confidence, educational aspirations, and satisfaction with college (Astin, 1993; Nora et al., 1996). Prior to the 1990s, the majority of literature related to cognitive and affective gains in the classroom environment was based on studies in K-12 schools (Slavin, 1990). However, researchers studying this topic recognized that similar findings were often applicable in the higher education setting (Cabrera et al., 2001; Gamson, 1994; Tinto, 1997).

In his widely cited theory of student departure, Vincent Tinto (1993) asserts that students acclimate to their academic and social environments in college, and identifies this integration as a necessary precondition for student persistence. In later studies, he addressed differences in the experiences of minorities and non-traditional students, and made classroom experiences a focal point of his work on student departure. Tinto (1997) argues that the classroom should play a more central role in theories related to student persistence, and greater attention should be placed on classrooms in addressing such issues.

In another student involvement theory based upon a longitudinal study of students who left college, Astin (1999) posits that the level of student involvement in a given assignment, course, or activity is directly related to the outcomes gained from it. Astin defines involvement as "the amount of physical and psychological energy that the student devotes to the academic experience" (p. 518). Consistent with findings from numerous other studies, he notes that student-faculty interaction is more strongly related to satisfaction with the college experience than any other variable. Interestingly, Astin suggests that intense academic involvement may actually isolate students from their peers and inhibit the development of some affective outcomes (Astin, 1999). He adds that intense academic involvement may actually aid in the development of undesirable outcomes such as a need for status.

The most explicit connections between classroom experiences and cognitive/affective outcomes have been made in studies intended to inform assessment practices (Cabrera et al., 2001; Lambert et al., 2007; Volkwein et al., 2007). In a study based on the classroom experiences of students majoring in engineering, Cabrera, Colbeck & Terenzini (2001) found direct connections between student learning and instructor interaction and feedback, collaborative learning practices, and instructor clarity and organization. In 2007, Volkwein and associates examined the extent to which accreditation criteria affected teaching and learning in engineering programs. The authors found that new assessment criteria for the Accreditation Board for Engineering Technology (ABET) enhanced teaching practices and strengthened student outcomes. These studies not only provide clear connections between classroom interactions and learning outcomes, but also propose strategies for faculty and academic departments to create academic environments more conducive to student learning gains.

Several studies have documented that positive classroom interactions lead to affective gains such as increased goal commitment, educational aspirations, satisfaction with college, and self-efficacy (Braxton et al., 2008; Kinzie et al., 2008; Nelson Laird et al., 2008; Nora & Cabrera, 1996; Pascarella et al., 2008; Strauss & Volkwein, 2004). These gains ultimately increase persistence and degree completion. Affective gains are also related to cognitive development, and increases in one dimension of outcomes often lead to gains in the other (Chang et al., 2004; Pascarella & Terenzini, 2005). Learning communities and collaborative learning practices are beneficial to student persistence/engagement. Other researchers' work has supported this argument (Cabrera et al., 2002; Lambert et al., 2007; Pascarella & Terenzini, 2005; Triesman, 1992).

Some researchers suggest that factors in the college experience other than the classroom experience are equally pertinent to retention and development (Chickering & Reisser, 1993; Perry, 1968, Thiry et al., 2010). Interactions with peers in residence halls, informal discussions about moral issues, and extracurricular involvement can all affect students' cognitive and affective development. These findings do not necessarily negate the role of classroom experiences, but suggest that they are not the only factor in development and retention. Interestingly, Nora and associates (1996) found that faculty-student interaction outside of the classroom context is most beneficial to female students. Even considering these alternative perspectives, it is clear that positive classroom experiences and interactions with faculty serve to benefit, not harm students. Existing literature about student experiences in STEM is largely comprised of studies assessing the impact of specific extracurricular programs, or analyzing trends in quantitative data. Considering the importance of classroom experiences in academic outcomes, we know very little about what actually happens in the classroom, and how students perceive the interactions therein.

Classroom Climate

Classroom climate is defined by the behavioral norms and hierarchical positions within the academic setting. Classroom climate is a complex, fluid concept, and perceptions of climate can vary person to person based upon their interpretation of interactions that take place in the classroom context. Specific elements of classroom climates include racial climate, verbal and nonverbal communication between instructors and students, the nature and frequency of faculty-student interactions, students' comfort level with asking questions or seeking assistance, and course curricula (Pascarella & Terenzini, 2005). Other elements include what types of knowledge, comments, and discussions are valued, and the presence of social hierarchies that may distance faculty from students or students from one another (Pascarella & Terenzini, 2005). These types of hierarchies may establish one individual or groups of individuals as viable sources of knowledge yet discredit or minimize the role of others. Students' learning styles in a given classroom may also affect the classroom climate, as some students may prefer to work in groups or connect theoretical concepts to real-world examples. Learning styles are particularly relevant to women and minority students, as there is evidence that women and minorities tend to favor cooperative problem solving, connected knowing, and socially based knowledge (Cabrera et al., 2002).

Within many Traditionally White Institutions (TWIs), women and minorities describe academic and social environments where they feel isolated, excluded, and marginalized (Fries-Britt & Griffin, 2007; Fries-Britt & Turner, 2001, 2002; Hall & Sandler, 1982; Johnson, 2007; Malone & Barabino, 2008; Nora & Cabrera, 1996; Solórzano et al., 2000). Hall & Sandler (1982) described these environments as having "chilly climates". In a different study, Solórzano et al. (2000) described subtle actions that make individuals feel marginalized as "microagressions". Microaggressions directed at women minority students in the classroom context include ignoring their presence and perspectives, expressing low expectations despite adequate performance in class, passive-aggressive or loaded comments, and exclusion from teams of peers (Solórzano et al., 2000). Fries-Britt & Turner (2001, 2002) compared the experiences of African American students at HBCUs and TWIs and identified differences in the experiences of students at each type of institution. They found that negative stereotypes and expectations to represent Black people collectively were particular sources of stress for students at TWIs. Although none of these studies were based solely classroom settings, the terminology that emerged from them is representative of experiences described by minorities and women in these learning environments.

Outcomes Related to Classroom Climate

Classroom climates have direct implications for student learning and development (Hurtado et al., 1998, Nora & Cabrera, 1996). I will examine two particular dimensions of classroom climates: the presence of diverse students and perspectives, and learning environments created by professors. The first dimension addresses the importance of inclusive classes, often reflective of an institution's broader commitments to campus-wide racial/ethnic diversity.   The latter dimension points to the unique role of faculty and instructors in creating learning spaces conducive to learning for all students.

Presence of Diverse Students and Perspectives

Arguments for diversity in higher education were brought to the forefront in landmark cases weighing the benefits of affirmative action in college admissions (Gurin, 1999). Gurin (1999) and other researchers sought to link the presence of students from diverse racial/ethnic backgrounds to gains in academic and psychosocial student outcomes. It is important to note that inclusive campus and classroom climates have particular benefits for women and underrepresented minority students, but result in gains for all students. Therefore, enhancing classroom climates is in the best interest of all students in a given course or department (Cabrera et al., 2002; Tinto, 1997).

In her work on this topic, Gurin (1999) found that diversity often changes the classroom climate by adding different perspectives, learning styles, and approaches to complex problems. Diverse classrooms and social experiences positively affected two types of outcomes in students: learning outcomes and democracy outcomes. Learning outcomes are directly related to the classroom experience, and "refer to active learning processes in which students become involved in college, the engagement and motivation that students exhibit, the learning and refinement of intellectual and academic skills, and the value students place on these skills after they leave college" (Milem & Hakuta, 2000, p.393). Democracy outcomes involve skills such as cultural awareness that will enable students to function in a diverse society and work environments (Gurin, 1999).

Students who interact with diverse peers in college experience greater gains in critical and active thinking relative to their peers who interact with more homogeneous groups. Students who report high levels of exposure to diverse ideas and people also report growth in complex thinking, intellectual engagement in classes, and motivation (Gurin, 1999). Discussions about race and cross-racial interactions have a positive effect on students' retention, intellectual self-concept, and social self-concept (Chang, 1999). Students with frequent interactions with diverse peers also reported higher overall satisfaction with college and graduate degree aspirations (Chang, 1999; Gurin, 1999).

Cabrera, Colbeck & Terenzini (2001) found that among undergraduate engineering majors, peer classroom climate was positively related to the development of group skills. Interestingly, peer climate did not have a significant effect on problem solving skills and occupational awareness. Similarly, Lambert and associates (2007) found that engineering students' analytical and group skills are enhances when they perceive that their programs are open to diverse ideas and people.

Although many of the studies linking interactions with diverse peers to outcomes are not solely based upon classroom interactions, Chang (1999) asserts that classroom interactions are some of the most frequent/consistent among other activities in college. Students attend classes multiple times each week with the same groups of students for extended periods of time. After class, students often reflect on discussions and study the material with peers. Furthermore, in classroom environments where active and collaborative learning practices are utilized, students are more likely to engage in intellectual conversations with peers from different backgrounds. Therefore, the classroom is a critical element in facilitating conversations and other interactions that lead to diversity-related outcomes in students.

Faculty Influence in Outcomes

Faculty and instructors play unique roles in sharing and creating knowledge with students. Although their influence is not the sole determinant of student outcomes, they have a major influence over the environments in which students learn and interact. Garcia & Smith (1996) characterized the crucial role of faculty in colleges and universities stating that their work "goes to the heart of the educational enterprise in terms of what is to be taught, who is to teach it, and how it is to be taught". Several researchers have examined outcomes related to classroom climates specifically shaped by professors through their curricula, pedagogical practices, and faculty-student interactions (Astin, 1993; Braxton, 2008; Kinzie et al.; MacPhee et al., 1994; Milem & Hakuta, 2000; Terenzini et al. 2001).

Astin (1993) found that students were more satisfied with college when faculty members emphasized diversity in their courses. Professors who emphasized diversity either expressed an interest in diverse perspectives in class discussions, or included a range of perspectives in their course curricula. Similarly, Cabrera & Nora (1994) assert that perceptions of prejudice from faculty and peers have indirect, negative effects on student outcomes. Therefore, faculty interest in diversity is part of a healthy classroom climate that leads to learning gains in students.

Collaborative learning is a high-impact classroom practice that is particularly effective for women and minority students, and has been clearly linked with gains in student outcomes (Cabrera et al., 2002). In a quantitative study of college sophomores, Cabrera and associates (2002) found that collaborative learning practices were positively associated with gains in analytical skills, understanding science and technology, personal development, and appreciation for art. Collaborative learning engages students by enabling them to "become active learners in the educational process" (Cabrera et al., 2001, p.31).

Role of Undergraduate Classrooms in Experiences of Women and Underrepresented Minorities in STEM

The classroom environment is particularly relevant for groups of students traditionally underrepresented or underserved in institutions of higher education. A number of studies have linked undergraduate classroom experiences to the retention and success of women and underrepresented minorities (Johnson, 2007; Kinzie et al., 2008; Nora & Cabrera, 1996; Seymour & Hewitt, 2007). Particularly within STEM disciplines, women and minorities consistently report experiencing subtle or overt differential treatment from their White and male instructors and peers. Several researchers have noted distinct behaviors, expectations, and negative stereotypes that exist in classroom environments, which may isolate these groups of students. Furthermore, instructors largely shape by the classroom environment; and in STEM departments instructors are disproportionally White males (NCES, 2010; Pittman, 2010). Thus, addressing classroom practices and student experiences therein should be central to any efforts to increase minority participation in STEM disciplines.

In their 1997 study, Seymour & Hewitt documented a wide range of factors in women and underrepresented minorities' decisions to leave STEM majors. Many of their participants made decisions to leave their majors despite earning strong grades in their classes. They did not leave their majors due to academic concerns. Instead, their decisions were largely based upon frustration with inhospitable classroom climates. Students in Seymour & Hewitt's (1997) study characterized STEM classrooms as competitive, isolating, and permeated by negative stereotypes. Minority students noted that advisors would often recommend that they register for classes below their skill level, and peers often assumed that they were less knowledgeable than white students. Women found that the competitive nature impeded collaborative learning and class discussions. In many of the experiences described in Seymour & Hewitt's (1997) study, women and minorities internalized negative experiences that ultimately influenced their decisions to leave STEM majors.

Johnson (2007) documented specific faculty behaviors and class characteristics that discourage women of color in STEM. Large class sizes were a source of frustration for the women, who found it difficult to interact with faculty in lecture settings among so many other students. The women also expressed hesitancy about asking or answering questions in their STEM courses, as they often felt extra attention and pressure to answer correctly. Furthermore, the women also noted that faculty often ignored the influence of race and gender and presented science as a meritocratic, objective enterprise. By ignoring key parts of their identities and reasons for pursuing STEM, professors distanced themselves from the women in the study.

Most of the students in Johnson's (2007) study expressed an interest in STEM as a means to serve their communities or society as a whole. This finding is consistent with literature that suggests that both women and minority students often pursue STEM majors for altruistic aims: to become medical doctors, to be role models for others, and to research diseases or other societal issues (Carlone & Johnson, 2007; Hanson, 2004, 2007; Hill et al. 2010; Johnson, 2007; Modi et al., 2012; Seymour & Hewitt, 1997). Subsequently, these groups of students often strive to understand science concepts in context or real-world applications.

Researchers in other disciplines have noted characteristics of STEM disciplines and departments that would lend to classroom climates that are inhospitable to diverse perspectives. Sociologist Thomas Kuhn (1996) identified some of the rigid norms and contradictions of STEM disciplines. He suggested that scientific research appears to be objective, yet scientists who work within traditional norms are not objective and independent thinkers. Instead, he argues that these individuals often work to reinforce existing theories rather than explore new topics that may challenge old paradigms. In sum, Kuhn (1996) asserts that there is a culture of science that encourages students to adopt traditional ways of knowing, and resists ideas that diverge from accepted paradigms. This work implies that female and minority students' accounts of their experiences may be indicative of more widespread norms in STEM departments that may isolate or deter women and racial/ethnic minorities.

In contrast, Perna et al. (2009) studied practices at Spelman College that have led to high rates of degree completion among African-American women in STEM majors. In their research, Perna and associates found that Spelman, a historically Black college, promoted a culture of accountability for collective success. Faculty members were aware of the specific issues and barriers that may have faced women in their classes, and made intentional efforts to combat them with academic and social structures to support academic success. Students were encouraged to support their peers, and classroom practices encouraged group work and collaboration. Classes were intentionally kept small to facilitate discussion and direct faculty-student interaction, and professors did not curve grades to ensure that no students would stand to gain from another's lower grade. Most importantly, the university administration and STEM departments played an active role in tracking student success or identifying problems early. Students were required to meet with academic advisors regularly, and early warning grades and notifications were utilized to flag students who may need additional support.

The structures and practices experienced by women at HBCUs like Spelman are quite different from the negative climates often experienced by other women and minorities in STEM at TWIs. Intentional efforts to support STEM persistence of these groups of students have proven to be effective at HBCUS, and show that these groups of students are highly capable of succeeding in their respective fields, but may be discouraged and marginalized by negative, unsupportive environments elsewhere.

Strategies to Improve Classroom Climate

Ineffective teaching practices such as extended lectures, relying heavily on textbooks, and providing delayed feedback to students, lead to negative outcomes in student learning (Lambert et al., 2007). Based upon studies related to classroom climate and the experiences of underrepresented groups in STEM, there are a number of strategies instructors and departments can adopt to enhance their classroom climates and learning outcomes. Faculty members are the key players in most of these strategies, however as evidenced by the policies and structures at Spelman College, institutions can also support the development of inclusive climates.

Instructors can facilitate collaborative learning through group projects, student study sessions, and group discussions in class (Cabrera et al., 2002; Museus et al., 2011; Perna et al., 2009; Terenzini et al., 2001; Treisman, 1992). Encouraging students to work together on assignments and share resources can minimize unhealthy competition (Museus et al., 2011; Johnson, 2005; Perna et al., 2009). Eliminating curved grading methods that put students in competition with one another may also aid in creating supportive climates (Seymour & Hewitt, 1997). Given our knowledge of differences in students' learning preferences, time in-class should consist of combinations of lectures, visual aids, supplemental reading materials, and group activities (Cabrera et al., 2002). Similarly, students should have opportunities to show comprehension through multiple measures, such as applied problems, laboratory work, and verbal responses.

Another way for instructors to engage women and minorities in STEM is to adopt feminist pedagogies (Brickhouse, 2001; Hooks, 1989; Luke, 1996). Feminist pedagogy is theory about teaching, where learning occurs, and the democratic creation of knowledge (Hooks, 1989; Luke, 1996). Instructors who employ feminist pedagogies aim to develop collaborative learning environments where student ideas are valued as contributions to knowledge and students must learn to be responsible for their own learning (Luke, 1996). Adopting aspects of feminist pedagogy would enable instructors to address topics that would resonate with their students' interests (Brickhouse, 2001; Espinosa, 2009; Johnson, 2007). Instead of solely addressing theoretical concepts or narrow research topics, instructors and STEM curricula should also aim to contextualize science material (Johnson, 2007). In developing course plans, faculty should consider why students should know about a particular issue, how they might use course concepts in their future research or career, and explain these connections in the classroom. Acknowledging contributions of a diverse group of scientists/cultures and recognizing plurality in STEM perspectives is yet another way to engage diverse students (Clewell et al., 1992; Johnson, 2007). This enables students to see that science is also influenced by researchers' priorities and perspectives in terms of what to study, how to approach a given issue, and what findings are considered to be relevant.

Finally, increasing the presence of students and faculty from diverse backgrounds may also lead to improved undergraduate STEM classroom climates. Structural diversity is defined as the "numerical presence of diverse groups" (Hurtado et al., 1999). Structural diversity is a necessary condition for cross-cultural exchanges in the classroom context, however the presence of minority students will not lead to cognitive or affective gains alone (Cabrera et al., 2002; Chang et al., 2004; Gurin, 1999). Collaborative learning and other practices that require students to engage with others in the classroom setting enable students to learn from one another and enhance learning outcomes (Cabrera et al., 2002). In sum, high-impact teaching practices are the vehicle through which structural diversity translates into cognitive and affective gains in the classroom environment.

African American Women – Cultural and Family Factors

Several authors suggest that African American women's perspectives are different from those of their white female and male counterparts due to differences in their historical and social experiences (Andersen & Collins, 1995; Collins, 1990; Hanson, 2004; Parks, 2010). Throughout their history, African American women have balanced multiple responsibilities in their families, managing responsibilities at home and working simultaneously (Gutman, 1976; Hill, 1971; Kane, 2000; Parks, 2010). Black girls are often told by parents to pursue their own interests and careers as a source of social mobility (Hanson, 2004, 2009; Higginbotham & Weber, 1992). Parks (2010) notes that African American women often balance multiple roles, and feel that pursuing an education or career does not stand at odds with having a family life. Hanson (2004) asserts, "The above patterns have contributed to more androgynous gender roles and greater self esteem, independence, and assertiveness as well as high educational and occupational expectations among young African American women (and their parents) relative to other women". Each of the aforementioned characteristics enables Black women to move beyond limitations typically placed upon women of other races, and is linked to success in science (Hanson, 2004, 2009). In contrast, research on white women shows that their perceptions of incompatibility between science and family life deters many of them from pursuing majors and careers in STEM (Hanson, 2004).

In her book titled *Swimming against the Tide,* Hanson (2009) provides greater insight into the ways in which African American women's upbringing can serve as an asset in STEM majors or careers. She says that there is "… evidence of a unique gender system in the African

American community, family and peer systems that sometimes works against all odds to encourage interest and activity in science" (p.5). She notes that black women she interviewed recalled being told that they could do anything they put their mind to, and to ignore all naysayers. She also found that Black women also recalled being exposed to science and math at an early age through summer camps, after-school programs, and encouragement from parents. She noted that women in Black families played a particularly important role, providing encouragement and resources to excel in STEM and serving as role models for young girls. Overall, Hanson notes that Black families invest in their girls in ways that other communities do not. Their investments are not always financial, but are often investments of time, support, and other resources. For example, one of Hanson's interviewees recalled that she was interested in finding worms and other bugs, and her mother sacrificed kitchen utensils to allow her to dig in the yard to find them. Her mother could have easily encouraged her daughter to do something else, but made sacrifices to allow her to pursue a positive interest in STEM. Hanson's findings are supported by other scholars who have identified the range of non-financial resources that Black families invest in their girls.

Parks (2010) examines images of Black women that pervade religions, history, and popular media. One of the most prevalent images is that of the "Strong Black Woman", who is "….wise, giving, selfless and self-effacing all at the same time" (p.xv). Strong Black Women balance successes in their education and careers with the responsibilities of supporting their families and contributing to their communities. By definition, the Strong Black Woman blurs traditional boundaries assigned to women. Parks also notes that the image of the Strong Black Woman is passed through generations, and is a part of black women's lives beginning in childhood:

> Training for the role starts at birth. Black people traditionally raise their daughters to be sensible and responsible and are often much harder on them than their sons, As girls become women….they are expected to become confident and worth of their idealized assignment as the universal helpers." (p.xiv)

One of the key complexities of the Strong Black Woman image is the expectation to care for the needs of others before her own, without recognition and without drawing attention to her contributions. This tendency to care for others connects to African American women's interests in STEM, and has strong implications for teaching practices in these fields.

Specifically, many African American women develop an interest in science as a means of serving their communities, families, or society as a whole (Hill et al., 2010; Hanson, 2004, 2007; Johnson, 2007; Modi et al., 2012). This motivation to serve others through science and connect research with larger personal goals has been termed "altruistic science" (Carlone & Johnson, 2007; Johnson, 2007; Seymour & Hewitt, 1997). Carlone & Johnson (2007) suggest that African American women and other women of color redefine science to make it relevant to their lives, and their "reasons for pursuing science… [are] less about science itself and more about science as a vehicle for altruistic ambitions". Altruistic science becomes problematic for African American women in classes or laboratories where faculty members prefer to study narrow intricacies of science and fail connect them to larger purposes and contexts (Johnson, 2007).

Discussion of Literature

Based upon existing literature, it is clear that African American women experience classrooms and course material differently than their male and white peers. It is also evident that African American women are often drawn to STEM disciplines for altruistic aims, and bring unique perspectives to their work. On a broader level, we know that the classroom environment plays a key role in student outcomes and persistence.

Despite existing knowledge about ineffective teaching practices, classroom climates and their effects on learning outcomes, there is still a dearth of information about the ways in which African American women experience postsecondary STEM classrooms. There is even less information about the ways in which African American women persist and excel in these environments. This study will provide greater insight into the mechanisms and experiences that help African American women successfully navigate undergraduate STEM majors.

Our current knowledge about African American women in STEM is largely based on qualitative studies within a single institution, or quantitative studies based upon large datasets that provide a snapshot of trends in enrollments and degree attainment. This study will provide unique perspectives on African American women's classroom experiences, as it is a qualitative study based upon the experiences of women from a range of institutions across the United States. The richness of data will enable me to provide context for findings, and follow-up interviews will provide information about degree completion and post-graduate experiences that spans up to seven years.

Expanding access and degree completion among African American women in STEM has direct implications for the future of our country. Women and Black, Hispanic, and Native American populations represent an increasing share of the United States population, but have not made comparable gains in STEM majors and careers. Negative classroom experiences often influence these groups to leave the sciences and pursue other careers, and research noted in this essay addresses the importance of improving the classroom climate as a means of increasing and sustaining one underrepresented minority group's interest in these disciplines. Promising practices of small class sizes, collaborative learning, and contextualized science may lead to gains in degree completion, and most importantly innovation and discoveries in STEM.

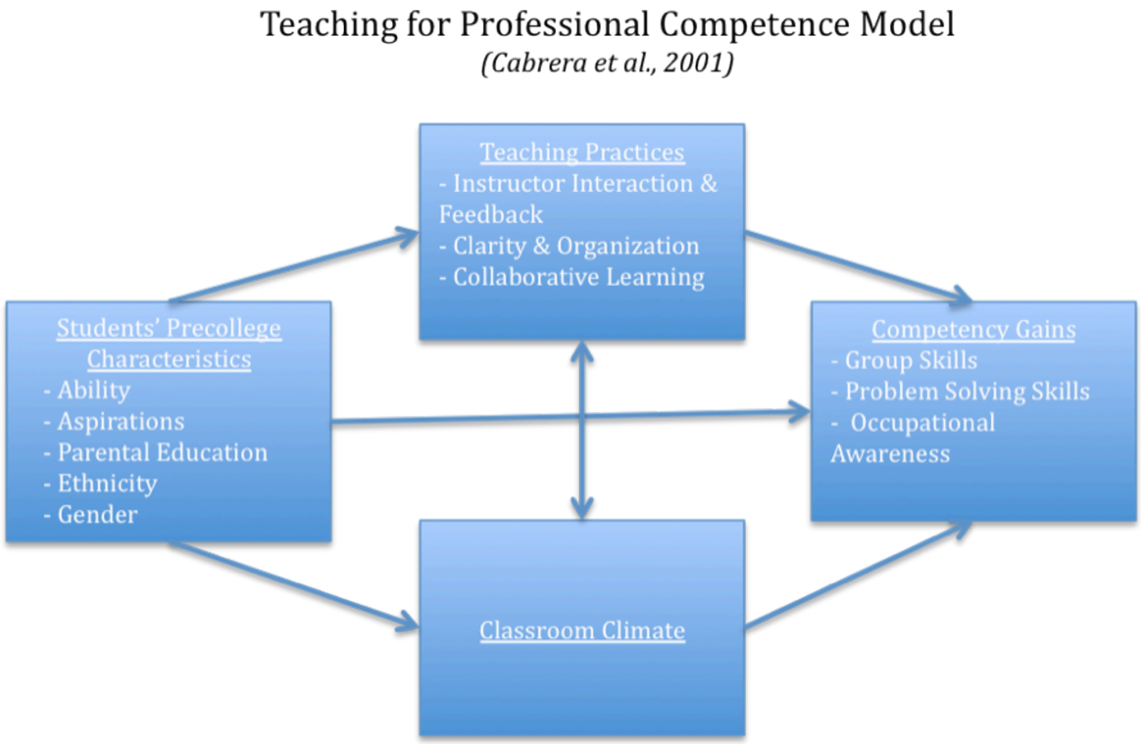
Theoretical Frameworks

Elements from three theoretical frameworks guided the development of this study: Cabrera et al.'s (2001) Teaching for Professional Competence Model, Carlone & Johnson's Grounded Model of Science Identify, and Bandura's (1977) concept of self-efficacy. Cabrera et al.'s (2001) model explains the role of the classroom in learning outcomes and the development professional competencies within STEM. Similarly, Carlone & Johnson's (2009) work identifies broad interactions that lead to the development of identities as scientists among women of color. Finally, self-efficacy provides a conceptual undergirding linking classroom interactions and science identity to outcomes such as learning and persistence in STEM.

Teaching for Professional Competence Model

Drawing from college impact literature, and Terenzini et al.'s (1995) Learning Outcomes Model, Cabrera et al. (2001) assert that interplay between a student's precollege characteristics and collegiate classroom experiences produce student learning and development. Precollege characteristics include educational aspirations, academic ability, race, gender, parents' education, and socio-economic status (SES). Collegiate classroom experiences include classroom activities such as interactions with faculty and peers, and exposure to pedagogical practices and curricula. Although Cabrera and associates recognize that extra-curricular activities such as working and involvement in student organizations can impact student learning and development, they place special emphasis on the classroom in their model. They specifically note the importance of teaching practices and classroom climate in producing learning gains, and after testing the model found that teaching practices including interactive lessons, timely feedback, organization, and collaborative learning had the greatest influence on professional competencies.

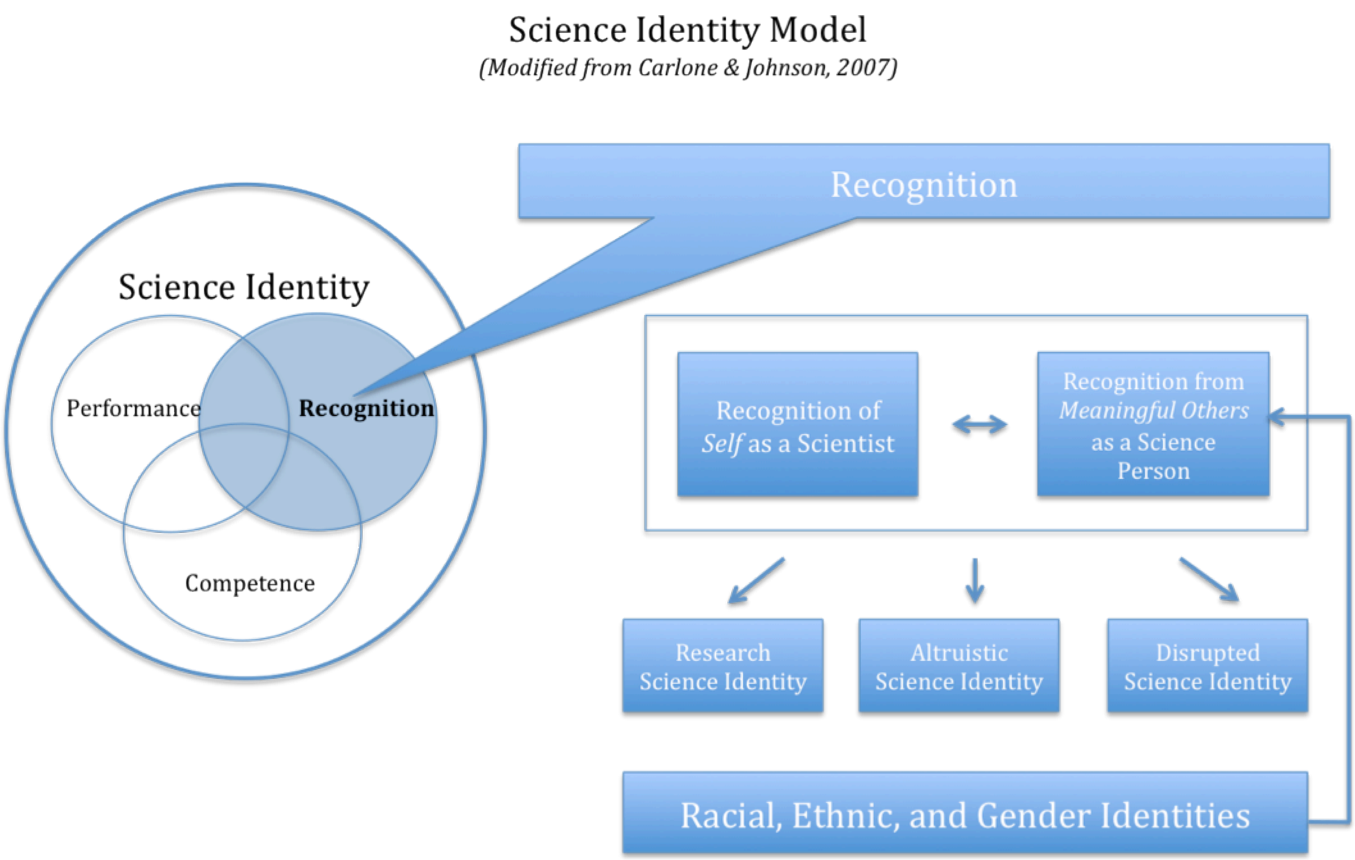
Figure 1: Teaching for Professional Competence Model



Science Identity Model

Carlone & Johnson (2009) stress the importance of recognition as a scientist as a critical factor in the development of identities as scientists among women of color in STEM fields. This recognition can come in the form of encouragement to pursue majors and careers in science, or recognition of talent in science. Recognition as a scientist can come from the self, meaningful others outside of science such as family and friends, and most importantly from meaningful others in the field such as professors and professionals. Critical elements of their grounded model of science identity are shown below in Figure 2. The full model is in Appendix B.

Figure 2: Grounded Model of Science Identity



Carlone & Johnson (2009) also distinguish between three particular types of science identities: research, altruistic, and disrupted. Research scientists identified with prototypical behaviors, logic, and ideologies in science. They expressed an interest in learning for learning's sake, and often worked in traditional laboratory settings. Women with altruistic science identities redefine what it means to be a scientist (or a woman of color in science specifically), to align their work with collective interests of their communities or society as a whole. Other women have disrupted science identities, resulting from a lack of positive recognition as a scientist, or an inability to reconcile racial, ethnic, and/or gender identities with an identity as a scientist. The distinguishing factor between these science identities is consistent, positive recognition of abilities and talent in STEM.

Self-Efficacy

Self-efficacy is defined as an individual's judgments of ability to successfully begin and complete a given task in the presence of obstacles or challenges (Bandura, 1977, 1986). Self-efficacy has been applied to STEM education to better understand students' educational aspirations, and the ways in which significant others such as family and teachers can influence efficacy (Gwilliam & Betz, 2001; Maple & Stage, 1991; Shain 2002; Zeldin & Pajares, 2000). Bandura (1977) proposes that increases in self-efficacy can be drawn from four sources: performance accomplishments, vicarious experience, verbal persuasion, and physiological states. Similarly, self-efficacy can be reduced with negative experiences in the aforementioned areas. In an educational setting, performance accomplishments are personal demonstrations of ability. Performance accomplishments may include earning a high grade in a course, or delivering a successful academic presentation. In contrast, through vicarious experience, students see other people similar to themselves excelling in a given course, major or career field, and subsequently view their own goals as being more realistic. Verbal persuasion may come in the form of encouragement and support from professors, peers, or family. Finally, physiological states are the physical responses that students may associate with a given task or course. For example, a student may feel a greater sense of self-efficacy in a course he or she feels excited about, versus a course that triggers feelings of stress.

Integrated Theoretical Framework

The integrated theoretical framework (Figure 3) incorporates elements from the three theoretical frameworks described above. The model depicts a combination of academic and social experiences, self-efficacy, and science identity, that ultimately leads to Black women's career and degree outcomes in STEM. The integrated model accounts for academic, social, and psychosocial factors, including individual students' family and academic backgrounds, beliefs about their abilities, and their perceptions of themselves as scientists. A more detailed depiction of the elements incorporated into the integrated framework is provided in Figure 4.

Figure 3: Integrated Theoretical Framework

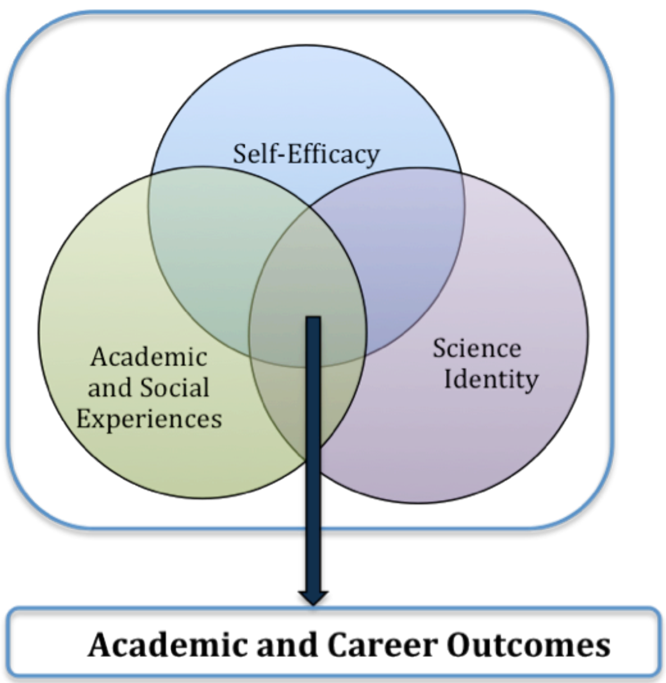
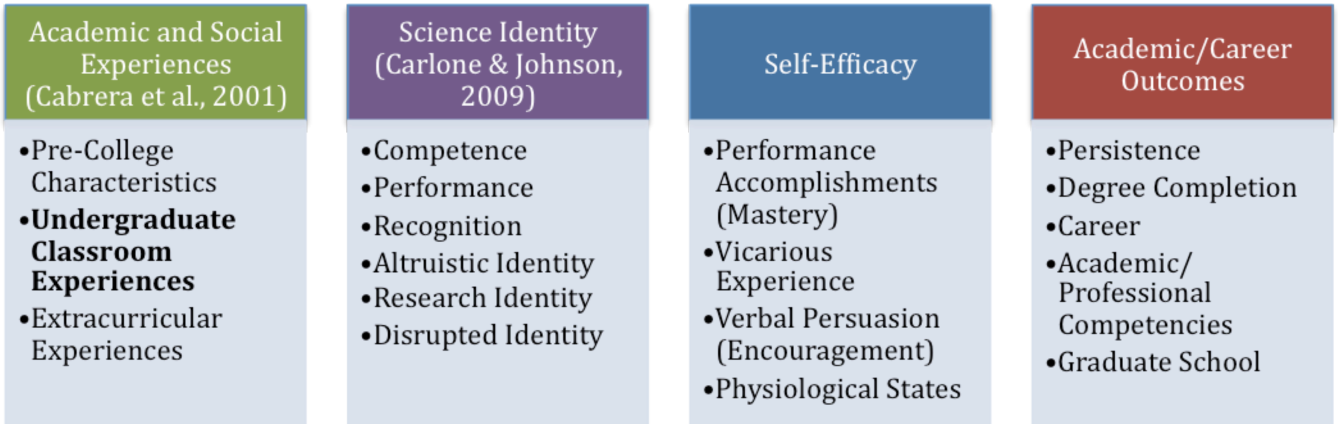


Figure 4: Elements of Integrated Framework



Elements included in the framework are consistent with findings from other studies related to minority student persistence and the experiences of women of color in STEM (Espinosa, 2009; Swail et al.,2003). The framework helped inform the interview protocols and data analysis. It also provided insight into factors that lead to persistence and degree completion among Black women in physics.

Chapter 3: Procedures and Methodology

The major research question guiding this study is: How do African-American women perceive the climate and interactions with peers and faculty in undergraduate STEM classrooms? Through this study, I also sought to address the following sub-questions:

a. How do African-American women attempt to succeed in these environments?
b. What classroom interactions and experiences do African American women perceive support their persistence in their majors?
c. How do they perceive that classroom experiences and interactions influence their identities as scientists?
d. How did classroom interactions compare with interactions with faculty and peers outside of the classroom? (i.e.: laboratories, social settings, office hours, etc)
e. What are key factors in persistence and degree attainment among African American women in STEM?

Beginning with a discussion of the study's design, this chapter will include details about the rationale for utilizing the chosen site, a discussion of sampling techniques, and a summary of participant characteristics. Finally, this chapter will address data collection procedures, proposed data analysis techniques, and researcher trustworthiness.

Research Site

This study draws from a database of interviews and focus groups conducted at annual meetings of the National Society of Black and Hispanic Physicists from the years 2005-2009. Follow-up interviews were arranged with past participants in the conference and focus groups.

The National Society of Black Physicists (NSBP) was founded in 1977 to "promote the professional well-being of African American physicists and physics students within the international scientific community and within society at large". The organization is committed to supporting Black physicists as students and professionals, promoting the work of these individuals, and creating greater awareness of physics within the African-American community. Similarly, the National Society of Hispanic Physicists (NSHP) was founded in 1995, and aims to increase the enrollment and persistence of Hispanic and Latino students in STEM majors, promote the study of physics within the Hispanic community, and recognize the accomplishments of Hispanic physicists.

From 2005-2009, the NSBP and NSHP held joint annual meetings with concurrent sessions, research presentations, guest speakers, networking opportunities, and career fairs. Conference workshop topics range from preparing for graduate school to preparing for a physics faculty position. Although many NSBP/NSHP annual meeting attendees major or have careers in physics, some members are involved with other disciplines such as engineering or chemistry. Even among physics majors, many students double major and they take a range of classes within other STEM departments. Thus I refer to their experiences as representative of STEM courses and majors beyond physics.

Rationale for Site Selection

The annual NSBP/NSHP conference was a fitting location to collect data for several reasons. First, students from a variety of schools attend the conference each year. Some attend Traditionally White Institutions (TWIs), others attend Historically Black Colleges and Universities (HBCUs) or other Minority-Serving Institutions (MSIs). Some attendees come from large, public universities, and others attend smaller, private colleges. Classroom dynamics and experiences in STEM vary across institutional types, therefore the annual conference offered a diverse sample of participants.

Second, the conference is largely comprised of students who are succeeding in STEM and engaging with a community of peers and professionals. Thus, I was able to focus on factors in their persistence, rather than attrition. The conference includes faculty, staff, undergraduate, and graduate students. Attendees in the larger study were nominated to participate in the NSBP/NSHP annual meeting by their departments, based upon their academic promise and potential gains from participation in the conference. Individuals selected to attend are required to be in good academic standing and persisting towards degree completion as verified by signatures from their department chair and academic advisor. Each student was also required to complete a form indicating the physics related courses in which they were enrolled at the time of the conference. Those who attend have the opportunity to engage in dialogues with peers and colleagues about their studies in physics and other STEM courses, career interests, and experiences in their major thus far. Within this conference community, the undergraduate students are exposed to others who have succeeded in STEM, and their focus should be similar.

Third, between 2005 and 2009 the NSBP/NSHP conference met every year, providing opportunities for the research team to collect data over time. Annual meetings also enabled the research team to review transcripts and notes, and adjust protocols to address any emerging themes or issues for the following year. Finally, the research team benefitted from consistent interest and support from the NSBP/NSHP conference leadership. The executive board and conference organizers took an interest in the research team's work from the beginning of the study; providing access to conference attendees and accommodations for the research team. The conference organizers were also supportive of efforts to reconnect with participants during the second phase of data collection.

Design of the Study

Data collection and data analysis were both conducted in two distinct phases. The research team conducted the first phase of data collection and analysis collectively, and I led the second phase of data collection and analysis as an individual researcher. Although information obtained during the first phase of data collection was used to inform findings from the follow up interviews, the second phase of data collection and analysis will largely serve as the basis of this dissertation research. During the first phase of data collection, participants engaged in focus groups led by members of the research team at annual meetings of the National Society of Black/Hispanic Physicists over a five-year period. During the second phase of data collection, I arranged and conducted follow-up interviews with ten African American women who participated in the research team's original interviews and focus groups.

During the first phase of data analysis, members of the research team coded for themes developed from literature and theoretical frameworks. During the second phase of data analysis, a new coding scheme was developed using the original themes/codes, as well as new themes representative of the experiences of African American women in STEM (Appendix G). The original interviews and focus groups were also re-coded using the redeveloped coding scheme. One other research team member coded the transcripts and compared findings and interpretations to ensure consistency. Emerging themes as well as information about the women's post-graduate careers and education were incorporated into findings from their original interviews to develop a more comprehensive understanding of the role of their undergraduate classroom experiences in their persistence, identities as scientists, and postgraduate endeavors.

Methodological Approach

I utilized a qualitative, descriptive case study methodology to identify classroom experiences that contributed to the persistence of 11 undergraduate African-American women in STEM majors who attended NSBP/NSHP Annual Meetings between 2005 and 2009. The intent of qualitative research broadly is "…to illuminate and better understand in depth the rich lives of human beings and the world in which we live" (Jones et al., 2006, p.2). A qualitative approach is most appropriate when the research is "exploratory or descriptive, assumes the value of context and setting, and searches for a deeper understanding of participants' lived experiences of a phenomenon" (Marshall & Rossman, 1995, p.39). This study will provide insight into the lived experiences of African-American women in STEM majors, with emphasis on the classroom setting. Therefore, a qualitative methodology was fitting to address the research questions.

Creswell (2007) defines case study research as

> …a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of data collection (e.g. observations, interviews, audiovisual material, and documents and reports), and reports a case description and case-based themes. (p. 73).

Each individual who participated in a follow-up interview and their respective undergraduate STEM courses represents a case. Multiple sources of data, including interviews, focus group transcripts form 2005-2009, observations, and document analyses of conference materials. From these data sources, I aimed to develop an understanding of course-taking patterns, student perceptions of professors, peers and course materials, and the ways in which classroom experiences influence African-American women's success in STEM. Key indicators of student success included persistence, degree completion, GPA, and engagement in science activities.

Case study methodology is suitable for exploratory studies; providing insight into topics with limited existing literature (Yin, 1995). Currently, few researchers have explored the experiences of African-American women in undergraduate STEM majors, and even fewer have centered such research on classroom interactions. Furthermore, utilizing case study methodology and multiple sources of information enabled triangulation of data to ensure that observations and interpretations aligned with students' academic performance and behaviors.

Throughout data analysis, I employed a constructivist epistemology, to enable new questions, themes, and ideas to emerge based upon participant responses. The research team also employed a constructivist epistemology during data collection. Creswell (2007) describes a constructivist approach as developing subjective interpretations of participants' understandings of the world in which they live and work. Thus, researchers utilizing this approach should ask broad, general questions and enable participants to construct meanings of situations for themselves. Given the subjectivity implicit in the constructivist approach, researchers must recognize that participants' responses, as well as their interpretations of these responses are influenced by social and historical factors.

During both phases of data collection, participants were asked broad, open-ended questions and the researchers remained open to new ideas and themes as they interacted with participants. Throughout data analysis, I coded data for some pre-determined themes based upon the literature and theoretical frameworks, and created new themes when unexpected responses arose.

Sample

Participants in this study were part of a larger study based upon the collegiate experiences of minority undergraduates and graduate students in STEM majors. Participants ranged in class rank from undergraduate freshmen students to several post-doctoral scholars or recent graduates. Specifically, the larger study consists of 4 freshmen, 19 sophomores, 21 juniors, 32 seniors, 82 graduate students (combining master's and doctoral level students), and 2 post-doctoral students. The majority of participants were classified as full-time students, and of the 162 participants in the larger study, 82 self-identified as African American, and 31 were African American women. The tables below detail the demographic characteristics of all of the African American participants in the larger study (Table 1, Table 2, Table 3).

Table 1

Demographic Information for African-American Participants (n=82[+])

Class Rank	
Graduate	39
Undergraduate	43
Gender	
Men	44
Women	38
Type of High School*	
Private	13
Public	65
Mother's Education*	
Elementary school	1
High school diploma	7
Some college	16
Associate's degree	9
Bachelor's degree	30
Some graduate school	2
Master's degree	16
Father's Education*	
Elementary school	1
Some high school	1
High school diploma	16
Some college	17
Associate's degree	3
Bachelor's degree	20
Some graduate school	6
Master's degree	4
Ph.D. or professional degree	6

[+] This includes 7 students that participated multiple years (2-4 years)

* Incomplete data; missing complete demographic information for 2006

Table 2

Student Status of African-American Female Participants (n=40+)

Average Age - 23 years

Student Status	
Freshman	2
Sophomore	5
Junior	4
Senior or beyond	8
Graduate student**	19
Post-Doctoral Fellow	2

**Unable to distinguish between number pursuing a master's or doctoral degree
*There were 31 total African-American women in the Study. Five of these students participated multiple years and are counted multiple times in the demographic forms.

Table 3

Parental Education of African-American Female Participants (n=40+)

Mother's Education* **	
Some high school	1
High school diploma	2
Some college	10
Associate's degree	6
Bachelor's degree	13
Some graduate school	1
Master's degree	7

Father's Education* **	
Elementary school	1
High school diploma	9
Some college	8
Associate's degree	3
Bachelor's degree	10
Some graduate school	6
Master's degree	2
Ph.D. or professional degree	2

*There were 31 total African-American women in the Study. Five of these students participated multiple years and are counted multiple times in the demographic forms.
***Incomplete data, missing demographic information for 2006

Criterion sampling was utilized to identify participants in both phases of the study. Criterion sampling uses predetermined standards of importance to the research topic to select participants (Merriam, 1998). The pool of potential participants was generated based on their status in good academic standing and persisting towards degree completion. These criteria were consistent with those established by NSBP and NSHP for selection of students to attend the national conference: Based on these criteria the research team determined that the students who were attending the conference had been verified as succeeding in physics. Among this group of students in STEM, participants in the second phase of the study were self-identified African-American women, as indicated in their demographic forms and comments during focus groups in 2005-2009.

African-American women in good academic standing and persisting in STEM are a unique group to study, because so much attention is often drawn to reasons why women and ethnic minorities leave STEM majors. Instead, this study identifies and examines the influence of classroom interactions in the experiences of African-American women who have persisted in STEM. Although the women shared some negative experiences during data collection, I focused on the ways in which the women overcame them to continue in their pursuit of their respective majors.

Phase 1: Participant Recruitment and Data Collection

NSBP attendees were invited to participate in focus group sessions through notices in the conference program and announcements during plenary sessions. Interested participants were instructed to meet with research team members in designated rooms for focus group interviews. Focus groups between 4-10 students were formed based upon the number of volunteers in a given time slot. Prior to any data collection, participants in each focus group were given a detailed introduction to the research team and the larger NSBP/NSHP research project. They were given an opportunity to ask questions or opt out if they desired. Then, the team obtained consent from each participant based on guidelines from the University of Maryland's Human Subjects Review Committee.

Each participant was then asked to complete a demographic form (see Appendix C), which included information about their age, race or ethnicity, gender, academic major, university affiliation, and level of study. The forms were collected and utilized to provide aggregate data about the pool of participants. The forms ultimately provided some additional context for comments and findings from the study.

Throughout the first phase of data collection, typically one research team member facilitated the dialogue, and at least one other team member took notes and observed participants' behaviors. Individual interviews were between 60-90 minutes in duration and the focus groups, which ranged in size from six to twelve people, often lasted 90-120 minutes. The research team utilized a semi-structured approach to focus group questions, beginning with a set protocol, but allowing for follow-up questions during the data collection process. The core questions were centered on themes of pre-college preparation, family influence, academic experiences in STEM, and aspirations after undergraduate or graduate study (Appendix D). All interviews and focus groups were recorded using electronic audio recorders and transcribed verbatim. After the initial review of transcripts, some questions were added or modified for clarity or to address emerging themes.

Phase 2: Participant Recruitment and Data Collection

Prior to the second phase of data collection, I led a sub-group of the research team tasked with reconnecting with former focus group participants. With input from Dr. Fries-Britt and the research team, I developed an online survey to be distributed to all former focus group participants. Then, Dr. Fries-Britt and I worked directly with the NSBP/NSHP leadership to distribute the survey. Given the time that passed between the focus groups and individual interviews, many participants' contact information was outdated. As an alternative method of reaching potential participants, I searched for current contact information for former focus group participants using web searches and social media sites such as LinkedIn and Facebook.

Once I found current contact information for women in the database, I invited self-identified African-American women to participate in in-depth interviews with me. 11 women participated in individual interviews. The interviews lasted approximately 60-90 minutes, and questions were centered on perceptions of their undergraduate classroom interactions and developments since their NSBP focus group (Appendix F). Participants that lived or worked in close proximity to the University of Maryland were interviewed in person. Participants who lived in other regions of the United States were interviewed using Skype, a video conferencing program.

Data Organization and Analysis

Dr. Fries-Britt and members of the research team initially analyzed interview and focus group transcripts from the larger NSBP project. The first round of data analysis included themes of faculty interactions, family support, institutional factors, peer interactions, academic experiences, and experiences related to race and gender. These themes were developed based upon literature centered on the experiences of minorities in STEM broadly. The coding and analyses were saved on one computer, and the electronic files containing this work were lost with that computer. Hard copies of the original coding reports were saved, however it is no longer possible to manipulate or revise the themes electronically.

During the second phase of data analysis, I began the coding process again; re-coding for the original themes developed in phase one of data analysis, and including themes of particular importance to the classroom experiences of African-American women in STEM. I also coded interview transcripts for themes found in theoretical frameworks and literature related to the classroom experiences of African-American women in STEM. These themes included pre-college STEM experiences, interactions with faculty, peer interactions, and institutional factors. I utilized a constructivist approach and remained open to themes that emerged during this process.

In reviewing participants' comments from their 2005-2009 focus groups and their more recent interviews, I looked for any changes in their responses over time. I also utilized cross-case analyses to determine similarities and variations in different participants' experiences. Most importantly, I sought to determine ways in which participants' responses matched or diverged from existing theories and literature related to the classroom experiences of women and minorities in STEM.

NVivo software was used to organize and code the data. NVivo is a qualitative data analysis package that enables users to upload documents, and identify and manage themes therein. The software also enables researchers to establish connections between themes, manipulate nodes, and compile findings from multiple transcripts.

Data was analyzed in several stages consistent with Merriam's (1992) three levels of analysis for case study research in education. These levels of analysis include descriptive accounts, category construction, and theory building. At the most basic level, descriptive accounts are a researcher's interpretations of qualitative data (Merriam, 1992). The next level of data analysis, category construction, involves constructing "categories or themes that capture some pattern that cuts across" the data (Merriam, 1992, p.179). Finally, theory building involves "making inferences, developing models, or generating theory" (Merriam, 1992, p.187). As a multiple case study, within- and cross-case analyses of the data were also appropriate (Merriam, 1992; Miles & Huberman, 1994; Yin, 1995). Yin (1995) describes the process of cross-case analysis as building "a general explanation that fits each of the individual cases, even though the cases will vary in their details" (Yin, 1995, p.112).

First, I reviewed the focus group transcripts to identify themes and demographic characteristics of participants. I coded participants' comments for major themes identified in the literature (Appendix G). Themes included development of an identity as a scientist, interactions with faculty, interactions with peers, pre-college experiences, and family influence. Finally, I sought to identify additional or emerging themes in the data, and coded transcripts accordingly.

After completing individual interviews, I reviewed interview transcripts to identify themes and key experiences in the women's academic trajectories. Again, I identified salient themes from the literature and frameworks, and coded for these themes in NVivo. I also identified themes that were not included in the initial coding scheme and coded them under the parent node of "Other/Miscellaneous", with more specific sub-nodes. After coding, I engaged in within- and cross-case analyses. I reviewed each interview to develop a detailed case profile, identify themes, and denote contextual variables that shaped each participant's experience. Next, I identified themes and contextual factors in each participant's interview and focus group comments, then compared them to themes from other participants' comments. Finally, I developed a Model of Undergraduate Achievement for African American Women. The model synthesizes themes that cut across the women's descriptions of academic experiences that contributed to their persistence in physics and other STEM coursework.

Ethical Considerations and Trustworthiness

In qualitative research, the researcher is the instrument through which data is collected and analyzed (Creswell, 2007; Jones et al., 2006). For this reason, it is particularly important to address the role of the researcher, and ways in which the researcher has aimed to minimize their influence on the direction of the study.

Researcher Role and Trustworthiness

I developed an interest in this topic through my own experiences as an undergraduate and my own passion for making higher education a more inclusive endeavor. I am an African-American woman, and I began my undergraduate studies with a keen interest in becoming a dentist. My family was full of educators, and although my greatest desire in a future career was to help others, I sought to be different and find ways to make an impact in areas outside of education. I saw dentistry as a way to help people through teaching about dental hygiene and making people more comfortable and confident with their smiles. I always had positive experiences with dentists and orthodontists, and wanted to provide similar experiences for other patients. Although there was no pre-dental program at my undergraduate institution, there was a series of science and math classes designated for students who wanted to pursue graduate study in the health professions. I took a number of these classes, and have distinct memories of feeling isolated yet hyper-visible at the same time. I recall feeling marginalized in lab groups, and expressing my opinions or offering solutions that were ignored by my peers until they were voiced by a man or White woman in the group. Most importantly, I remember feeling like the work that I was doing had nothing to do with my reasons for being there. I saw little to no connection between the course material and dentistry, and I never recall professors or advisors making those connections explicit.

In contrast, I excelled in Spanish courses wherein I learned the Spanish language and I was able to speak it among my classmates, hall mates, and translating in a local dental clinic. I saw Spanish as being relevant to a future career in dentistry, as it would enable me to serve a growing Spanish-speaking population. In classes, we were regularly engaged in exercises, conversations, and presentations. We were also encourages to seek out opportunities to practice/utilize our knowledge through service, seminars, study abroad, and conversations with peers outside of class. I ultimately majored in Latin American and Iberian studies and pursued graduate study in higher education.

There are several other core beliefs that shape my understanding of African American women's experiences in STEM. Specifically, I see diversity as a desirable characteristic in classrooms and other learning environments. I value the presence of a range of perspectives, opinions and experiences in educational settings, and I tend to expect that others will have a similar appreciation.

Peer and instructor feedback throughout the development of this project helped me recognize points where my assumptions may have affected my perceptions and interpretations of findings. Furthermore, other team members conducted many of the initial focus groups that informed this research, therefore I could not lead participants toward my own assumptions and expectations during the first phase of data collection. During the second phase of data collection and analysis, participants reviewed initial themes from their interviews (member checks), and I had a peer review coded interview transcripts, themes, and drafts of my findings. Member checks and the peer review process provided constructive feedback, new ideas, and supported many of the themes I identified within the transcripts from focus groups and interviews. More detailed descriptions of measures taken to ensure trustworthiness are detailed below.

Peer Review

Several qualitative methodologists suggest that human coders are subject to fatigue and mistakes throughout the coding process. Furthermore, new codes may be added after the original coding scheme is developed, and coders' understanding of the categories and coding rules may change subtly over time. All of these natural processes may lead to greater inconsistency during data analysis (Miles & Huberman, 1994; Weber, 1990). To minimize errors, peer reviewers familiar with the NSBP study were involved in both phases of data analysis.

During the first phase of data analysis, the research team reviewed notes and transcripts for common themes, interpretations of comments and to clarify points that were discussed during the focus groups. Thus, peer reviewers helped minimize any individual biases or omissions. After the transcripts were returned the team reviewed them to ensure that the interviews were transcribed accurately and completely.

During the second phase of data analysis, I had a peer review themes identified in the data and code the transcripts for the same themes. The two data analyses were checked for consistency and any major variations in interpretations of the data were discussed and clarified. This comparison of analyses was repeated at several stages during the data analysis process to ensure consistency. Overall, these measures to involve a peer reviewer minimized researcher bias and strengthened the research findings.

Member Checking

Member checking is defined as sharing data, analytic categories, and interpretations of data with participants in a study to ensure that researcher interpretations are consistent with participants' intended meanings (Creswell, 2007). Lincoln and Guba (1985) posit that member checking is a critical technique for establishing credibility in qualitative research. By involving participants in the data analysis process, new perspectives may be revealed, and researchers have an opportunity to clarify any points that were unclear after data collection.

During the second phase of data analysis, member checking was utilized to ensure that follow-up interviews were accurately transcribed and interpreted. Complete follow-up interview transcripts were sent to each participant via e-mail. Transcripts included notes and coding for themes alongside the text. A list of themes and corresponding NVivo codes was also sent to each participant so that the coding could be easily interpreted. Each participant was asked to provide comments, feedback, or additional information about their comments and my interpretations.

Triangulation

Triangulation of data is the use of multiple data sources to corroborate findings (Creswell, 2007). Triangulation facilitates deeper understandings of data and enriches findings. Data from conference proceedings, observations, and researcher notes were used to reinforce findings and interpretations of data. During the second phase of data analysis, comments from follow-up interviews were compared with those made by the same participants in focus groups between the years of 2005-2009. I also reviewed ant public university and departmental websites, student pages, syllabi, and degree requirements. These documents enabled me to see variations in students' institutional contexts, and compare participants' perceptions with public information about their programs.

The findings for this study are presented in two chapters. Chapter 4 includes findings from the focus groups, and will include a review of themes from the coding scheme developed from theoretical frameworks and literature. Chapter 5 is a more detailed review of findings from individual follow-up interviews with 11 participants. Chapter 5 will also include case profiles for each participant, cross-case analyses, and emerging themes.

Chapter 4: Findings (Focus Groups)

Through the larger NSBP study, the research team led by Dr. Sharon Fries-Britt sought to gain a more nuanced understanding of experiences, personal characteristics, and skills that enabled minority students to excel in STEM majors. Participants took part in focus groups between the years of 2005-2009 at annual meetings of the National Society of Black and Hispanic Physicists. During this time, all of the participants were current undergraduate or graduate students in physics or other STEM majors.

For the purposes of this study, responses from Black women in the focus groups were analyzed for themes relevant to the experiences of this particular subgroup. This chapter will provide an overview of findings from analyses of focus group transcripts and other relevant documents for all African-American women in the larger study. This chapter is based on themes from the theoretical frameworks and literature related to the classroom experiences of minority students and women in STEM. These findings informed the second phase of data analysis, as questions for follow-up interviews were partially based on findings from the focus groups.

Participants

There were 31 self-identified African American women in the NSBP study. Participants are from a variety of geographic regions and institution types. The table below provides some general information about the African-American women in the larger study (Table 4). Information is based on participants' comments in focus groups, individual interviews, and web searches. Question marks are used in the table to represent missing information about participants. To protect participants' identities, names of educational institutions are not included. Descriptors of student population, geographic location, and institution type (TWI or HBCU) are used in place of university names. Participants' current occupations are also generalized as 'STEM', 'Non-STEM', or 'Graduate Student'. Although detailed demographic data were collected for the larger NSBP study, it was not linked with individual students' names to protect their privacy.

Table 4: Participant Profile Summary – African American Women in NSBP Focus Groups

Name/Pseudonym	Undergraduate Institution Type	Geographic Region	Major/Area of Study	Completed UG Degree?	Student Status at time of Focus Group	Current Occupation (STEM/outside of STEM)
Brandy	HBCU, urban, 1,000-3,000 undergraduate enrollment	South	Physics	yes	Post-doctoral fellow	STEM
Alicia*	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	STEM - Graduate Student
Valerie*	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	STEM - Graduate Student
Sharee	HBCU, urban, 1,000-3,000 undergraduate enrollment	South	Physics	yes	Graduate Student	STEM - Graduate Student
Imani	?	?	Physics	yes	Graduate Student	?
Stephanie	HBCU, rural, 5,000-7,000 undergraduate enrollment	South	Physics	yes	Graduate Student	STEM
Kristen	PWI, urban, 13,000-15,000 undergraduate enrollment	South	?	?	Undergraduate Student	?
Danielle	HBCU, suburban, 5,000-7,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	outside of STEM
Lawanda*	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Biology/Physics	?	Undergraduate Student	?
Myriam	Carribean/Outside of the US	Carribean/Outside of the US	Physics	yes	Graduate Student	STEM
Annie	HBCU, urban, 1,000-3,000 undergraduate enrollment	South	Physics	yes	Post-doctoral fellow	STEM
Valerie*	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	STEM - Graduate Student
Dawn	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Engineering/Physics	yes	Graduate Student	STEM
Lori	?	?	?	?	?	?
Karen	PWI, suburban, 25,000-27,000 undergraduate enrollment	South	Physics/Astronomy	yes	Undergraduate Student	STEM - Graduate Student
Latasha*	HBCU, urban, 7,000-9,000 undergraduate enrollment	South	Physics	yes	Graduate Student	STEM - Graduate Student
Daphne	HBCU, urban, 7,000-9,000 undergraduate enrollment	South	Physics	yes	Graduate Student	STEM - Graduate Student
Jordan	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	?
Nicole	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	?	?	Undergraduate Student	?
Marissa	HBCU, urban, 1,000-3,000 undergraduate enrollment	South	Physics	yes	Post-doctoral fellow	STEM - Graduate Student
Whitney	PWI, rural, 1,000-3,000 undergraduate enrollment	Midwest	Physics	yes	Undergraduate Student	STEM - Graduate Student
Shelby	HBCU, suburban, 5,000-7,000 undergraduate enrollment	South	?	?	?	?
Alexis	HBCU, suburban, 5,000-7,000 undergraduate enrollment	South	?	?	?	?
Gabby	PWI, suburban, 23,000-25,000 undergraduate enrollment	Midwest	Physics	yes	Graduate Student	?
Ebony	HBCU, urban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	STEM - Teaching
Lindsey	PWI, suburban, 1,000-3,000 undergraduate enrollment	West	Biology	yes	Undergraduate Student	STEM - Graduate Student
Toni	HBCU, rural, 1,000-3,000 undergraduate enrollment	Northeast	?	?	Undergraduate Student	?
Noelle	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Graduate Student	STEM - Graduate Student
Patrice	HBCU, urban, fewer than 1,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	STEM
Felicia	HBCU, urban, 1,000-3,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	STEM - Graduate Student
Jackie	HBCU, urban, 7,000-9,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	STEM - Graduate Student

Themes from Re-Coding Process

The purpose of this chapter is to provide a summary of findings identified during the re-coding process of focus group transcripts from the larger NSBP study. It is not intended to be a detailed accounting of all of the experiences of the women in the larger study. Instead, it is intended to identify common themes across the 31 African-American women and inform the more detailed analysis in Chapter 5.

Findings in this chapter are solely based on African American women's comments related to the undergraduate classroom experience in NSBP focus groups. The focus group transcripts were coded based on themes identified from the theoretical frameworks and existing literature on the experiences of women of color in STEM majors (Appendix G). Although there were numerous themes covering a range of topics in the coding scheme, there were several themes germane to the undergraduate classroom experience: *Postsecondary Experiences, Faculty Interactions, Peer Interactions, Institutional Factors,* and *Science Identity*. Two sub-nodes from *Race/Ethnicity/Cultural Issues* are also included in the focus group findings. These sub-nodes are *Proving Process* and *Racial Experiences*.

The recoding process served several purposes. First, it enabled me to become more familiar with African-American women's comments across multiple years. I was able to identify recurring themes among the African-American women, and develop relevant questions for the follow-up interviews. It also enabled triangulation of data collected at different points in the women's academic and career trajectories. From the re-coding process, I was able to compare the women's expressed goals with actual outcomes evidenced by web searches and follow-up interviews. I was able to identify deviations from established frameworks, and identify emerging themes for further exploration in individual interviews. For example, the women referenced different interactions with international peers and faculty, and began to allude to a culture of physics/STEM. There were not direct questions about these themes in the original focus group protocols, but I included these types of questions in protocols for individual interviews.

Based on findings from the re-coding process, questions for individual follow-up interviews were refined to include more direct inquiry about topics such as the women's classroom interactions, development of science identities, STEM culture, and transitions to careers and graduate programs. Chapter five will include a detailed case profile for each participant, cross-case analyses, and a more thorough discussion of findings based on the follow up individual interviews.

Postsecondary Experiences

Focus group transcripts were coded for postsecondary experiences at the undergraduate, graduate, and post-doctoral levels. The focus of this study is the undergraduate classroom experience; therefore only undergraduate experiences are included in this analysis. Participants' comments were coded as postsecondary experiences when they described the general climate in their undergraduate degree programs, as well as comparisons between their undergraduate experiences and K-12 or graduate school experiences.

Participants described feeling challenged moving from their K-12 academic experiences to their undergraduate STEM coursework. In many cases, participants also described classroom climates that differed from their high school classes. They encountered lectures with far more students, and less direct interaction with their professors. They also described more competitive classroom climates, and higher expectations from professors.

In many cases, they described feeling unprepared in comparison to their peers from college-preparatory schools and high schools outside of the United States. One participant, Nicole, recalled a professor from China who explained that there is greater rigor in the Chinese education system in comparison to the United States;

> …A lot of our foreign teachers have a lot higher standards than our American teachers because of their background, and I had a professor…from China…she would always explain to us how these classes were things that she had to have and how the structure of – their education in foreign countries is so much different than ours here.

Nicole's professor's educational background led her to have higher expectations for her students here in the United States. Again, Nicole said;

> …. And so it seems like they have much higher standards for us as students than some of our own teachers, some of the people that are from the U.S., well, that were raised in the U.S.

Felicia described heightened expectations from international faculty based on their pre-college experiences outside of the United States;

> ….they're really – they're a lot more strict, I think because they were taught under like a [different] system. So, they expect us to know a lot more…. they hate the American system of education. They can't stand it because they're like, "You don't know this?!" It's like, "I had this when I was two years old."

There were distinct differences in depictions of undergraduate experiences across institution types. Students who attended HBCUs often described more supportive classroom climates and departmental cultures than peers who attended TWIs. They described environments where faculty encouraged peer collaboration, and sought to develop relationships with their students outside of class. Similarly, those who attended smaller campuses also recalled more personal connections with faculty. Students who attended larger TWIs described the most competitive and isolating classroom environments, as they often felt lost in large lectures, and has less interaction with faculty.

Participants developed a more keen sense of their career aspirations in their undergraduate programs. They were exposed to individuals working in STEM fields through colloquia, conferences, research presentations, and recruitment visits. A number of students also participated in undergraduate research programs, summer internships, and student organizations that helped them identify and refine their career goals. Participants who were graduate students at the time of the focus groups were able to reflect on their undergraduate experiences in comparison to their graduate programs. This retrospective perspective was helpful in identifying individuals and practices that had the greatest long-term impacts on their success. They were also able to speak to their preparation for graduate programs and careers.

Faculty Interactions

There were mixed responses to questions around faculty interactions in the focus groups. Nearly all of the women in the study recalled interactions with faculty that they perceived to be discouraging or condescending. In the classroom setting, these interactions included negative responses to questions in class – such as "you should have already learned this", or comments predicting negative outcomes based on their gender, race, or nationality (i.e.: American students don't do well in this class). In these cases, women developed negative perceptions of their professors' beliefs in their abilities, which negatively affected their classroom participation.

Several participants described feeling a sense of anxiety about speaking in class or answering questions because of their professors' responses to incorrect answers or questions they perceived to be irrelevant. Annie attended both an HBCU and TWI as part of a combined degree program. She had positive classroom interactions at the HBCU, but felt more apprehensive in the TWI environment. She attributed this anxiety in part to professors' behaviors, stating; "I had a professor – yeah, he wasn't really responsive to questions. But he'd throw…maybe he'd throw an eraser or something if you asked what he considered a stupid question."

In other cases, there were faculty members who developed reputations among students for being racist or sexist. Daphne recalled one professor in her department who she and multiple peers perceived to be sexist:

> I've had an experience with a teacher in undergraduate who refused to give me high grades because I was female…he taught quite a few of our courses.

She described her frustration with this professor and his courses, but used these experiences as motivation to work harder:

> …But him doing that never made me feel like I couldn't do it. And it never discouraged me. But it always made me mad. And that motivated me more so than made me say, "Oh, I just quit."

She saw his behavior as part of social/societal issues bigger than herself, and sought out support from individuals outside of his class:

> ….Because one thing that I've realized about professors, whether they treat you nicely or not, it's not about me. You know what I mean? This has happened to somebody before. Someone's been through this before. And it has absolutely nothing to do with me, because he doesn't even know me. …So you seek out other ways to be successful. You seek out other people who you know are here to help you. And that helps. Because one thing you can't do is bank on everybody liking you and bank on everybody wanting to lend you a hand.

The women in the study noted some increased pressure in classrooms to avoid embarrassing themselves in front of their peers and professors. In some cases, they mentioned less personal interaction with professors in lecture settings. Gabby, who attended both an HBCU and TWI as part of a combined degree program described what she perceived to be lower expectations and limited interactions with professors in class based on her race:

> …Being the only African American in the classroom with other nationalities, it's really bad for me. It's a bad feeling because I don't feel like they think I know what I know, so I have to perform on tests, and that's how they know "Oh, okay," 'cause I don't even get looked at. You know, they're lecturing. And I sit dead smack in the middle, every class, in the front. Front row.

Nearly all participants recalled multiple courses in which professors failed to engage them in the classroom. They recalled detailed memories of classes in which professors taught “to the board”, rarely even making eye contact with students. Many professors focused on theoretical concepts, but failed to explain how those concepts could be applied to real-world problems. The majority of participants in this study sought to understand applications for the material they were learning, and struggled to see the value of the concepts they were learning in these classes.

Language barriers with international faculty were frequently mentioned as reasons why students felt disconnected from their professors and course material. Alicia described interactions with one professor in an introductory physics course:

> It was like ‘we have a deadline - we have to get through this much material, we need to get through it. If you don’t get it, come to my office hours’, and even when you’d come to his office hours, there was still like kind of a barrier…a language barrier between questions you have and trying to get your question out and getting him to understand what you were asking, and trying to actually get what you wanted to know.

Not only did Alicia feel rushed through the material in class, but she was unable to communicate well enough with the professor to take advantage of assistance during office hours.

In contrast, some participants recalled professors who worked to engage their students in class through group work, organizing study sessions, and applying course concepts to real-world problems. These practices resonated most with the women in the study. Latasha recalled her undergraduate advisor's efforts, stating, "….when I was an undergrad, my advisor was just top-notch, like he made sure we had work-study, we had weekly meetings. We did all these different things with him; we always knew what was going on." Her advisor was not only concerned about his students' academic progress, but also sought to ensure that they were aware of requirements and opportunities outside of class. Alicia also recalled a professor who went above and beyond his required duties to ensure that she and her classmates understood course material. His willingness to extend himself made them feel more responsibility to do well in his class:

> …. He was more concerned about, like he gave us his cell phone number, you can call me anytime of night until like two a.m. or something like that. And call me anytime with questions, come by, it was just more, he was like yeah, we have class and even though our class was I guess a fifty minute class, sometimes we would go over, maybe two hours in the class like we have so much to do. Like we have to, he was so passionate about what he did it kinda like rubbed off on us, like oh we have to learn this, you know?

These faculty behaviors made the women feel that their professors were not just experience in the field, but were also invested in them as students.

When asked what types of teaching practices they found to be most beneficial, the women in the study discussed making clear connections between past courses and new topics being taught in their classes. They also described practices wherein faculty seemed to be excited about the material, and brought positive energy into the classroom. A professor in one of Alicia's physics courses was animated in her teaching, and would even demonstrate concepts through motions. Alicia described this type of demonstration, saying, "…she'll be in class and like she'll start jumping around like, "This is the electron jumping up!" In some cases this energy was fueled by the professors' own research interests. Similarly, Ebony recalled one physics course in which her professor would sit in a desk like a student, and instruct his students to 'teach' the material they learned earlier in the week. This activity engaged the students and enabled the professor to identify areas where the students may have lacked understanding. These types of experiences made the women more interested in the material, and in come cases sparked their own interest in teaching and research.

Nearly all of the women discussed the importance of understanding applications of concepts learned in class. Undergraduate research is one way to accomplish this, but the women especially appreciated when practical applications were infused into their courses. Marissa linked her understanding of applications with interest in her courses:

> I would say – more demonstrating, you know the application of the physical laws. Like bringing something in. That definitely helps when learning physics...Like demonstrations…And it makes you want to learn physics, well, in my eyes it does.

Jackie recalled a professor at her undergraduate institution who demonstrated concepts in a physics course:

> He's way younger and he's just like – I feel like he just caters to the student because he knows what we need…He'll be like, "You're not

getting it?" He'll try so many different ways. He'll actually get – like he brought some materials to show us a concept for a physics class, like, "What?" Like "Introductory physics?" Like he bought materials to show you in person.

Other participants also mentioned applications of course concepts. Latasha asserted that physics, by definition, is applied mathematics. Therefore, she felt that the most effective professors were able to not only teach equations, but show their applications:

> Well, I think for a professor in physics, it's applied math. So in addition to the math you have to have a professor who can really show you the physical properties of why you're doing what you're doing. And if you can't really see that or they don't care if we see it, it makes it difficult. It makes it difficult for me. Because I need to be able to see why I'm doing the math. And there's some professors who will just put something on the board and say, "Figure it out." And that doesn't really help you, cause it doesn't make you want to really figure it out.

Noelle noted she appreciated faculty who connected class concepts with research:

> I like when they include like research, like, "Okay, you can use this to do this type of research." Or like, "With this that we're teaching you today, you really need this for this type of research." And so I like that…When they make it relevant.

Connecting course concepts with applications in the field was a common theme among African-American women in the focus groups. For many of them, this was a means for them to link general coursework to their individual career interests.

Aside from the negative interactions, many of the women could recall at least one professor with whom they forged an advising or mentoring relationship. These professors were instrumental in helping the women make connections with faculty in graduate programs, encouraging, and providing references. Toni identified one female professor that was a source of support in hr undergraduate program at an HBCU:

> ...She takes me under her wing, and she's here with us – like she'll watch out for me every step of the way…She makes sure that I will not fall down. If I am struggling in the class, I can come see her, come to

> her office hours, after her office hours, call her. They really like grab you, and they keep you here, because there's only a few of us in this major...

Although they drew support from faculty with a range of racial/ethnic backgrounds, participants recalled distinct differences in their interactions with African-American faculty members versus White or International faculty members. They valued African-American faculty members' willingness to be open about their own experiences and challenges. They also felt that African-American faculty members could relate to their experiences as underrepresented minorities in their respective fields. Noelle recalled:

> … I just felt like I could relate to them more. And they would tell you about their experiences, versus the others, they would just push you academically…. international faculty would just tell you, "Do this, do that," or give you the tools academically, but not socially…"

Similarly, another student, Valerie, described differences in her interactions with international faculty and faculty from the U.S. She also notes that she appreciates professors who seek to get to know her beyond a name and face in their lectures:

> I think it's just cultural differences between some of our foreign professors. I don't think they mean it like in a negative light or any manner that they don't like you or anything like that, but I think they're more kind of like they teach the material, you take the test, and that's it. It's not really too much outside of that. Some professors, though, go beyond and they actually get to know you and your learning style and try to help you. So I guess I prefer the people that actually you get to know versus the people that you just sit and listen to a lecture and leave.

In spite of some difficulty relating to international faculty, Felicia recognized some advantages to her exposure to scientists from other countries. She noted that international faculty provide insight into the beliefs, behaviors, and expectations of the science community beyond one institution, saying "I think the international faculty members kind of – I think they prepare you more for the rest of the world."

Participants described their interactions with international faculty in greater detail in their individual interviews.

Participants frequently described experiences with other faculty members in physics who were not interested in their lives and interests outside of class. Several students also described professors who seemed to disregard their other academic commitments. Nicole described her perceptions of faculty expectations as a source of stress:

> … They pretend like there's – you have no life when you're in their class. There's nothing else that goes on in your world but math or physics or anything else, like if teachers would be more sensitive to not necessarily your social life but just your outside life period, even other classes …they think that their class is your only class, your only priority, and when other teachers try to pile all the work on you, that's why everybody feels so stressed out.

They alluded to the fact that this expectation to solely focus on science/physics was part of a larger culture in their academic discipline. Some elements of this STEM/physics culture were identified in the literature review, but individual interviews will give more insight into Black women's responses to it. Questions about physics/STEM culture were not part of the original focus group questions, but they were included in the follow-up interview protocols. Findings from those interviews will be presented in chapter five.

Peer Interactions

Peer dynamics in many participants' programs were shaped by students' sex, race, and culture. Again, several participants mentioned large proportions of international students in their programs. In some cases, they were able to identify with international students as minorities, and saw their presence as enhancing the learning environment. In other cases, they perceived that international students would develop cliques that only shared information and resources amongst themselves. The women found these cliques difficult to permeate, and felt excluded both from groups of white students, as well as groups of international students. Some participants also discussed difficulty with entering into study groups with male students. This was typically an issue with White males and males from international backgrounds in the TWI environment. The women described supportive relationships with their Black male peers. At TWIs they typically had positive relationships with Black male peers, as they perceived that Black males were also excluded from networks of white and international peers.

Peer dynamics in the classroom setting also varied by institution type. Students at HBCUs frequently reported perceptions of supportive peer cultures, whereas students at TWIs more frequently described competitive environments. Felicia took undergraduate courses at an HBCU, and recalled having close relationships with her peers outside of class, but being competitive in courses and assignments

> ...In the sciences, we're all competitive… we're friends but when it comes to taking tests and doing what we gotta do, we're kinda like on our own… if you're gonna take a test, you're gonna study by yourself and you're gonna get that A by yourself.

In most cases, peer dynamics also varied by the level of the math or science course referenced. The women's introductory level courses were larger, and included students from a range of majors and pre-medicine students, whereas the upper-level courses were usually smaller, and solely comprised of physics and engineering majors. In smaller classes, there were a limited number of classmates, so they would support one another in study groups.

Particularly at larger TWIs, the women felt a sense of constant competitiveness amongst their peers in their physics and other STEM courses. They perceived that their peers were reluctant to help or share information, to ensure that they stayed ahead of others in their classes. This competition was sometimes based on countries of origin. For example, Myriam recalled a group of students from China who overtly aimed to exceed the performance of students from the United States. In one particular case, Myriam recalled helping a Chinese classmate with an assignment. When he saw that she understood the material, he became stressed, saying that he could not let her score higher than him on an exam "…because you're not Chinese."

As an international student herself, Myriam had different relationships with international students. She described a shared experience of being in a new place and learning the academic expectations in the United States:

> … Most of the time, we all go through the same things. One is – it's more of an emotional roller coaster you're on. Because you come here and you're away from family and all that; and then you have to cope with school. …So interacting with other international people—you will find that the international people group together because we are not accustomed and we are now trying to get into the system. So interacting with them is really, really helpful. It helps you go through the same things together, and you have more support.

One other participant, Whitney, attended a TWI and forged close relationships with international students. She recognized that they shared feelings of isolation, as she was the only minority in her program, and there were just a few international students. They also had a shared understanding of being far away from home and family. She described these relationships, saying "..I kinda tend to hang out with more international students because like this is not where they're from and I feel like I'm not from here either."

In many cases, the women in this study were members of student organizations and clubs in their department or with a STEM focus. These were important sources of support for them, and peers in these groups served as invaluable resources, providing information about courses and professors. As members or officers in these organizations, the women were often able to attend conferences such as the NSBP Annual Meeting. There were great opportunities for participants to get exposure in the field and network.

Institutional Factors

The most commonly mentioned institutional factor in the focus group interviews was the differing climate between HBCUs and TWIs. Several participants attended more than one institution, either as part of combined degree programs, or for undergraduate and graduate programs. The women drew comparisons between different institutions they attended, and described faculty and peers as more supportive at HBCUs. They also identified differences in financial resources at the two types of institutions.

Annie attended a combined degree program at an HBCU and a TWI. She noted a distinct difference in her perception of the climate at each institution. She saw the climate at the HBCU as much more nurturing than the TWI:

> When I got to [the TWI], it was the first time I ever found myself not wanting to ask questions in class, and not feeling comfortable. And I still don't, to this day, know why. But I remember feeling differently from how I felt when I was at [an HBCU]. At [the HBCU], you felt

> like you could ask any question at any time. You weren't intimidated. You could get it wrong, and you just didn't feel intimidated.

Gabby attended an HBCU for her undergraduate degree, and a TWI for graduate school. She also felt a much stronger connection with faculty at her undergraduate institution, stating

> The advantage on the other side of attending an HBCU, I think, is more of the one-on-one interaction. I think you get more even just advice for life. To me, I always – or for me, rather, I always had professors that took an interest in me, in my life and my goals and things like that. That just really did something for me.

Alicia perceived that she and her peers at an HBCU were expected to engage in research or other supplementary activities, and faculty pushed them to do so:

> …Well I know as a physics major, the advantage of going to a HBCU is like a focus on research. There's a lot of research opportunities and they really push to get you out and do research…our professors are like, "Oh yeah, you should really do research this summer." Like you should really start, even in your freshman year.

A commonly cited downside to the HBCU environment was perceptions of limited resources. Alicia also attended an HBCU for her undergraduate program, and a TWI for a graduate program. She found that in the HBCU environment there were fewer resources, and more restrictions on how and when they could be used:

> I guess I've been on both sides of the fence now. I've been at [an HBCU] now and I've been at [a TWI] and just being at the Traditionally White institutions, you notice that there are more funds available. Its' very different. Even the -- I wouldn't say the teachers -- but more so the academic environment. Being at [the HBCU] feels very restricted and closed off again as if you have – you can't really do what you wanna do and it's kind alike you always have rules and whatnot….
> …Whereas at [the HBCU], even for the small whatever resources we have, they keep them all locked and you have to be like – everyone's just trying to scramble for that little bit and they're' like, "Oh well, I need to see this, this and this before you can check it out" or even get anything."

Several other women who attended HBCUs described having limited resources on their campuses, compared to TWIs where they engaged in research programs, courses for combined degree programs, or graduate programs.

Science Identity

Early Identification with Science

Many of the focus group participants identified people who recognized their talents and abilities from a young age. This recognition often came from K-12 teachers, and mentors in the form of affirming their potential, or suggesting that they would succeed in specific STEM careers. A number of the women said that family members told them that they would 'make a good' doctor, engineer, or researcher in the sciences. One participant, Daphne, described recognition from others even before she realized her own abilities: "I've had people that have invested in me in ways that I didn't see for myself. You know when adults see you as a child, you know they see these things in you." Similarly, Myriam described the importance of recognition from meaningful individuals outside of academia in her own experience: "I think non-academic people are the ones that give you more support than faculty members. Actually, they are the ones who see the potential in you, who see the passion for what you want to do." Her comments were not intended to negate the importance of faculty recognition, however she noted that recognition from family and others was outside of academia was helpful in the absence of recognition from faculty, saying "…your faculty, normally … don't give you moral support. They want research done."

For many of the participants, recognition often came in the form of encouragement from faculty, friends, and family members. They drew confidence from these affirmations. Gabby attended an HBCU for her undergraduate degree, and recalled feeling capable based on support and encouragement from her professors:

> When I think back to undergrad, the first thing that comes to mind is how I tended to flourish in the undergraduate environment when the professor was very affirming. Again, I went to an HBCU, and because of the small classroom size, there's a lot of – there's more one-on-one. I mean, you can just talk. You can ask questions. And just knowing that I get it and the teacher knows I get it, that just really boosted my confidence. So I think, for a student, that's really important.

Myriam described encouragement from faculty at her undergraduate institution as motivating her to excel in her graduate studies:

> I think the beliefs of the faculty in me as a person and believing that I can do it has made me want to reach further and has made me strive for where I wanna go and where I'm at right now.

Encouragement was sometimes more subtle than verbal affirmations. Myriam also drew from her experience with other Black physicists in her undergraduate program to see herself in a similar position:

> …And I think the support from my faculty back home—because it's mainly black. And to see that they have made it has also encouraged me to know that I can also make it.

One student, Annie recalled feeling empowered to pursue physics after taking a course with a Black professor:

> In undergrad, I went to an HBCU. I thought I liked physics, but all of my classmates told me that this was too hard for me to major in…So I was kind of deterred from doing the major as a freshman… But when I had a black physicist as one of my professors…it made me realize that I could do it because I saw him—and I changed my major from math to physics.

Myriam and Annie both benefitted from the presence of minority physics professors in the sense that it made them feel like their goals were attainable.

Competence and Performance/Mastery

All of the women described themselves as competent and capable in science and math. They described having a knack for science, taking difficult science and math courses in high school, and excelling in them when many of their peers struggled. At the undergraduate level, they did face significant learning curves in physics and math courses, however in most cases they were ultimately able to succeed. The women felt a personal sense of accomplishment when they mastered a concept, earned a high score on an assignment, or had a successful conference presentation. The women felt especially empowered when they were able to show their skills to peers and faculty. Although their competence was not directly discussed in the focus groups, participants alluded to it in other conversations about their academic experiences. Furthermore, the women's competence/mastery is evident from their enrollment and completion of undergraduate and graduate programs. More extensive findings about this theme will be detailed in chapter 5.

Race/Ethnicity/Cultural Issues

The women's conversations around race and ethnicity provided some interesting insight into the climates in which they studied physics, and their perceptions of race in those settings. Interestingly, when asked directly about racial experiences in their departments, the women often said that they could not recall experiencing racism. However, as they discussed interactions with peers and faculty, and other themes such as proving, they all described instances when they were treated differently or felt that they had to prove their abilities based on their race. These interactions were always in predominantly white environments, or courses taught by international professors. They were not called offensive names or barred from classes, however they were frequently made to feel as though they did not belong in some courses or in physics as minorities and as women.

The women clearly saw their race and gender as inextricably linked, and often described their experiences in terms of both race and gender. Therefore, many of the subsequent descriptions of racial experiences and proving processes will include experiences related to both race and gender.

Racial Experiences

Focus groups participants experienced a number of situations in which their race affected their interactions with their peers and professors. Lori, who attended a TWI, said

> I think that all white faculty have it set up against me. I'm just convinced that they're all against all students of color. They don't want us to succeed, they're not helpful at all….maybe it's just me and I've just had bad experiences, but I'm just really, really upset with some of the faculty and some things that are happening. I think that it's impeding my success.

She went on to describe feeling that she was constantly given negative feedback on her work, when she felt that it was comparable or superior to that of her peers.

Sharee attended classes at an HBCU and TWI. In physics courses at the TWI, she felt that her classmates and professors underestimated her knowledge because of her race. She noted that there were usually only a couple of Black students in those classes, and her peers assumed that she would not know the answers to questions in class: "….they look at you - don't even attempt to raise your hand and answer a question. Everybody's attention is automatically on you like, 'Do you really know what you're talking about?'" Her professors also seemed to be skeptical of her responses, and asked that she show her work, while accepting other students' responses at face value:

> Or the professor even – you know, you raise your hand, everybody else is sitting down answering questions, and then when he gets to you he's like, "Oh, well show me on the board," because they just want you to make a fool out of yourself because they do not expect you to know what you're talking about.

Kristen also identified differences in the classroom climate at HBCUs and TWIs. She felt that her peers supported one another in the HBCU environment, but at the TWI, she felt that her classmates assumed she was there to fill a quota. She said, "it's like, you don't even deserve to be here, you probably just got in because they have a quota."

Several women discussed research and internship experiences on other campus, or in off-campus labs. They noticed differences in the ways they were treated in comparison to their majority peers. They endured isolation, menial assignments, and negative comments from their supervisors and lab mates. Lawanda and Alicia gave two of the more detailed descriptions of racism in summer research experiences. Lawanda's supervisor assumed that she did not know how to use basic lab equipment despite the fact that she was an upperclassman in a science major, but trusted that her white peers were familiar with it. Then, while other students were assigned research projects, she was assigned tasks in a supporting role, such as "Pouring people's plates, pulling things for other people, not actually working on my project…" Similarly, Alicia worked in an off-campus lab, and was assigned simple tasks while her white peers were assigned much more complex research projects. Ultimately, her breaking point came when the individual assigned to serve as her mentor "…proceeded to ask me to go get him some coffee." After that experience, she asked to be assigned to another lab.

In some cases, they experienced more blatant references to negative stereotypes. One student described attending a reception early in her undergraduate program, and being told by her department chair, "You don't look like a physics major". Valerie interned at a national laboratory and dealt with isolation as the only minority and the only woman working there. She endured racist comments and jokes from staff and supervisors there. She described one incident, saying,

> they're all white men, foreign, or American. And they make comments. Like, sometimes I think they think they're kidding, but sometimes they really bother me… like – they made a fried chicken and watermelon comment that really made me really angry, and they thought they were kidding, but I didn't find it very funny. So, I try to show them that there's people that live to higher standards and that that is not like black people. We don't sit around and have fried chicken and watermelon every day for dinner.

In the TWI environment, Sharee described assumptions about Black students as athletes vocalized by her peers:

> …Blacks really being the minority on campus, the rest of the students expect you to be an athlete. If you're a black and you're at this institution, [it's] automatically assumed, "Hey, do you play basketball?" "You know, what kind of athletic scholarship are you here on?"

Sharee was most bothered by the implication that she and other Black students' presence was based on athletic prowess rather than merit or academic ability. Even as physics majors, the women in this study dealt with negative stereotypes and racism from their peers, professors, and supervisors.

Proving Process

A number of focus group participants discuss feeling that they had to prove their abilities to peers and faculty based on their race and gender. They frequently described proving as burdensome, yet seemed to accept it as just another aspect of their experience. Several participants linked the proving process directly with their perceptions of their undergraduate classroom experiences, saying that they felt more stress and anxiety in classrooms where they felt that had to demonstrate their abilities in order to be respected as a physicist. In contrast, they were more readily engaged in settings where they felt that they were accepted as a competent peer in the field.

Latasha alluded to a sense of needing to 'prove' herself as a Black woman in physics and work harder than her white peers, saying "I believe that black tax does exist. I believe that we do have to fight harder. We're not the norm. We're not the majority. You have to be there early. You have to stay late sometimes.". When asked directly if she felt the need to prove herself among her professors and peers, Latasha responded by saying:

> I don't think I've never not felt that need. I mean to be honest with you….I don't know any other – I mean I've never not been black. I've never not been female. I don't know any other way but to know that I have to do it better or attempt to try harder or have that extra something that is gonna push me over the top. And that's just all I know.

From her comments, it is clear that Latasha has accepted 'proving' as a permanent part of her experience as a student and as a scientist. Other focus group participants agreed with her comments, and expressed that they too felt a constant need to prove their abilities in physics and other STEM courses.

In some cases, focus group participants were motivated from their professors' and peers negative assumptions about their abilities. Thus, for them, the proving process may have had some indirect benefits. Toni was one participant who responded this way, saying

> …the dean of the physics department just stressed to me that, "I don't think you'll be able to do it. I don't think you'll be able to hold out in this field," which is kinda motivating me, because I'm proving him wrong, because I'm doing it, I'm going to tutoring, I'm doing what I have to do to get through it….And when I have his classes, I make sure I sit in the front, and I do everything that he asks me to do.

Another woman, Shelby, described using negative feedback as motivation to succeed: "…the more you say I can't do something that I think is productive… then the more I'm gonna strive and do it to prove you wrong, but at the same time for my benefit too…" Myriam also embraced the challenge of disproving negative stereotypes. She suggested that among peers and faculty of other races, she and other students push themselves to succeed: "Sometimes the only way we push ourselves is when we have competition—and competition from a different race. Because we are told that we are not good enough; so we want to prove that we are good enough." Despite the women's optimism about their proving experiences, it was clear that proving does not come without costs of stress, fatigue, and strained relationships.

Nearly all of the women described their perceptions of needing to prove themselves as a burden that amplified the stress of being in a challenging major. Kristen described this feeling, saying "…it's just so much to take on own shoulders to be like, 'Well, I'm gonna do this for, you know, black people and I'm gonna show them how we can be', but I'm really just trying to keep my head above the water…it's just too much if you worry about trying to prove yourself to people." Daphne discussed feelings of stress and anxiety in academic settings where she felt she had to 'prove' herself. She also expounded upon other women's comments to acknowledge the role of instructors in creating learning environments where Black women could feel free from pressures to prove their competence. She described one class wherein the professor made negative comments about women in physics. In that setting, she felt that she had to carry herself in a formal manner and get correct answers in order to show her abilities. She said,

> I remember thinking, "Okay, I can't mess up because he thinks that I'm going to mess up"…. "Oh my gosh, I have to do this. I have to do that. I have to be certain this is done. I can't look this way or that way. Can't be late. Cell phone off. Don't want that to ring by accident. People looking at you crazy."

In contrast, she described feeling at ease in settings when her professors and peers treated her as an equal:

> …if I get into the room and I meet people that are not really necessarily looking for me to be different, then I immediately relax and I perform still. But it's not like I have the race on my shoulders. You know what I mean? It becomes, 'okay, good, I can work comfortably in here.'

Daphne's comments shed light on the stress and pressure associated with 'proving' among Black women in physics. Her comments also show the importance of professors in setting the tone for interactions in their classrooms.

Summary of Focus Group Findings

Re-coding transcripts from the NSBP focus groups provided valuable insights into African-American women's undergraduate classroom experiences in physics. The women all expressed strong beliefs in their abilities from an early age, describing themselves as "good at" science and mathematics. They identified individuals who recognized their talents and invested time and energy in their academic pursuits. These pre-college experiences seemed to set precedents for their achievements in undergraduate STEM courses.

Despite their family support and advanced high school coursework, the women felt that they had to make major strides academically to succeed in college.

They were often in classes with peers who attended private, college preparatory programs, or attended high schools abroad with rigorous math and science curricula. The women perceived that these students knew more about course topics than they did, and professors moved quickly through course material.

In their introductory classes, the women did not receive the level of individual attention that they were accustomed to in their high schools. They had to adapt to a variety of teaching styles, but were most engaged when professors were able to connect course concepts with practical applications. The women also drew distinct contrasts between their experiences at HBCUs and TWIs. In HBCU classrooms, the women felt that they were supported by faculty, and they were encouraged to work collaboratively with peers. In TWIs and other predominantly white academic environments, they described feeling isolated, and feeling pressured to disprove their professors' and peers' negative perceptions of minorities and women.

Finally, the women noted a strong presence of international faculty and peers in their STEM courses. A few participants saw advantages to engaging with international colleagues, such as developing a global awareness, and having a shared experience of being in an unfamiliar setting. The majority of the women felt excluded from networks and study groups comprised of international peers. They described difficulty communicating with faculty from other countries, and sensed that they looked down upon students educated in the United States.

Analysis of Focus Group Findings

The women's focus group comments begin to provide insights about their development of identities as scientists and the ways in which they perceived their undergraduate STEM learning environments. Consistent with Carlone & Johnson's (2007) grounded science identity model for women of color, participants consistently recalled recognition of their talents from scientists and meaningful others. They also described having opportunities hone their skills in science and math.

Interestingly, when asked about the role of race in their experiences in physics, the women often responded that they felt that race did not affect their experience. However in responses to subsequent questions, they described instances when they felt that they were discouraged or their abilities were questioned based on their race and gender. The women's delayed responses about racial experiences may be indicative of the subtle nature of some of their racialized experiences. Their responses may also point to a culture of physics/STEM departments in which race is not a common topic for discussion. As students who had been in science courses since their freshman year, many of the women may not have been accustomed to discussing their race and racism within the science community.

Often, the women described subtle racial experiences, yet the implications of these interactions were profound. When the women felt judged or assessed solely on their race and gender, excluded from the physics community, and felt additional pressure to dispel negative perceptions. In this sense, they were more reluctant to seek assistance or engage in thought processes publicly, out of concern that their professors and peers would see them as less capable. The subtle nature of the racism the women experienced is consistent with research on classroom climate (Brown, 2004; Cote & Levin, 1997; Crawford & MacLeod, 1990; Fries-Britt & Turner, 2001;

Green & Glasson, 2009; Johnson, 2007; Lewis et al., 2000; Museus, 2008; Museus et al., 2011; Seymour & Hewitt, 1997; Solórzano et al., 2000). Solórzano and associates (2000) described these subtle actions that isolate or exclude certain individuals in classroom settings as microaggressions. Participants described numerous instances when they experienced negative interactions that they perceived to be based on their race and gender. For example, Gabby's professor's failure to make eye contact with her despite her position in the front of the classroom suggests that his behavior may have reflected his negative perceptions of her abilities.

The women described the first year of their undergraduate physics majors as one of their most difficult adjustments. They attended large lectures and struggled to find meaning in the theoretical material they were taught. Many participants resigned to the fact that the large lectures would not be a positive learning experience, but acknowledged that they had to pass them in order to advance in their major. These findings show the importance of engaging women in introductory courses when many students attrite. Their experiences are consistent with other studies citing ineffective teaching practices frequently used in STEM lectures (Johnson, 2007; Seymour, 1995; Seymour & Hewitt, 1997). Application of course concepts is a theme present in existing literature related to undergraduate STEM retention (Cabrera et al., 2001; Lipson et al., 2012; National Research Council, 2005). Particularly for the African American women in this study, applications enhanced their understanding of course material.

Nearly all of the women noted a strong presence of faculty and students from countries outside of the United States in their programs. The United States is the destination for the majority of students who study outside of their home countries worldwide (OECD, 2008). Foreign student enrollments in undergraduate STEM programs in the United States have grown consistently since 2006. Approximately one third of foreign students studying in the United States are enrolled in STEM programs, and most of these students come from China, South Korea, India, Canada, and Japan (National Science Board, 2012). These trends are even greater in graduate education and the professoriate. In 2010, 60 percent of foreign graduate students studying in the United States were enrolled in STEM degree programs (National Science Board, 2012). Given the shifting demographics of STEM faculty and students (National Science Board, 2012), it is increasingly important for educators to understand how these changes affect classroom climates in STEM programs.

The findings support literature that recognizes HBCUs as supportive spaces for Black women in STEM (Brower & Ketterhagen, 2004; Lent et al., 2005; Perna et al., 2009; Whitten et al., 2003, 2004). This also corresponds with data on underrepresented minority graduation rates in STEM, indicating that HBCUs produce more graduates in these disciplines (AAAS, 2004; AIP, 2010; Babco, 2003). HBCUs comprise less than 5% of colleges and universities in the United States, yet more than 25% of Black graduates in science and engineering come from these institutions (AIP, 2010; Babco, 2003). In the years 2008-2010, HBCUs awarded 45% of physics Bachelor's degrees earned by African Americans (Mulvey & Nicholson, 2012). Between the years of 2004-2008, HBCUs represented 13 of the top 15 baccalaureate granting institutions for Black students in the physical sciences (AIP, 2010).

In spite of the support provided by HBCUs, the women identified some inadequacies in resources in comparison to their peers who attended TWIs. Peers who attended TWIs often had access to state of the art laboratory equipment, and studied with renowned scholars. Resource differences between HBCUs and TWIs have a long history (Allen & Jewell, 2002; Allen et al., 2007). HBCUs have been underfunded relative to TWIs, and these disparities are apparent at the department level. Since 2008 a number of HBCUs have been forced to discontinue their physics degree programs due to financial constraints or limited student enrollments (Mulvey & Nicholson, 2012; Williams, 2010). In more recent years, a number of government agencies, foundations, and private corporations have begun investing in STEM scholarships and infrastructure at HBCUs. Participants' comments shed light on the importance of continuing these initiatives.

Postgraduate STEM Involvement

Through my efforts to identify current contact information and other information about the African-American women in the larger study, I was able to gain insights into patterns in their degree completion and postgraduate involvement. Specifically, I was able to confirm that at least 25 of the Black women in the database completed their undergraduate degrees in physics. At least 23 participants went on to pursue STEM careers or graduate programs. There were several participants I was unable to locate, therefore information about their degree completion and careers remains unknown. However, the successful undergraduate and graduate degree completion of the vast majority of the women supports their designation as highachievers. They represent a unique sample of Black women who persisted and excelled in a field where they are severely underrepresented.

Findings from the focus group interviews provided insight into interactions and individuals that contributed to their success in physics. In the next chapter, I will turn to an examination of findings from follow up interviews with 11 African-American women from the NSBP study. Chapter five will also include case profiles for these women, and a more detailed analysis of findings related to their classroom experiences and persistence in physics.

Chapter 5: Findings and Discussion (Individual Interviews)

In 2012 and 2013, I was able to locate 25 of the women in the NSBP study. For my dissertation research, I conducted follow-up interviews with 11 participants. Findings from these interviews are discussed in this chapter. The individual interviews focused on questions directly related to the women's undergraduate classroom experiences and frameworks relevant to the experiences of women of color in STEM. I also asked questions related to their involvement in graduate programs and careers after their 2005-2009 focus group interviews.

This study is guided by the following research question and sub-questions:

2. How do African-American women perceive the climate and interactions with peers and faculty in undergraduate STEM classrooms?
    a. How did they attempt to succeed in these environments?
    b. What classroom interactions and experiences did African American women perceive supported their persistence in their majors?
    c. How do they perceive that classroom experiences and interactions influenced their identities as scientists?
    d. How did classroom interactions compare with interactions with faculty and peers outside of the classroom? (i.e.: laboratories, social settings, office hours, etc)

From this work, factors in persistence and degree attainment among African American women in STEM will be identified.

The chapter begins with participant profiles in two formats. First a table that includes an overview of all individual interview participants and generalized information about their undergraduate institutions, degree attainment, and post-graduate pursuits is presented (Table 5). Next, is a case profile for each interviewee, including information about parental education, early exposure to STEM, and academic and career trajectories. These profiles also include characteristics that may have affected their perceptions of their undergraduate programs. Finally, an overview of findings from analyses of individual interviews will be presented in two sections. The first section will include a summary of themes directly related to the literature and theoretical frameworks, and the second section will be a description of emergent themes from the interviews.

The follow-up sample included a diverse group of women from a range of backgrounds. Eight participants attended HBCUs in the south for their undergraduate degrees. Two attended TWIs, and one participant attended a university outside of the United States. All of the participants confirmed that they completed undergraduate degrees in Physics, and pursued graduate programs in STEM disciplines. Three participants completed Masters' degrees and were working in STEM-related careers at the time of their interviews. One participant completed a Ph.D., and the remaining seven participants were enrolled in graduate programs at the time of their interviews. A table summarizing the demographic data of interview participants is below. To protect participants' identities, their educational institutions are not named. Descriptors of student population, geographic location, and institution type (TWI or

HBCU) are used in place of university names. Participants' current occupations are also generalized as 'STEM', 'Non-STEM', or 'Graduate Student'.

Table 5: Participant Profile Summary – Individual Interviews

Name/ Pseudonym	Undergraduate Institution Type	Geographic Region	Major/Area of Study	Completed UG Degree?	Student Status at time of Focus Group	Parental Education/ First-Generation	Current Occupation (STEM/outside of STEM)
Myriam	Carribean/Outside of the US	Carribean/Outside of the US	Physics	yes	Graduate Student	First-generation	STEM
Annie	HBCU, urban, 1,000-3,000 undergraduate enrollment	South	Physics	yes	Post-doctoral fellow	Not FG	STEM
Dawn	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics/Engineering	yes	Graduate Student	First-generation	STEM
Karen	PWI, suburban, 25,000-27,000 undergraduate enrollment	South	Physics/Astronomy	yes	Undergraduate Student	Not FG	STEM - Graduate Student
Whitney	PWI, rural, 1,000-3,000 undergraduate enrollment	Midwest	Physics	yes	Undergraduate Student	First-generation	STEM - Graduate Student
Noelle	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Graduate Student	First-generation	STEM - Graduate Student
Jackie	HBCU, urban, 7,000-9,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	Not FG	STEM - Graduate Student
Latasha	HBCU, urban, 7,000-9,000 undergraduate enrollment	South	Physics	yes	Graduate Student	Not FG	STEM - Graduate Student
Alicia	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	Not FG	STEM - Graduate Student
Felicia	HBCU, suburban, 3,000-5,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	First-generation	STEM - Graduate Student
Patrice	HBCU, urban, fewer than 1,000 undergraduate enrollment	South	Physics	yes	Undergraduate Student	Not FG	STEM

Case Profiles

Alicia

Alicia recalled having an affinity for math throughout her K-12 education, however she did not participate in summer programs or other STEM-related extracurricular activities. She attended a predominantly-Black high school with special emphasis on science and mathematics. She excelled in her math courses, but had limited exposure to science courses. She had no physics classes prior to college. Both of her parents completed undergraduate degrees, but neither worked in a STEM profession. She noted that prior to college she was not aware of many career options in STEM and had limited exposure to STEM career paths. She identified one extended family member who was a professor in a STEM field, but noted that they never discussed her interest in STEM. She did recall that family members and friends said that she should pursue a degree in the sciences or engineering because of the earning potential. One person responded saying "Oh, yeah. If you're not going to be a doctor or a lawyer, be an engineer."

As she was considering college options, Alicia met some current undergraduate students at an HBCU who encouraged her to consider majoring in physics. They shared information about a summer bridge program that would enable her to get some exposure to the subject and earn credits toward her undergraduate degree. Alicia ultimately participated in the program and attended the same school for her undergraduate studies, majoring in physics.

She still was unsure of what she wanted to do after college graduation, but steadily pursued her passion for science and math. Like high school, she still excelled in her mathematics courses in her undergraduate program, and she preferred the teaching styles of her mathematics professors compared to professors in physics. Alicia noted that there was a large share of international faculty in her department which often resulted in a disconnect between the international faculty and students due to language barriers, different communication styles, and professors' preconceived notions about students educated in the United States. She stayed in her physics major because she appreciated the range of applications of the course content. She described a collaborative peer culture at her undergraduate HBCU, especially among other physics majors. She noted that there were very few people in her program, so they tended to "stick together". During her undergraduate studies, Alicia was involved in a number of extracurricular/enrichment activities that helped her identify and refine her career interests.

Alicia graduated from her physics program and considered pursuing other interests for graduate school or a career. A friend encouraged her to continue studying physics, and she ultimately entered a graduate program at a TWI. She excelled in her undergraduate program and earned a competitive, prestigious fellowship to support her graduate studies.

Alicia noted that she found that the campus climate and expectations of her professors in her graduate institution were different from her undergraduate experience. Her peers in her graduate program were more competitive with one another, and less inclined to offer assistance and support to one another. She also found that faculty expected students to be solely focused on their research and other academic pursuits. Attending a TWI for graduate school also made Alicia more aware of the rigor and exposure that undergraduate students had at that institution. She found that students at the TWI studied with faculty members highly regarded in the physics community, and followed a curriculum that more closely resembled those in graduate programs. At the same time, she saw that students at the TWI had more difficulty getting opportunities to make personal connections with faculty or engage in undergraduate research. This aspect of their experience caused her to develop a greater appreciation for the faculty support and opportunities she had at her undergraduate institution.

Alicia was still enrolled in a STEM graduate program at the time of her one-on-one interview. She has developed an appreciation for scientific research, but also recognizes the need for more undergraduate physics professors who can engage students. She hopes to pursue a career that enables her to conduct research and teach. She also hopes to return to work at an HBCU at some point in her career.

Myriam

Myriam is a first-generation college student who grew up in the Caribbean. She described her family as working-class, and recalled that her parents made their children's education a priority. Both of her parents worked in STEM-related professions (health care and STEM industry). Although they were not well off financially, her parents worked multiple jobs to ensure that she and her siblings would have an opportunity to pursue their education.

She described most of her family as having strong math interests, saying, "… Everyone in my house… we're all mathematically-driven." Myriam recalled that she was always good at science and math, and enjoyed these courses in her early education. She also recalled that she always had an interest in teaching. She attended an all-girls school through middle school and was exposed to women as science and math teachers. She later attended a co-ed high school, but felt well prepared compared to her male peers. In her country, high school students were tracked in subject areas intended to prepare them for their future careers. The students and their teachers chose academic tracks, and Myriam was tracked in a rigorous science and mathematics curriculum. Myriam credited her family and high school friends for pushing her to go to college, where she pursued a physics degree.

In her undergraduate degree program, Myriam recalled always being one of the only women in her classes. She was not uncomfortable in these settings because she "…had worked with guys before and [she] came from a family with guys." She completed her undergraduate degree in her home country, then began a graduate program there. Soon after beginning her graduate program, she pursued an opportunity to attend a graduate program in the United States. In spite of being away from her home country, she wanted to remain connected with family. She was able to find family near her graduate institution, and sustained relationships with them during her program.

Myriam described experiencing "culture shock" in her graduate program in the United States. She described faculty and peers' constant assumptions that she was African-American, or attended an HBCU because she was Black. Ironically, Myriam knew nothing about HBCUs. She also experienced some difficulty understanding the culture of her department and academia in the United States, where she felt she was constantly expected to prove her abilities. Myriam ultimately completed a graduate degree and pursued her science and teaching interests as a science educator.

Annie

Annie drew inspiration from her mother, who attended college, earned a graduate degree, and worked as an educator. In her K-12 education, Annie recalled having a love for reading and writing more so than science and mathematics. She attended a high school for Math and Science, but only took math and science courses required for graduation. In her senior year, she took a required physics course and developed an interest in the subject, saying, "I really, really liked it…and people thought I was crazy." She enjoyed solving the word problems most, and saw that as a connection to her interest in reading.

Annie received a scholarship to attend an HBCU for her undergraduate degree, and began a combined degree program between the HBCU and a nearby TWI. At the HBCU, she majored in physics, and found a supportive learning environment wherein classmates supported one another on assignments an in study groups. She also recalled that she had a number of female professors in her STEM courses, including several Black women. She felt at ease in their classes, saying "you never felt like you couldn't ask a question in class… just that level of familiarity, I think made you a lot more comfortable when you're learning." In the TWI environment, she found that classes were larger, and she felt more anxiety about speaking in those settings. She said, "I remember distinctly not feeling as comfortable asking questions in class." Among students and faculty at the TWI, she also perceived that there was a culture of immersing in science, while neglecting other interests. In contrast, her professors and peers at the HBCU seemed to lead more balanced lives with families and interests outside of physics.

In addition to interactions with peers and faculty, Annie discussed a scholarship program and staff who worked with the program as supporters in her undergraduate studies. She spoke about the program staff in familial terms, and likened the program director to a 'grandmother'. Similar to family members, these staff members provided social and emotional support, and held Annie accountable for earning good grades and taking advantage of opportunities to gain exposure in the field.

Annie went on to work in STEM industry, but returned to pursue two graduate degrees at TWIs. From her work and academic experiences, she realized that she was not interested in scientific research as a long-term career. Instead, she identified career opportunities that would enable her to use her writing skills and "…not have to be in a lab for the rest of my life." Annie ultimately earned two graduate degrees, and has combined her passion for writing and her interest in physics as a STEM education researcher.

Dawn

Dawn grew up in a Southern state, as part of a working-class family. She was a first-generation college student, and attended an HBCU for her undergraduate degree program. Dawn recalled having an interest in teaching since childhood. She also had an interest in science and math, but was not aware of career options in STEM.

In high school, Dawn had a guidance counselor that encouraged her to consider a college major in a STEM field. This counselor would give her students assessments to identify their academic and career inclinations, and Dawn would often have high scores related to her science and math abilities. Outside of school, Dawn recalled that no one in her family encouraged her to pursue a STEM degree or career, mainly because it was unfamiliar to them. However, they provided support in other ways, such as pushing Dawn to persist when she became discouraged. This family support continued through her college years:

> …They were supportive, giving me that emotional support when there were times when I felt, "Oh my God, if I had to do another exam or look at another formula. Do I want to stay at this school?" They were very, very supportive.

Dawn was first admitted to an HBCU as a student in a non-STEM major. Based on her high quantitative SAT scores, she was recruited for a STEM-focused summer program before her first semester in college.   She excelled in the program courses, and decided to change to a STEM major. Her decision to pursue a STEM major was due in part to her academic interests, but was also based on the availability of scholarship funding to support her studies. She shared, "I got a full ride, which was another motivating factor to go into the science field, because they pay for me to go."

Dawn characterized her undergraduate department as "supportive." Her classes were very small, and she felt comfortable asking questions in class.   She noted that all but one of the professors in her department were men, and the majority of them were born and educated outside of the United States. For these reasons, she perceived that she had few role models with whom she could identify in the field.

She also felt that her physics professors tended to lecture rather than engaging students in group discussions or activities.

Even in her undergraduate degree program, Dawn was not fully aware of her post-graduate options, and returned home after graduation and worked in a job unrelated to her physics background. After about a year, she missed the challenge of physics, and applied to graduate programs. She was admitted to a TWI and returned to school for a Master's degree. She completed her graduate degree, and was working in a STEM-related job at the time of her interview. She discussed having an interest in education, and was seeking ways to engage in science and education issues simultaneously.

Karen

Karen attributed her earliest interest in science to cooking. As a child, she enjoyed mixing ingredients together to make a completely different product. Academically, she recalled that she enjoyed math and science and classes from an early age, and pursued this interest in high school by taking science courses beyond those required to graduate. She remembered having an interest in chemistry, but shifting toward physics after taking an extra science course in high school, saying, "I really enjoyed chemistry and thought I would continue with that. And then, in high school, I took a physics class and I really liked that class." Karen attended a Traditionally White, all-girls high school. She recalled having all female science and math teachers, and female classmates in these courses. Both of Karen's parents completed college, however neither parent worked in a STEM-based profession.

Karen went on to attend a large TWI for her undergraduate degree program. She described experiencing "culture shock" because the University was much more diverse than her high school, and her classes were much larger than in high school. She also felt that her peers in STEM courses were better prepared than she, and felt some anxiety about speaking in class. Some of this anxiety stemmed from her identity as a Black woman, and attempting to avoid playing into negative stereotypes about minority students' and women's abilities in STEM. She said that support from administrative staff and peers helped her navigate her undergraduate institution and avoid pitfalls that may have hindered her progress. She was involved in STEM-based student programs and organizations, which were key sources of support and information that helped her excel in her program. Aside from these extracurricular organizations, she noted that there were only one or two faculty members in her department who really seemed to take an interest in her future as a physicist. She felt that faculty in her department were much more focused on their research than mentoring undergraduate students.

In spite of some challenges adjusting to the climate of her undergraduate department, Karen still felt a passion for physics. Comparing her perceptions of physics to other science disciplines, she recalled

> …Most of the sciences to me felt like a lot of memorizing. And with physics, it was more of a concept thing. It was more if you start with a concept, you can always deduce from there and end up at the same spot. So I never felt like I had to remember so much, I just had to remember concepts and then I can build from there.

After completing her undergraduate program, Karen went on to pursue a graduate degree at a TWI. Although she had made good progress in her studies, she had not been able to develop a strong relationship with her advisor or other professors in her department. She was still enrolled in this program at the time of her one-on-one interview.

Latasha

Latasha recalled always being good at science and math, but she also had an affinity for writing and history. She was not a first-generation college student, but was the first person in her immediate family to pursue a STEM major. Latasha's mother encouraged her to pursue higher education, and played a key role in exposing her to science and math at an early age. She said, "Every summer I was always doing something…", and recalled participating in summer camps and other activities that exposed her to engineering, robotics, and computer science. During one summer program, she met a physics professor who encouraged her to consider a physics major. He told her about a range of professional opportunities available to physicists, and ultimately became a long-term mentor.

Latasha described herself as introverted, and said that she performed better in smaller classes where instructors were able to get to know her learning style. She had smaller classes in high school, and felt well prepared for her college science courses. Latasha also noted that her school counselors were very involved in helping her and other students choose courses that would prepare them for college.

Latasha kept in contact with the physics professor from the summer program, and she was admitted to the university where he worked. Latasha attended this institution, a small HBCU, and majored in physics. Her physics classes were small, and she had mixed experiences with professors in her department. She noted that the majority of the professors in her department were men, and several were international. There were at least two professors with whom she had negative experiences, but she also had positive experiences with her mentor and several other professors. Latasha appreciated instructors who catered to different students' learning styles, and would use multiple measures to assess their knowledge. As an introvert, she was not eager to speak in class or solve problems in front of her classmates. Therefore, she felt most comfortable in classes where professors used clickers, quizzes, and written assignments to assess students' comprehension.

Funding her education was a concern, so the availability of scholarships for students in STEM was an added bonus to opting for a physics major. Latasha developed a strong mentoring relationship with two professors in her department. She said that overall, she felt well supported in her STEM courses at her undergraduate institution, and felt well prepared for graduate studies. She went on to pursue a graduate degree at another HBCU, but found that she lacked faculty contact and support there. After a series of negative experiences, she transferred to another program at a TWI. Throughout her graduate studies, she kept in contact with her professors from her undergraduate institution. She was still enrolled in her graduate program at the time of her one-on-one interview.

Whitney

From an early age, Whitney was identified as a student with exceptional talent in math and science. She was identified as a gifted and talented student in elementary school, and recalled having an elementary school teacher who taught multiplication to her students. Even though others recognized her talent, Whitney was not fond of the additional assignments and extra work that came with being part of gifted and talented programs. Only after winning a school science fair did she begin to enjoy her studies, and felt more confident in her abilities.

Whitney came from a large family with a limited income, and described herself as a first-generation college student. She was chosen for a program that supported her attendance at a private college-preparatory high school. There, she continued to excel in her math and science courses. She also participated in summer programs that gave her a sense of life as a college student. Her school guidance counselors were proactive in sharing information about college admissions, financial aid, and scholarship programs. Despite her school's efforts to prepare students for college, Whitney felt that there were still a lot of surprises and challenges for which she felt unprepared in the college environment.

She attended a TWI in the Midwest, and had a close group of peers early in her major. As she progressed in her major, she felt more isolated from her peers, and had more negative interactions with faculty. After several negative incidents, she largely dissociated herself from peers and faculty in her department. In addition to perceiving an inhospitable climate in her department, Whitney had to work multiple part-time jobs to support herself in school. She felt that she missed out on both of social time and study time due to her commitments outside of class: "So a lot of the times when everybody was getting together to do homework, I couldn't work with them because I had to go to work...when you have to struggle alone, that was kind of difficult." She still managed to remain involved in student organizations, and spent her summers doing research. She had positive experiences in summer programs, and said that her research ultimately shaped her research interests as a graduate student.

Toward the end of her undergraduate program, Whitney described herself as "burned out". She returned home to work in a position unrelated to her major for about a year, but missed the challenge of science and sought to pursue an advanced degree in physics. Whitney was admitted to a graduate program closer to home and family, and she earned a fellowship to support her studies. She was enrolled in her graduate program at the time of her individual interview.

Noelle

Noelle is a first-generation college student who grew up in the South. She recalled having an interest in math and science from an early age. Toward the end of her high school years, she began considering prospective colleges and majors. Her older sibling majored in a STEM discipline, and encouraged her to consider physics as a major. Noelle was initially interested in a career in medicine, but after getting exposure to a surgical environment she decided that she was not cut out to practice medicine. Instead, she focused her attention on physics.

Noelle attended HBCUs for both her undergraduate and graduate degrees. At both institutions, she described supportive academic environments and positive relationships with faculty. She mentioned specific faculty members who encouraged her to pursue a graduate degree, and helped her make connections in the field. She acknowledged that there were very few women and minority professors in her department, but she found that several faculty members took an interest in her success and supported her throughout her studies.

Noelle discussed having an informal style of speech and a southern drawl when she enrolled in her undergraduate institution. At first, she felt that she did not fit in, and her peers judged her academic abilities by her speech. As she developed closer relationships on campus, her peers began to recognize her talent, and she said, "…I ended up tutoring these same students who were calling me dumb to show them that I'm smart."

Once she developed a rapport with her professors and peers, Noelle described a supportive peer culture in her undergraduate degree program. She recalled that there were very few students in her major, but there was a fairly even balance between males and females in the program. Given the small size of their department, it worked to everyone's advantage to work together on assignments and study together. She noted that she tended to work with other women in her program most frequently, and the male students "… just wanted to do their own thing." Noelle engaged in research programs and internships during summer terms as an undergraduate. These experiences sparked her interest in pursuing a graduate degree.

Even as Noelle searched for graduate programs, she recalled that other women from her program were engaged in the process with her, offering support and insight along the way. She went on to pursue a graduate degree at another HBCU. She described positive experiences with her advisors there. Noelle was still enrolled in a graduate program in physics at the time of her one on one interview.

Jackie

Jackie is the first person in her family to attend a four-year university. Her father worked in a technical field, but no other family members had careers in STEM. Jackie said she developed an interest in STEM during a summer program at the K-12 level. She saw a female scientist as a guest speaker during the program, and developed an interest in being a scientist herself. At the end of the speaker's presentation, Jackie recalled thinking, "I want to be like you."

Jackie's sister suggested that she apply to a particular HBCU, and Jackie eventually attended that institution for her undergraduate degree. When she first began introductory courses in her program, she felt that she was in a supportive academic environment. As she progressed into more advanced courses, she felt that she did not have adequate advising, and subsequently overextended herself. She said, "I just took way too many classes. I took on way too many extracurricular activities. I didn't have professors who would just sit down and be, like, 'Look, you can't do [list of extracurricular activities]….You need time to devote to your studies.'"

In her upper level physics courses, there were far fewer students in her classes, and she sometimes felt that she lacked the peer support that students in other programs had. She had much more one-on-one interaction with professors in her department, and recalled feeling discouraged and intimidated in classroom settings. She perceived that professors in her department made assumptions about students' potential in the field. Whereas they recognized the talents of male students in her program, she felt that her abilities were underestimated as a woman. When she began considering graduate programs, she did not feel supported by faculty in her department, and relied on mentors outside of her own institution for support as she applied to programs.

Jackie attended a TWI for her graduate studies, and found her professors and advisors to be more supportive than those in her undergraduate program. With her graduate program as a point of reference, she described ways in which she believed she could have been better prepared and supported in her undergraduate studies. Jackie was enrolled in a graduate program at the time of her one-on-one interview.

Felicia

Felicia is a first-generation college student from a working-class family. Neither of her parents worked in STEM-related fields. She attended a college preparatory boarding school through the support of a scholarship program, and took a rigorous course load in STEM. Felicia recalled several individuals who mentored her and encouraged her to pursue a STEM major. One of her high school teachers told her that she thought she would be a great scientist. Two other individuals from her church told her about science careers and provided information about college programs. Although she did not go to college herself, Felicia's mother encouraged her to attend an HBCU because she wanted her to interact with other Black students and faculty.

Felicia went on to attend an HBCU, as part of a combined degree program in STEM. There were small class sizes in her department, and she benefitted from individualized attention from her professors. Specifically, she noted that she got timely feedback on her assignments, and her professors were able to work with her individually when there were concepts she did not understand.

Felicia acknowledged that she was not as focused on her studies as she should have been at the beginning of her undergraduate studies, saying, "I think at the time I was just in a different state of mind. I was kind of in party mode and I wasn't doing everything I could have been doing to get passing grades…" During her last years in her undergraduate program, she applied herself in her classes, and even took on leadership positions in student organizations in her department. She was able to attend conferences, network, and engage in research projects. She developed an interest in continuing her research, and decided to pursue graduate study.

Felicia enrolled at a TWI for graduate school, and was enrolled in a graduate program at the time of her interview. She found a dramatically different environment in her graduate program, and shared that she felt unsupported by both peers and faculty there. She commented that a large percentage of international students and faculty in her program made it difficult to forge relationships. Felicia perceived that other faculty members were not invested in seeing her complete her degree program, and she was seeking mentors in her department or outside of her program.

Patrice

Patrice grew up in a large military family and attended several different K-12 schools prior to college. She was educated in military schools, and developed an interest in being a teacher at an early age. Her mother completed an undergraduate degree, however Patrice was the only one of her siblings to pursue postsecondary education.

Patrice recalled developing a passion for science from going on camping trips with her grandfather. She was fascinated with stargazing, and developed an interest in astronomy. Despite her interest in astronomy, she disliked her science and math courses in elementary and middle school. She recalled, "…I actually hated math when I was in middle school. I just didn't like it….it was like 'I don't understand', like 'what's this?'" Her first high school geometry course sparked her interest in studying STEM. She recalled having a charismatic teacher who was also an African-

American woman. This teacher fed Patrice's curiosity by setting aside time to answer her questions and getting to know her interests. She described her relationship with this teacher saying, " I really stayed after and asked her questions and was always in her office at the time she had during lunch or whatever it was." From that point on, Patrice found the challenge of her math and science classes to be enjoyable.

Patrice said that she "really always wanted to be a teacher" and engage in work that introduced other students to science. After high school, Patrice went on to attend an HBCU to study education. During her freshman year, she took a physics course for non-majors as part of her degree requirements, and caught the attention of her physics professor. He recognized her talent in physics and discussed scholarship opportunities for her in his department. Patrice was interested in receiving additional financial support, however she had to be a science major to be eligible for the awards. She ultimately changed her major to physics to receive the scholarships, and developed a close mentoring relationship with her physics professor for the duration of her undergraduate program. Her advisor helped connect her with his colleagues in the field to engage in undergraduate research opportunities. Based on her involvement in research, she was awarded another scholarship intended to prepare underrepresented minority students in STEM majors for graduate school.

She mentioned that as a minority student who was talented in physics, she felt that she was pushed by advisors and mentors to pursue a career in academia. She said, "…my goal was to get a PhD because that's what we are told, go get a PhD and then do those things you desire to do." Patrice still saw a career in academia as another way to teach, so she went on to pursue a graduate degree, and considered going on to complete her PhD. She had a difficult time in her Master's program, feeling unsupported by faculty and advisors, and feeling pressured to devote all of her time to research. Her graduate advisor did not support her efforts in applying to PhD programs, which left her feeling hurt and discouraged. After completing her Master's degree, she re-evaluated her career interests, and went on to pursue a career that combined her passions for physics and connecting with K-12 students.

Organization of Findings

In the subsequent pages, findings and analyses from the individual interviews will be presented. The first section will include findings related to the integrated theoretical framework. These findings include broad themes of *Pre-college Preparation, Undergraduate Classroom Experiences, and Science Identity.* The second section will include findings related to emerging themes and sub-themes. These findings include broad themes of *Perceptions of Physics/STEM Culture, Preparation for Graduate School/Careers, Being a Black Woman in STEM, and Variations across Institution Types.* All of these themes will be integrated into a model depicting salient factors in the undergraduate classroom experiences of African-American women in physics in Chapter 6.

Early Preparation, Undergraduate Experiences, and Science Identity

This section includes findings related to major themes from the literature and theoretical frameworks. It also expounds upon some of the themes identified in Chapter 4. The women's undergraduate classroom experiences in STEM were shaped by interactions in the physical classroom and laboratory space, as well as personal characteristics. Personal characteristics such as individual identities, pre-college experiences, and personal beliefs about their abilities all served as lenses through which the women viewed their classroom experiences. Thus, findings are organized around three major themes of *Pre-college Preparation, Undergraduate Classroom Experiences, and Science Identity.* Self-efficacy is not described as a standalone theme, however it is a process present in the discussions of each of the other three major themes.

Pre-College Preparation

Pre-college preparation was a common theme in the review of the literature and theoretical frameworks (Cabrera et al., 2001; Hanson, 2004, 2009; Modi et al., 2012). In the individual interviews, participants discussed early academic experiences that sparked their interest in science and mathematics. They also described parents and other family members who nurtured their interest in science. Finally, several of the women described learning about opportunities to study or work in science fields. Details about each sub-theme are described below, followed by an analysis of findings related to pre-college preparation.

Pre-College Academic Experiences

K-12 educators played an important role in exposing the women to science and mathematics and fostering their interest in these disciplines. Each participant identified a K-12 class, teacher, or counselor that played a major role in developing their interest in science or math. In elementary school, Whitney had a teacher who worked with her on a science fair project on a regular basis. At first, Whitney was resentful of having to spend time on her project after school, but the project led to a critical point in her recognizing her talent in science: "…My third grade teacher, we had a really, really close relationship. So that particular year I ended up staying after school with her everyday to work on my science project. And then I won first place for the science fair, and I was like, oh man, maybe I'm good at this right?" Latasha described an engaging high school physics teacher who developed creative activities to pique her students' interest:

> …My physics teacher in high school was very instrumental in making me feel like I could actually do the work….She was my hardest teacher but she was really great. We had to build bridges with toothpicks and put weight on them to see how much it would actually take to break them…it was just a really good experience.

The women's K-12 teachers developed their interest in STEM by challenging their students, and creating engaging learning experiences. They also expressed their belief in the girls' abilities, and made them feel capable of excelling in science and math subjects. Patrice and Whitney's teachers went above and beyond their required duties to foster their students' interest and talent. In both cases, the girls' teachers sacrificed their lunch breaks or hours after school to help with their students' projects.

Exposure to K-12 teachers from underrepresented populations in STEM also seemed to have a profound impact on participants in this study. For some participants, attending all girls' high schools exposed them to women who were talented in science and mathematics. For example, Karen attended a single-sex high school, and referencing her science and math courses, she noted "I was taking classes with girls the whole time." Myriam made a similar comment, saying "All of our teachers were female … So I had female teachers all my life." Both participants shared that they were less conscious of women's underrepresentation in physics prior to college, because they were accustomed to being in science and mathematics classrooms with other women. In both cases, the women described a greater sense of self-efficacy from seeing individuals of the same sex as scientists and mathematicians.

Myriam was the only participant who received her K-12 education outside of the United States. She described experiences different from those of her peers educated in the United States. Specifically, she described her classes as very regimented and structured. She and other students were expected to memorize large amounts of material, but there was little emphasis on applications or abstract problem-solving. She also described being tracked as a science/engineering major in high school, and receiving rigorous training in science and math courses. In terms of rigor and content covered, Myriam compared her high school coursework to that of first-year college courses in the United States.

Pre-College Parental/Family Involvement

The women's parents and other family members made efforts to cultivate their children's' interest and abilities in STEM through extracurricular activities, summer camps, tutoring, and involvement in their K-12 schools. Several women had distinct memories of parents and family members who took time to engage them in science-related activities. These family members often had no formal science training, however they recognized the women's potential and enthusiasm for science. Patrice described spending time with her grandfather, who would take her on camping trips and show her stars and constellations. She developed an early interest in physics and astronomy from this exposure. Latasha, Monique, and Jackie recalled that their parents and other family members kept them involved in science-based summer camps and extracurricular activities. Latasha noted, "…my mom always kind of had me involved in something. I was in Upward Bound and I did summer camps where would build computers and build robotic things." Jackie's sister identified a summer program that ultimately fueled her interest in STEM: "My sister put me in this program…It was for females who were interested in science, but it was specifically for biology. I met a plasma physicist and ever since then I kind of was just drawn to that field."

In the women's descriptions of their K-12 educational experiences, it was clear that their parents were present in their schools and monitored their progress. Felicia described a teacher who discussed her potential in math and science directly with her parents: "…she sat with my parents and basically told them that I would make a good genetic engineer one day." At least two other participants (Annie and Latasha) had parents who were educators. Therefore, their parents were familiar with their school systems, communicated with their teachers, and ensured that they were given opportunities to take rigorous courses.

All of the women described education as something that was valued in their families. For most of them, they knew that their parents expected them to excel academically and go on to college. Their families not only expressed their commitment to education verbally, but made sacrifices of time and money to ensure that their girls would have opportunities to pursue their education. Myriam recalled her mother and father taking on second jobs to pay for school for her and her siblings. Other women's parents paid for them to attend private high schools, sought opportunities for them to attend boarding schools, or enrolled them in magnet schools for math and science.

Pre-College Exposure to STEM Majors/Careers

The women in this study were exposed to STEM topics and careers from a variety of sources. For some, their parents were professionals in science fields, and encouraged them to explore STEM topics. For others, they met other scientists through extracurricular activities, or developed an interest in science from commonplace resources around them.

Two participants had parents who worked in STEM-related fields. Their parents had personal interests in science, and would encourage their daughters to consider professions in STEM. Other participants had no family members who majored or worked in STEM. For these women, their exposure to STEM careers came from extracurricular programs and everyday applications of science. Whitney recalled first developing an interest in engineering through a program for high school students sponsored by a local college:

> …they had like a high school day where all the high school students could come and look at the engineering department. So I went there and that's when I first like, oh man, I want to be an engineer. That's what I want to do. And from there on I was like, okay, I'm going to be an engineer.

Several women developed an interest in science and math through everyday applications such as assembling electronics, stargazing, and cooking. Karen enjoyed cooking, because measuring and mixing separate ingredients to make one different product reminded her of science: "I liked to bake, and I think it's because that felt like science to me, so I would do a lot of that." Alicia recalled disassembling things in order to try re-assembling them, saying "…I just I really liked learning how things work. I was one of those kids that used to take everything apart, and I'd try to put it back together and see what I could do….Like taking pews apart in church and trying to fix the spring."

In other instances, parents were influential in connecting the women with mentors who could share information about college and careers in STEM. Felicia was a first-generation college student, however her mother ensured that she had opportunities to learn about the college process and post-graduate opportunities. Her mother enrolled her in an SAT preparatory program in her church, and she was exposed to mentors in STEM careers there. She identified two mentors who were scientists themselves. These two individuals shared information about summer programs, and encouraged Felicia to pursue a STEM major in college. She described her experience saying:

> I had a good mentor who was a physicist. He was actually working in [a National Laboratory]…And he would expose me to a lot. He was helping me prepare for my SATs in high school, he kind of knew I was interested in engineering, so he was telling me to apply to different summer programs at colleges for students or minorities that wanted to, you know, go into STEM, so that's what I did.
>
> And another mentor of mine was an engineer, she is a woman, and she also introduced me to a few people and got me into this program at [a TWI], just for, like, a summer. It was, like, a computer programming camp for high schoolers.

Although the program was intended to prepare her for the SATs, Felicia gained much more in the form of mentors and other information about programs and colleges.

Analysis of Pre-College Findings

Findings about pre-college experiences suggest that the women's pre-college exposure to STEM originated in K-12 academic settings, from family support, and from exposure to STEM careers. Several participants did not know what types of careers they wanted to pursue after college, and were unaware of options for STEM careers. They pursued STEM majors based on their interest and talent in science and math courses, and figured out career options after reaching college.

Pre-college academic experiences had the greatest influence on the women's undergraduate science and math courses. Their coursework provided the foundation for their understanding of more advanced concepts in the collegiate environment. This finding is consistent with existing research linking pre-college academic preparation with success in undergraduate STEM majors (Bonous-Hammarth, 2000; Brainard & Carlin, 1998; Chang et al., 2008; Denson et al., 2010; Maton et al., 2000; Seymour & Hewitt, 1997). Particularly during the first few semesters of science majors, many students leave or change majors due to academic challenges and classroom climates (Brainard & Carlin, 1998; Seymour & Hewitt, 1997). The women in this study were provided opportunities to engage in rigorous K-12 coursework, which enabled them to persist through their undergraduate courses. Specifically, they discussed taking advanced math and science courses, which has been consistently linked with persistence in undergraduate STEM majors (Anderson, 1996; Chang et al., 2008; Fenske et al., 2000; Museus et al., 2011).

Several women noted that they took the most advanced classes offered in their schools, yet they felt that they were lacking some of the requisite knowledge for their introductory science and match courses in college. Despite the well-documented linkages between K-12 science and math coursework and college persistence in STEM majors, underrepresented minorities often enter undergraduate programs underprepared for college-level science and math (Bonous-Hammarth, 2000, 2006;

Maton et al., 2000; Moore, 2006; Seymour & Hewitt, 1997). Their under-preparation often stems from limited course offerings in their schools, and disparities in material actually taught in these courses (Adelman, 2006; College Board, 2012; Ladson-Billings, 1997; Modi et al., 2012). The women in this study overcame these academic obstacles because they had other experiences that exposed them to STEM careers, family support, and high beliefs in their own abilities. Therefore, in courses where they felt academically unprepared, they were equipped with study skills and motivation that enabled them to master the content.

Aside from academic experiences and career exposure, discussions about the women's pre-college experiences shed light on early sources of self-efficacy and motivation. From an early age, the women were told that they were capable scientists and mathematicians, and they had opportunities to demonstrate their abilities inside and outside of the K-12 classroom setting. These types of verbal affirmations positively influence students who aspire to be STEM majors (Colbeck et al, 2001; Holt, 2006; Leslie et al., 1998). Based on this encouragement and their parents' expectations, the women in this study developed high academic and career aspirations. These findings are consistent with literature linking career and degree aspirations with college persistence (Cabrera & La Nasa 2000; Peltier et al., 1999). Furthermore, their families' investments of time and energy in their girls' science and math pursuits are consistent with Hanson's (2004, 2009) work, which suggests that Black families tend to support their girls' interests in STEM.

Undergraduate Classroom Experiences

Participants in this study described a range of experiences in their undergraduate STEM classes. Their responses varied depending on the type of institution they attended, and interactions with professors. There were four recurring themes in their descriptions of the undergraduate classroom experience in physics. These sub-themes include *Introductory v. Advanced Courses, Pedagogical Practices, Interaction with Peers, Comparisons with Non-STEM Courses*.

Introductory vs. Advanced Courses

Participants in this study described their introductory STEM courses as large, impersonal, and largely lecture-based. Many students in these courses were not science majors, but took them for a range of reasons including fulfilling general education requirements and medical school admission requirements. In their comments, the women seemed to distinguish themselves from these students in the sense that they were in physics/STEM for the 'long haul', whereas others were simply fulfilling requirements for other endeavors. Given the variety of students present in these courses, the women in this study observed a range of skill levels and academic interests among their classmates. They also felt that faculty did not take as much personal interest in students in these introductory classes because they too knew that many of the students would only be in their department for one semester.

Not surprisingly, there were also distinct differences in class sizes between introductory courses and upper-level science courses. The women in this study described upper-level courses as smaller, with between 1 and 20 students. They described more personal interaction with faculty, more group assignments, and fewer traditional lectures. They noted that peers in these courses were nearly always fellow STEM majors who had more at stake than peers in the introductory courses, since they needed to be successful in order to complete their degrees.

In several cases, the women were alone or one of very few students in classes. There were several instances when participants described feeling that they learned more in these types of environments, because they knew they could not be anonymous in class, and would be expected to be present/know the material/have assignments completed. One participant, Felicia, described getting more detailed, immediate feedback in small classes:

> I did better with that, with more one on one time with professors, you know, because…if I write a scientific paper, like, it's easy for them to just kind of talk me through my mistakes, versus just, you know, sending me back a grade because they have a whole bunch of other papers to grade.

Whitney also described her perceptions of greater individual accountability in small classes, saying, "…it was forcing you to be disciplined and to come to class prepared because there weren't a lot of people in the class that you could hide behind, you know?"

Although individual attention in courses is often associated with increased student engagement and learning gains (Chapman & Ludlow, 2010; Pascarella & Terenzini, 1991; Westerlund, 2008), two participants in this study described classroom experiences in which they received too much individualized attention. They felt pressure to respond in ways that professors expected, and felt that their work was overly scrutinized. In classes where participants were the only students, they had no classmates with whom they could consult if they struggled with an assignment or topic. One woman described this experience, saying "I was just like, 'I don't know what I'm doing… I need help', and no one was there."

Interactions with Faculty in Undergraduate Physics Majors

There were clear distinctions across institution types in participants' descriptions of interactions with faculty. Whitney, Chrystal, and Jackie characterized faculty in their departments collectively as unsupportive. Two of these three participants attended TWIs. In contrast, seven of the eight women who attended HBCUs for their undergraduate degrees characterized faculty in their departments as supportive collectively. Among women who generally felt supported by professors in their department, every participant identified specific classes and professors that were problematic. Across institutions, the women discussed similar challenges, and often described difficulty working with international professors.

The women's descriptions of supportive professors included themes of belief in their abilities, making an effort to get to know their interests, and supporting their post-graduate endeavors. Patrice described a faculty culture of supporting students in her physics department, and felt that they were committed to her success:

> The faculty was always supportive and … they really were pushing for your education and pushing for you being a minority in the sciences. So they really put me in an environment where people were – there were other people doing what you want to do and it's a support group and we are all in this together.

Alicia shared her experience with a professor who became a mentor and got to know her well outside of class:

> And she definitely became a mentor. She invited us over to her house. We knew her [family]. And so it was just like that relationship was awesome. I think that was probably the closest to any professor that I got. When she had a conference …she took us up to the conference with her to present and talk about [our institution] and

> everything. We rode up for the weekend, and we all stayed in the hotel room together, stuff like that. She took us out to eat. Yeah. So, like that…

Felicia noted that faculty in her program were very supportive of her completing her degree and staying involved with physics long-term. She described her perceptions of her faculty's interest in her success saying

> All of them really helped. Every single one of them in physics, like, advised me with something to do...they offered me a lot of help, as far as graduating. Like, everyone was kind of, like, make sure Felicia is going somewhere after she graduates and she's staying somewhere in physics. Like, we're not going to just let her graduate and, you know, not do anything with her degree.

She mentioned two professors in her department who really went above and beyond to ensure that she had opportunities in their field after graduation. These two individuals shared information about summer opportunities and graduate programs, and followed up with recommendation letters and contacting programs on her behalf.

The women shared contrasting narratives about departments and individual professors that they perceived to be unsupportive. Karen, who attended a TWI for her undergraduate degree felt that the majority of faculty members in her department were not very supportive of her as an undergraduate student. Instead, they seemed to be more focused on their research projects. She identified one or two supportive faculty members, but mostly sought mentorship in student organizations and support units in her department. She spoke candidly about having difficulty finding support in her own department, saying:

> …There were one or two professors that were very encouraging and wanted me to continue and actually were interested in the decisions I was making…But outside of that, it was hard. It was really hard in that college to find kind of a mentor or somebody that was just really interested in seeing you do well. I think a lot of professors get wrapped up in their own research that they're not really paying attention to the student so much.

A professor for one of her courses was rarely in class, and he leaned heavily on another student to teach the course:

> There were some professors that were very busy, I think. This one particular professor taught, like, maybe three of our classes and then one of the students taught us the rest of the lecture for the rest of that semester. So we hardly ever saw him.

Again, from this absence Chrystal perceived that teaching undergraduate students was not a high priority for professors in her department. In another course, she felt that a professor discouraged students by dwelling on concepts they did not understand, rather than helping them grasp the material:

> … A few of us were struggling with it and the professor was not really in a place of helping us. He was almost upset that we weren't getting it. So when we would go to him and ask him things, he would really be hard to work with, 'cause it just seemed like he was so caught up on 'you guys aren't getting this. Like, I don't understand. You shouldn't be here if you're not getting this' or something like that…So, that one was a little discouraging….Like, uh, he just told me I don't belong here.

In that incident, Karen perceived that her professor solely faulted students for concepts they did not understand, without re-evaluating his own teaching, or pre-requisite courses. It seemed particularly disheartening for Karen to hear him suggest that she did not 'belong' simply because she struggled with a concept in class. Jackie and Annie's experiences shed light on a specific behavior that intimidated them as undergraduate students. Even after completing their undergraduate programs, they have vivid memories of those experiences.

Jackie sensed a disconnect with at least one of her undergraduate physics professors, saying, "He was kind of hard to connect with. I actually thought he hated me the whole time, so it was really hard for me to talk to him. I was so glad when I left those classes." She described her experience with another professor who belittled her when she sought extra assistance from him. She recalled that he would have her solve problems on a chalkboard and throw things at her when she answered incorrectly. These interactions were discouraging and intimidating, and haunted her in her graduate program:

> …I would go to the board and, honestly, I can vividly remember just being like, "I really don't want to do this. I really don't want to go to the board." I just had such a fear to go to the board, to the point where it kind of came here, as I'm in graduate school, I would go to my professor to get some help and they'll be like, "Okay, Jackie, go to the board and do this," and I would freeze, not because I couldn't do the problem, but because I was just waiting for chalk, for his chalk to be thrown at me.

Interestingly, in her focus group interview Annie described a similar experience in her undergraduate program. She attended a different university, with a different professor, who threw erasers and other projectiles at his students when he was displeased with their questions or answers in class.

Several of the women, including Alicia, Noelle, Latasha, and Felicia noted that they had a large proportion of international faculty in their undergraduate departments. They identified both benefits and challenges that stemmed from this trend. Several women felt that they benefitted from having a global perspective of science with international faculty. These professors were able to present information in the context of what is done in other parts of the world. Four women in the study were able to forge mentoring relationships with professors from other countries. Alicia had one international professor who mentored her, invited students to her home, and invited students to attend conferences with her. Noelle also described this professor as a mentor. Patrice developed a very close mentoring relationship with an international professor in her department, who provided invaluable advice, and helped her secure research opportunities and internships.

Despite having some appreciation for international professors' perspectives, the women consistently noted challenges in communicating with international faculty in the classroom setting. They perceived that some international faculty members viewed them as less capable compared to students from their home countries. Latasha shared her surprise to find such a large share of international faculty in her department at an HBCU: "For it to be an HBCU I felt like there weren't a lot of African-American academics there in that department." Alicia's comments paralleled Latasha's, as she noted, "…at an HBCU, I thought it was strange the fact that here you have a Historically Black University, but you don't have any black professors in physics…as role models in the classroom. That was kind of strange." She also described having a major language barrier with a professor in an introductory physics course: "I just remember I couldn't understand him. And so it was just really hard. Mind you, you're getting into physics, and you never had physics before, and you can't understand your professor. So, that was I think one of the biggest challenges." She shared that after doing poorly on one section of an exam, another international professor told her class "…I don't understand what's wrong with you guys….We were doing [this] when we were in elementary school [laughter]." Based on these interactions, Alicia felt that her progress, and the progress of her peers was sometimes inhibited by a lack of effective communication with international professors, and their negative perceptions of students' abilities in the United States.

Latasha recalled a mathematics course with an international professor who she sensed had negative perceptions about HBCU students' abilities. Latasha indicated that this particular professor rushed through course material, and claimed her students were unable to understand the concepts she taught because they were lazy and "not trying hard enough." Latasha described some of the discouraging comments this professor made to students in her class:

> …She told us during midterms that she thought we should drop the class because she thought we were going to fail… from what I can remember; she had a lot of hang-ups with HBCUs– she just had a lot of hang-ups about what we knew or what she thought we knew…and it just made it really difficult to learn.

Ultimately a number of students did poorly in the course.

Latasha also spoke of one international professor in her undergraduate degree program who seemed to be biased against women in his courses. She said that he developed a reputation for failing women who took his course, and was often condescending to women in his classes. She described some of this behavior: "But I remember really with me and the girls in particular it became a real problem, like we couldn't ask a question. It would become a, "Don't question me. I'm the professor, you're the student."

Pedagogical Practices in Undergraduate STEM Courses

Participants described a range of teaching practices utilized by their instructors. Particularly in introductory STEM classes, every participant described frequent use of lecturing without student involvement. This practice may have been due to larger course sizes. All participants noted that their introductory science and math courses were larger than more advanced courses in their majors, and included students from a range of majors and pre-health concentrations.

The courses in which the women recalled the most positive experiences were those in which professors encouraged student participation, connected concepts to real-world applications, and seemed enthusiastic about the material themselves. Alicia described her professor's energy in her favorite undergraduate mathematics course, saying

> We had to go to the board and talk problems and everything. And he was very animated…And he would jump around class and everything. And so I definitely think that was one of the best experiences I had when it came to the science at the university.

Latasha remembered one professor who sought to get to know his students individually, and developed pedagogical practices based on their learning styles. She perceived that he sought to build his students' confidence and maximize their learning: "…he wanted to see the different things that kind of made us tick and to see what would make us get the most confidence; so we did a lot of those things in that class." She specified two different practices that helped her feel engaged in classes, without feeling pressured to get the 'right' answer, or putting her on the spot in front of her classmates. One practice the professor utilized was regular quizzes with a generous grading system. She described the quizzes saying,

> A lot of times they were multiple choice. And you know sometimes you would not study or you would just totally not feel confident in the subject at the moment and so what he would do is – if it was like A, B, C, D – if you picked one answer you got more points, but you could pick two and if one of them was right then you get half the points, or if you picked three you could get like a third of the point. So it made you feel like you weren't going to get a zero.

The same professor used clickers to get instant responses from students. A self-described introvert, Latasha felt that this pedagogical practice enabled her to participate in class, but eased her anxiety about answering questions. She explained her affinity for the clickers, saying "…And I really liked that because I'm an introvert, I'm pretty shy, and a lot of times in classes, you're measured on class participation, which can be really kind of lead to anxiety if you think you have the answer but you're not sure."

In their undergraduate STEM courses, the women in this study sought to understand the ways in which their course material could be used to address challenges in the world around them. They valued instructors who understood the theoretical underpinnings of physics, but also knew how to apply those concepts in practical scenarios. Alicia described taking a physics seminar course that was intended to show the real-world applications of concepts learned in class. She saw this as one of her best undergraduate physics courses because "It was more about what's going on in the world of physics now and what's cutting edge and new as opposed to what people did 100 years ago." In these types of courses, participants were able to see the relevance of the concepts she learned, and began to develop a sense of her career options as a physicist.

Whitney also described pedagogical practices that helped her learn, as well as those that were problematic in her undergraduate STEM courses. She said that in order to learn new concepts, she needed to see details and step-by-step solutions to problems. She recalled one professor who taught in this way. She would take detailed notes, then go to office hours with any questions to fill in any gaps in her understanding. In contrast, she described another professor who seemed to expect students to figure out the material on their own:

> …He would just write out the problem and then like do some steps and then write out the answer and he expected us to go and figure out what happened in the middle. And I was like; I don't understand what's

> going on here. I'm lost. And then when I would go talk to him, it was like we didn't speak the same language. So it was no help.

Although breaking down concepts was helpful to most of the women in the study, they cautioned that too much handholding could be debilitating. Jackie described her experience with one professor who oversimplified his course material for her: "…he tried to help me a lot, but he actually set me up for failure, and the reason I'm saying this is because he dumbed it down too much, because now I'm paying for the repercussions." Later, as a graduate student she felt that she was lacking a full understanding of the material.

Over-reliance upon lecturing as a pedagogical practice was also a common theme in the individual interviews. All of the women recalled professors who would "talk at the board" and ramble without engaging students or checking to see if students fully understood their lessons. Latasha shared an example of one professor's teaching style that was particularly problematic:

> ….He would go through the book and he would, you know, face to the board, write down everything and – he would have his own notes. If you asked him a question about the notes he would yell at you, he would tell you don't question him, he's the teacher, just write down – you know, write it down and figure it out later. But it's hard to figure it out later if you don't even know what's going on in the classroom.

In this case, the professor not only seemed to ignore his students as he was teaching, but refused to offer assistance, and positioned himself as the sole authority in the classroom. All of the women expressed issues with the traditional lecture without student involvement, as it made them feel disconnected from the course material. In these situations, they felt like spectators rather than participants in the learning process.

Despite the frequent issues the women raised about lectures as a teaching method, Karen noted that lectures could be valuable when executed effectively. She recalled experiences with a few professors who were able to use their lectures as a basis for discussion and interaction with their students:

> …It got to a point where I was very much comfortable with the lecture scenario, but it was much more of an interactive kind of lecture. It was like between writing something up on the board and then talking and then going back and forth between the two. And I've had professors that did that very well, where I was, like, very engrossed in what they were saying and I was following what they were saying.

Again, the 'effective' lectures Karen described were used as a starting point for more thorough conversations and activities in which students could participate.

Several participants described learning theoretical concepts, but lacking an understanding of real-world applications for topics learned in courses. Myriam attended an undergraduate program in the Caribbean, and she observed that coursework there was completely centered on memorization and accurate results:

> I would say in the Caribbean, because our education is British it's very content-driven. It's very teacher-led. I would say we did labs, but they were for grading. They weren't for creativity. They were for producing results. You had to get the right answer. It was very strict, very inside the box. I would say you learn something, you memorize. The teacher told us to do it a million times. You did repetition. There wasn't any space for thinking outside the box.

When she came to the United States for graduate school, she was expected to apply concepts, and had a difficult time doing so:

> … It's more student-driven, think outside the box. I was stronger content-wise than my peers. I knew all the information and I knew how to recall, and if I just looked at something I knew how to identify it. But if you give me an open-ended question, that's where I would be where I don't know what I'm talking about. So I would say I was more very structured

Jackie also described memorizing, but not applying material in her undergraduate courses, saying that she would solve problems, but

> … I don't actually understand it. I'm lost, so all I'm doing is taking these notes, doing exactly what the professor says, and not actually taking it in, digesting it, making it my own. I'm just memorizing. That was my experience, memorization, not being confident.

Jackie linked her lack of experience with applications to her confidence and self-efficacy, in the sense that she did not feel that she had full command of the material.

Interactions with Peers in Undergraduate STEM Courses and Programs

Several women in the study described subtle behaviors among their white and male peers in the classroom setting that made them feel isolated. Whitney shared an incident from her first undergraduate physics course that made her feel different from others there:

> So my very first physics class, the teacher says, 'okay, turn to your partner and work in pairs'. And the girl who was supposed to work with me turned to the other group who already had two people in the group. So now it's three people working in a group and I'm sitting by myself…

Even when her professor intervened, she placed the onus on Whitney, and told her that she could not work alone and had to find a partner. One student reluctantly worked with Whitney after this comment from the professor. Whitney interpreted her peers' behavior as assuming she was less capable than them, and therefore had no interest in working with her. She felt that her professor was blind to this behavior, and saw her as isolating herself rather than being ostracized by her classmates. She said that this type of interaction was not uncommon throughout her undergraduate program in classrooms and labs.

Other women shared similar experiences. Karen expressed feeling hesitant about speaking in class, and attributed her hesitation to concerns about her peers' perceptions of her:

> I was looking at what other students were doing and it would take away from the lecture. So I think I was constantly comparing myself to other students. I just personally did not feel comfortable asking questions. I'm not sure. Unless I was, like, very sure that it was not, like, a stupid question or anything…it took a while to feel more comfortable asking questions during lecture.

She also recalled "…I was afraid to ask a question if I felt like other people would already know the answer and it was like a common answer that everyone would know." She said that she would often save her questions, and ask peers or instructors outside of the classroom setting. Karen's comments are representative of several participants' anxiety about asking questions in class. In some STEM classrooms, the women perceived that there was constant assessment and comparison taking place amongst peers, which was indicative of an underlying sense of competition. To this point, Karen stated "I feel like especially in physics, people are trying to probe, like, how much smarter they are than the next person."

Several of the women spoke candidly about competition among peers in their undergraduate programs. Jackie recalled a male classmate who was initially open to working with her on assignments, until she began earning grades that were higher than his. At that point, he became preoccupied with her grades and reluctant to work with her anymore: "He always wanted to know what grade I got, and honestly, I didn't want to embarrass him, because I would get A's. He would sit there and he found out that I ended up getting A's, so he's like, 'You know, you really should just help *me*'." Jackie felt that this behavior ultimately pushed them apart, saying that once he saw that she was earning better grades "It was always a competition with him." At the beginning of their partnership, Jackie clearly saw her relationship with her classmate as one of mutual support and mutual benefit. However, her classmate's actions and comments made him seem envious of her success, and more interested in competing against Jackie than collaborating with her.

Seven of the eight participants who attended HBCUs described supportive experiences with peers in the classroom setting. They shared that faculty encouraged them to work together by organizing study groups, requesting lounge spaces for them, and hosting social events outside of class to enable them to get to know one another. Furthermore, due to the small sizes of their programs, they developed a sense of community among peers who could relate to the rigors of being in a physics major. Felicia remembered studying with her peers often:

> …Everyone was helping each other. I don't feel like it was super competitive, because I feel like where I am now, this is competitive, but at [HBCUs], everyone was just – you know; everyone was helping each other out. Like, everyone wanted everyone to succeed.

Patrice described a similar experience, saying "We were really close. I never felt competition from my peers and I honestly felt like my peers helped me. I think we were assets to each other… We always did homework together."

In several cases, these peer connections lasted beyond a single course, and even beyond graduation. Felicia described making lifelong friends in a math course, saying, "I made friends in math. Like, some of the greatest friends that I have now are where I met them in my Calculus 2 class, and we still talk. So we're still good friends. We used to study together." Latasha spoke about a small group of classmates who took all of their courses together, and remained close beyond their undergraduate program:

> … They're still my friends to this day …We were a team, we were a group. We did our classes together, we studied together, we did everything basically together….we all really tried to work together because it was just easier because it was such a small group.

Noelle also spoke of a supportive peer culture in her undergraduate program, "…my peers were supportive. We weren't very competitive with each other because I guess because it was so new to us and we were just trying to make sure we made it through. So we were very supportive, it wasn't competitive." She observed that a small group of Black women in her program had a tendency to work together, whereas the male students "just wanted to do their own thing." All of the women in her close group of peers completed their degrees in physics and maintained contact beyond their undergraduate years.

Latasha alluded to developing close peer groups out of necessity in a small department, however some other students (like Jackie) still lacked close relationships with peers in small programs. In these cases, faculty who were actively involved in students' experiences seemed to be a distinguishing factor. All of the six women who described supportive peer relationships at HBCUs mentioned actions that faculty took to facilitate positive peer interaction. These professors sought out lounge spaces for students, took students on trips to conferences together, and organized group study sessions.

Comparison with Undergraduate Courses outside of STEM

When comparing their classroom experiences in non-STEM departments, participants noted clear differences from their home departments. These differences shed light on the unique culture that exists in STEM classrooms, as well as the environments that these African American women found most engaging. Specifically, the women found that there were more women and Black professors in other departments. They also perceived that professors taught these courses in ways that kept students engaged, encouraging discussions, and welcoming multiple perspectives.

In most cases, the women in this study appreciated the opportunity to have classes taught by other professors, with more diverse peers. They welcomed variety in their course topics, and appreciated having the opportunity to have more discussions in class. Jackie felt that professors in other departments were more supportive the professors in her department, and offered constructive feedback on her work:

> … They were always the type of people who always communicate with me, like, "Hey, you can do better. You can do this and that." They gave me much more feedback, like direct feedback, that I was able to improve in comparison to those physics professors who were just kind of like, "Oh, you don't know how to do this."

Alicia noted that in her classes outside of her department, she had more African-American professors. She also felt that professors outside of her department used more effective pedagogical practices, which she described as "active learning",

> …. The idea of getting students involved in the classroom and the lesson, asking questions to check understanding while you're going through the lecture. Trying to get people to think about whatever topic that you're talking about, right? So, that wasn't really the case in the science classes. It was all basic lecture on the board, just straight board work. If you have a question, then you'd ask the question and then get an answer. But, it wasn't like a time to engage students.

Several other women felt more engaged in classes outside of their program, including Karen, who noted that student input drove discussions in classes outside of her department. She also described feeling more confident contributing to discussions in those courses because

> …They wanted your input…Like, the lecture depended on you being able to express your thoughts on something as they showed it to you

> and interacting with the professor….And, in those arenas, I was, like, strangely a lot more confident. Like, I was usually the one participating and speaking with the professor in class. It was so funny. It was like 'why can't I do this in my own arena?'

In discussions about their confidence about participating in STEM v. non-STEM classes, Karen and other women described feeling like there were expected "right" answers in physics and other STEM classes. However, in non-STEM electives they perceived that a range of responses were acceptable, as long as they could explain the logic behind their responses.

Analysis of Findings Related to Undergraduate Classroom Experiences

The women's descriptions of their undergraduate experiences confirmed that African-American women may experience distinctly different classroom experiences in STEM, depending on the quality of teaching, classroom climate, and level of the course. They also described clear differences between the size and climate of courses taught at HBCUs and TWIs. These findings are consistent with research acknowledging the role of varying institution types in student persistence. Specifically, there is a positive correlation between investments in undergraduate education and student persistence (Griffith, 2010). Griffith (2010) found that students who attend smaller or more selective institutions that invest in undergraduate education over graduate education are more likely to persist than peers at large institutions that prioritize research and graduate education. There is a positive relationship between smaller classes and students' perceptions of their learning (Chapman & Ludlow, 2010). Literature on women and minorities in STEM also supports findings that the women had positive perceptions of their classroom experiences at HBCUs (Fries-Britt et al., 2010; Perna et al., 2009). From the women's comments and supporting literature, it seems that Black women excel in smaller STEM classrooms that are undergraduate student-centered. Courses at HBCUs often have these qualities, along with supportive classroom climates.

The women frequently used their elective courses outside of physics as a basis of comparison in their descriptions of their classroom experiences in physics. All but one participant saw these courses as a welcome change from their STEM classes. Participants described feeling more confident engaging in class discussions and responding to questions in these environments. They saw non-STEM courses as spaces where discussions were welcomed, and they were active participants in creating and sharing knowledge. Findings from the women's perceptions of their involvement in classes provide valuable insight into their beliefs about the construction and validation of knowledge. Their comments are consistent with literature about women's ways of knowing and communication styles (Belenky et al., 1986, Gillgan, 1982, Hill Collins, 2000). Belenky et al. (1986) and Gilligan (1982) also assert that women make decisions and define themselves based on their relationships with others. Consistent with this work, the women in this study placed great emphasis on their relationships with peers and faculty members, and more readily engaged in classrooms where they felt supported and valued as colleagues. Belenky et al. (1986) also assert that women favor connected knowing, in which they consider others' perspectives as a way of validating knowledge. Based on their appreciation of classroom discussions with peers and professors, most of the women in this study seemed to favor this type of approach to knowledge. Similarly, in her work on Black feminist thought, Hill Collins (2000) suggests that Black women have unique ways of validating knowledge, and often believe that knowledge is influenced by politics of race and gender. In both of these theories, the authors assert that women tend to see knowledge as subjective, and influenced by the individuals who create it. Furthermore, both authors describe ways in which women see themselves as creators of knowledge. In contrast, scientific knowledge is often presented as objective, or free from the influence of the researchers and scholars who conceived it (Kuhn, 1996). It seems that the women's discomfort with contributing to class discussions may stem from conflicts between the ways in which they communicate and validate knowledge, and the ways in which scientific knowledge is presented.

Comparing Black women's perceptions of STEM courses and non-STEM electives may also lend to valuable insights about their interests and course-taking patterns. Particularly during their first year, they describe experiencing ineffective teaching practices in their introductory STEM courses, and having positive experiences in electives in other departments. These contrasting experiences may lead this population of students to pursue other majors. Griffith (2010) found that among students who began with STEM majors and changed to another major, 28% took a course in the department to which they switched during their first semester. Therefore, developing programs and other interventions to improve classroom experiences during the first year may lead to increased long-term retention among Black women in STEM majors.

Science Identity

Carlone & Johnson's Grounded Science Identity Model for women of color (2007) served as a theoretical framework for this study (Appendix B). The creators of this model assert that women of color develop identities as scientists based on a combination of factors, including recognition from scientists and meaningful others. Recognition as a scientist, along with competence in STEM subjects and performance of science-related tasks among colleagues leads to the development of one of three distinct science identities: Research, Altruistic, and Disrupted. Research scientists typically pursue science careers for science's sake and identify with prototypical science activities such as lab research, and academic publications. Altruistic scientists redefine science as a means to serve societal or community interests. Disrupted science identities are borne out of a lack of positive recognition from peers and professors in one's respective field of study. Women with disrupted science identities tend to experience significant detours on their academic and career paths, and may leave STEM altogether. The majority of participants in this study developed altruistic science identities, and a few developed research identities.

Professors, peers, family members, and mentors all helped to shape the women's science identity development by recognizing their talents, encouraging them to pursue majors and careers in the sciences, and providing opportunities for them to master critical concepts. Unlike Carlone & Johnson's (2007) model, interviewees typically discussed sub-themes of competence, performance, and mastery together. The women described themselves as competent scientists, then described 'performing' or demonstrating their knowledge among peers and professors through presentations, publications, or class assignments. When participants effectively demonstrated their abilities, they considered these experiences to be mastery experiences. Therefore, the women in this study described performance and mastery as means of demonstrating their competence. With this in mind, findings related to science identity are organized around themes of *Altruistic, Research and Disrupted Science Identities, Recognition*, and *Competence, Performance, and Mastery*.

Altruistic, Research, and Disrupted Science Identities

Carlone & Johnson's (2007) science identity model accounts for the fact that scientists may have different career interests within their field, including research, altruistic aims, or they may have disrupted science identities. Scientists do not have to select just one career area, but they most likely identify with one area more over others.

Consistent with other literature on women of color in STEM, the majority of the women in this study were interested in teaching at the K-12 or postsecondary level, or using their science background to inspire another generation of students (Carlone & Johnson, 2007; Hanson, 2004; 2009). Most of the interview participants explicitly stated that they were not interested in careers in research, as they felt that they would be 'trapped' and isolated in labs. One of Dawn's statements supports this finding:

> I like social interaction. I enjoy working with people, so I found that in this discipline, a lot of times you're isolated; you're working by yourself…I found even myself and other women in STEM that they want to kind of interact in some regards. Most engineering and science jobs don't afford you that opportunity.

Similarly, Annie described herself as strong in physics, but expressed that she always had an interest in teaching and writing rather than research. She felt that she reached a "threshold" in physics research in her graduate program, and began pursuing opportunities to blend her physics training with her passion for writing and education.

Two participants, Felicia and Whitney, said that research was their passion. Felicia made this clear to her undergraduate professors and mentors, saying, "…they kind of knew I didn't want to teach… I definitely wanted to do research. Like, everyone knew that. So wherever I was placed, I was going to do research." Similarly, Whitney participated in a summer program teaching K-12 students, and said that she valued the opportunity to learn more about herself and her interests, but "…that also just showed me that I didn't want to be a teacher. For a lot of my friends, that was like the track that they were following… And that was just something I couldn't do." In two other summers, Whitney worked on undergraduate research projects, and really enjoyed those experiences. This was the beginning of her interest in pursuing a graduate degree program.

Several of the women went through periods of disrupted science identities. The women's disrupted science identities were often prompted by receiving poor grades during a given semester, frustration with faculty and peers, or discouragement from advisors. During these periods, the interviewees assessed their reasons for pursuing physics majors, and considered alternative majors and career options. In every case, the women chose return to physics based on their love of physics, perceived lack of other options, or out of a desire to disprove naysayers.

Whitney's story was characteristic of the conversations around disrupted science identity. On multiple occasions, Whitney questioned whether or not she should be in the sciences, and in college in general. At one point she had a particularly difficult semester. She described working hard, but doing poorly in all of her classes "So I was taking these classes and midterms came, and I failed all of them. Every single one. I had to write a paper. Failed. Had to take a test. Failed. I was getting 50s." Toward the end of that semester, she made arrangements to go home and had no intentions to return to campus. Just as she was about to leave, a snowstorm prevented her from traveling, and she returned to campus. After having several negative incidents with faculty in her undergraduate degree program, she felt stressed and drained, and was not confident that her advisor and other faculty members would support her in pursuing admission to a graduate program. With all of that in mind, Whitney took a hiatus from physics, "So I was just like, okay, I'm done with physics. I'm done with science. Like once I graduate I'm just gonna get a job and that's what I did." She worked in a non-STEM position for about a year, but she missed the challenge of science ad research, and returned back to a STEM graduate program.

Recognition

All of the participants in individual interviews recalled occasions when teachers, family members, or mentors recognized their talents in science and mathematics. In many cases, this happened well before college, in elementary, middle, or high school. K-12 teachers often pointed out the girls' exceptional abilities in class, and went further to make their parents aware. As a high school student, Felicia recalled having a teacher tell her parents she would excel in a specific STEM career field: "…in high school, I did pretty well in biology, and at one point we had a parent-teacher conference and my biology teacher told my parents I would make a good genetic engineer." From that point on, Felicia too saw her potential to be a genetic engineer. She sought out information about the profession and found degree programs that could prepare her to pursue it as a career.

In later years in college or graduate school, recognition served as a reminder for many participants that they were still capable of excelling in the sciences, and made them feel validated as members of the science community. Latasha recalled that her undergraduate advisor recognized her talents, saying, "He always would kind of tell me he expected me to go to the PhD level; he felt like I was competent enough to go to the PhD level." Beyond simply recognizing her ability, he extended opportunities for her to explore her potential.

Competence, Performance, and Mastery

All of the women in this study described themselves as capable scientists, noting that they were always "good at" math and science. Their sense of competence in physics stemmed from experiences where they were able to demonstrate their knowledge or master a subject. The women felt a special sense of accomplishment when they were able to overcome a particularly difficult challenge. For example, Whitney took a physics course in high school that she found to be quite difficult, but she was intrigued by the challenge it provided:

> …My senior year in high school I had to take a physics class and I was like, this is the hardest thing I ever had to do. I loved it. Like you know I have to master it. It's something I have to get good at because I never actually got something – encountered something where I was like, wow, I have no idea what I'm doing.

Interviewees were also asked when they felt most competent and capable as scientists. All of the women responded by describing mastery experiences when they were able to effectively demonstrate their knowledge to peers and faculty. Latasha referenced an internship experience when she began making connections between her coursework and real-world applications. She recalled that her research mentor would push her to try to solve problems independently, but was willing help her figure things out if she was unable to do so on her own. She described this as a mastery experience, saying:

> … It was, you know, my first real internship where I was just on my own … it forced me to figure it out, and that's where I felt most like a scientist. And I was coding and I was doing all of these different things … And it taught me that now you had to actually apply the science…so that's when I felt my most confident because I was doing this data analysis and I was able to compare it and analyze it and I just felt like a true scientist.

At the end of her internship, Latasha was able to publish a research paper as first author. Again, this served as a mastery experience that bolstered her identity as a scientist:

> And then when it got published that's probably when I felt my most accomplished …that's when I felt most like 'this is what I'm supposed to be doing.'

Similarly, Dawn and Karen described feeling most competent having opportunities to home in on their skills and present their work among peers and scholars in the field as undergraduates. Karen described mastering in-class assignments and presentations:

> ….Any time I took an exam and I would come out feeling really good about it or …after I've done a presentation, that feels really good to me. 'Cause then I feel like preparing for a presentation, I learn more about where I stand and then I just feel overall better about the direction I should be going.

Dawn described her experiences presenting at conferences:

> … I would have to say in my undergraduate, getting the opportunity to go and do research in different areas and being able to go to different conferences and present my findings and stuff like that. I felt like during that time, I was most confident because it's like you're constantly sharpening your skills, and I feel like as you get out into the real world, you don't have those opportunities as much.

Analysis of Science Identity Findings

Several studies based on the experiences of women in STEM indicate that women of color are frequently inclined to pursue careers in the sciences as a means of solving societal problems, or giving back to their communities in some way (Brickhouse et al., 2000; Carlone & Johnson, 2007; Hanson, 2009; Johnson, 2007; Seymour & Hewitt, 1997). The women in this study did have a tendency to pursue physics as a means of fulfilling altruistic aims of teaching science at the K-12 or college level. In other cases, they may have pursued physics based on their personal interests, but almost always cited altruistic aims like mentoring younger students as secondary reasons for pursuing physics. The range of the women's reasons for pursuing physics majors and careers suggest that Black women in physics are by no means a monolithic group. Their decisions to pursue physics majors were complex, and inextricably linked to their identities as Black women.

Findings related to the women's development of identities as scientists showed that science identity is not a final, static status. Instead, the women constantly negotiated academic experiences and interpersonal interactions to maintain their identities as scientists. In all cases, interviewees experienced periods of disrupted science identity, when they felt major conflicts between their interests and their actual experiences in physics. What distinguishes these women from others who do not complete physics majors is their ability to overcome disrupted science identities to persist in physics. The women in this study described supportive mentors, peers and family members who helped them return to seeing themselves as capable scientists who could make valuable contributions to the field. Their experiences offer valuable insight into ways to prevent and overcome disrupted science identities for other Black women in STEM.

Findings related to science identity also show the importance of providing opportunities for undergraduate women to hone their skills and share their knowledge with colleagues. All of the women in this study described these opportunities as critical contributors to their identities as scientists. They relished in opportunities to present themselves as knowledgeable among peers, professors, and professionals in classes, internships, and conferences.

Emerging Themes

In addition to themes established from research questions and frameworks, several other themes emerged that provided valuable insight into the participants' experiences. This section includes unanticipated, yet compelling findings from interviews with African-American women in physics. The women discussed four major themes of *Perceptions of Physics Culture, Preparation for Graduate School and Careers,* and *Being a Black woman in Physics/STEM.* Detailed findings related to each emerging theme will be presented in the following section.

Perceptions of Physics Culture

The women's classroom experiences in their majors varied depending on their professors and institutional context, therefore there was no definitive, singular "physics culture" across all cases. However, when the women in this study were asked if they perceived that there was unique culture in physics, they all responded that there was. There were some recurring themes in the ensuing descriptions. Specifically, participants described feeling that they were constantly expected to prove their competence to peers and faculty, and they sensed a common disregard for their lives and interests outside of physics. One participant, Alicia, sensed that peers and faculty in her graduate program always described themselves as "busy" and kept themselves occupied to avoid developing personal relationships with others. The women were also very conscious of the fact that the physics community is very small, and closely linked. Several participants noted that race, gender, and other social issues were never discussed in their STEM courses, even though they sensed that their own social identity heavily influenced their interactions with peers and professors. These findings are consistent with literature about "meritocracy" in STEM disciplines; which contradicts with conversations about privilege and prejudice.

The interviewees described a relatively small group of scholars and scholars in training who expect one another to immerse themselves in physics and prove their knowledge/competence to one another. As undergraduate and graduate students, the women felt pressured to conform to these 'norms' in their discipline. When they resisted these expectations, they felt that they were frowned upon or labeled as uncommitted. Jackie described working on a research project with a professor in her department who was fully immersed in his work. When she sought to have a life outside of the lab, he challenged her commitment to physics, commenting "…You don't really like physics, because if you did, you would wholeheartedly get in this research project that I have set up for you." The theme of immersing in physics began at the undergraduate level, but carried over into the women's descriptions of their graduate experiences. Patrice discussed faculty expectations around 'presence', and recalled professors in her graduate program who worked long hours and expected their students to be in the lab for 10 or more hours each day: "…they were really big about presence, being there…that was an unspoken thing. Or not even unspoken, it was spoken… they wanted to see you there all the time."

In the physics classroom setting, the women described regimented processes for solving problems, and clear 'right or wrong' answers. Even in classroom settings where the women perceived that there were supportive peer interactions, there was an underlying sense of competition to be recognized. Felicia said, "…In physics…if your professor is asking you, like, what is the answer to this, you want to be the first person to say, 'I got it'." These two themes of structured processes to solve problems and competition among peers were described in greater detail under "Undergraduate Classroom Experiences".

Several participants described the small, close-knit nature of faculty and scholars who have established themselves in the physics community. The women in the study benefitted from this close community when advisors and mentors were willing to connect them with colleagues at other institutions, or were able to help them secure research/internship opportunities. In other instances, participants felt pressure to please (or endure abuse from) their advisors/mentors to avoid burning bridges or developing a negative reputation within the physics community.

The women also perceived a consistent avoidance of discussions about race/equity/social issues. Only one student, Whitney, acknowledged her program's efforts to be inclusive about gender, however there was still no discussion about race:

> …They were very conscious of, like, gender. So that they would be more aware of saying 'he' all the time and sometimes they would say 'she' or 'they' or they would try to use, like, ambiguous noun/pronouns …to try to be more inclusive. But I think that's kind of

> where people are more comfortable talking about those things. Like male versus female type of dichotomies and not necessarily race. So I think race was kind of like ignored a lot.

In a similar comment, she noted some positive interactions with faculty early in her program, but felt that race was always the "elephant in the room that nobody ever wanted to talk about."

Analysis of Physics Culture Findings

Again, interviewees' perceptions of physics culture as undergraduates varied depending on the type of institution they attended. Students who attended HBCUs typically perceived a more supportive environment, but implied that their experiences were not representative of the larger physics community. Thus, their descriptions of physics culture were mainly based in TWIs where they engaged in research or attended graduate school.

The women in this study described a common physics culture in which they were expected to solely devote their time and energy to their work in their major. They felt that they were expected to prove their competence in order to develop relationships with peers and classmates. They recognized the influence of a small group of scholars who could help or hinder their progress in the field. Finally, participants noted that there was little to no discussion of social issues such as race and gender in physics.

Several researchers have identified similar elements in science culture (Carlone & Johnson, 2007; Eisenhart & Finkel, 1998; Guiffrida, 2006; Johnson, 2001; Kuhn, 1996; Museus & Harris, 2010; Nespor, 1994; Ong et al., 2011; Seymour & Hewitt, 1997; Traweek, 1988; Varma, 2002). Seymour & Hewitt (1997) describe the widespread presence of “weed-out” courses, in which science professors intentionally make assignments and exams difficult in order to determine which students ‘belong’ in their departments (Seymour & Hewitt, 1997). Similarly, a number of researchers have described STEM cultures that encourage competition over collaboration, and reward individual success (Guiffrida, 2006; Lipson & Tobias, 1991; Museus & Harris, 2010; Rosser, 1993; Seymour & Hewitt, 1997). Literature on STEM culture also suggests that Professors and researchers in STEM have a tendency to maintain an appearance of science as objective, meritocratic, and context-free (Haraway, 1991; Harding, 1991; Kuhn, 1996; Ong et al., 2011; Traweek, 1988; Varma, 2002). In this sense, science is presented as a space in which those who excel have done so solely based on their intellect, which “ignores the social realities of racism and sexism in science environments” (Ong et al., 2011, p.183).

The physics culture the women and other researchers describe stands in stark contrast with our knowledge about the interests and learning styles of women and women of color. Women and women of color tend to favor learning in the context of social influences, value multiple perspectives, and often prefer collaborative academic environments (Belenky et al., 1986; Carlone & Johnson, 2007; Hanson, 2004, 2009; Collins, 2000; Johnson, 2005; Tobias, 1990). In some ways the HBCU setting seemed to provide a safe space in physics for the women. In most cases, participants described HBCU physics departments as spaces where they were encouraged to work with their classmates and they felt supported by faculty and staff. They were provided opportunities to build their skills and often had professors who supported their endeavors. When they left this environment to go into careers or graduate programs at TWIs, they were exposed to more of the negative aspects of physics culture. Findings related to the women's perceptions of physics culture are consistent with research citing the supportive nature of STEM programs at HBCUs (Fries-Britt et al., 2010; Giguette et al., 2006; Kim & Conrad, 2006; Lent et al., 2005; Perna et al., 2009; Solórzano, 1995; Whitten et al., 2003, 2004). In these studies, researchers have noted smaller class sizes, faculty and support and encouragement, and departmental practices intended to increase student retention and success.

Preparation for Graduate School/Careers

The women in this study frequently described their undergraduate classroom experiences in terms of preparation for their graduate programs. Although all of the women in this study went on the complete graduate degrees in STEM, there was a common theme of encountering major challenges and obstacles in these programs. Seven of the women described feeling isolated, having difficulty finding advisors and mentors, and feeling judged unfairly based on their race and gender in their graduate programs. Latasha found that her graduate program was drastically different from her undergraduate program. She felt unsupported by both faculty and peers, and said, "It was completely different. It was every [wo]man for themselves. There was no study group, there was no physics lounge, there was no structure; it was every [wo]man for themselves. And it was totally unexpected because I was just so used to it being another way." Felicia, who attended a TWI for her graduate program said, "I feel like I'm being assessed differently. Like, I'm not being looked at fairly." Karen described difficulty communicating with her advisor and said, "It took a while to feel like I belonged in the program."

The women also described feeling that they had to pursue graduate degrees because of limited career options with an undergraduate physics degree. It is important to note that all of the women expressed a desire to work in physics. They recognized that they had valuable skills that were desirable in other industries such as finance, however they had a passion for physics. Most of the women felt that their undergraduate courses did not align well with required courses in their graduate programs, in terms of material, rigor, and professors' expectations.

Limited Options for Undergraduate Physics Majors

All of the participants in individual interviews went on beyond their undergraduate programs to pursue graduate degrees. This was in part, due to perceptions of limited career options with a Bachelor's degree in physics. Several women recalled recruiters from government agencies and corporations coming to their campuses to recruit engineers or other students. As physics majors, their technical skills and knowledge of science and math concepts were desirable to employers, but the women perceived that they would not have opportunities to engage in work related to physics. Jackie recalled her concerns about entering the workforce with a Bachelor's degree:

> …What can you do with a bachelor's degree in physics? You really can't do much unless you work for a random Fortune 500 company and you end up being a data analyst or something. I didn't want to do that…
> …[Recruiters were] Visiting the campus, talking to the people, I was like, 'man', I just had a feeling that this was going to be the end of it, that this was just going to be a corner that I can't get out of, because once you work for these folks, you can't do physics. You have to do computer systems, or you have to do cyber security, stuff like that. You can't do what you want. You're a subject to them.

Karen shared similar concerns, and felt that physicists with Bachelor's degrees had a more difficult time getting jobs than graduates in other STEM disciplines:

> …Physics is weird in that when you have that degree – like, when I was graduating, I was just kind of like what do you do with a B.A. in physics? And really there's not, like – with engineering, they can get hired, like, [snaps fingers] easily. Physics, it's not quite the same. Like, they're looking for a higher degree after that. So it was almost like 'I have to do this in order to find a job outside of this.'

She noted that corporations and government agencies heavily recruited engineering majors. She also admitted that had she majored in engineering, she may have been less likely to pursue a graduate degree after completing her undergraduate program.

Applying Coursework in Graduate Programs and Careers

Given the longitudinal nature of the data informing this study, the women were able to give reflective feedback that described how their undergraduate classroom experiences prepared them for future endeavors in graduate programs and careers. When asked about their preparation from undergraduate courses, several women shared that despite earning good grades in their undergraduate programs, they felt academically unprepared for graduate programs. Jackie summarized this well, saying:

> Now that I'm in graduate school, I can compare. My God. There is no comparison. I was telling my friends lately…"I really think [my undergraduate HBCU] set us up to fail." I don't think they prepared us for where we need to be. You can graduate with a 4.0 in physics. For instance, [my friend], she graduated with [close to a 4.0], and she really doesn't know the stuff. She's like, "Really, honestly, don't even ask me."

She described another occasion when one of her graduate professors asked her how she passed a course in her undergraduate program, but did not understand concepts that should have been covered in the course. Jackie responded saying that her undergraduate professor "…didn't teach me that stuff. He taught me a totally different syllabus." In her undergraduate program, Patrice perceived that her professors made an effort to connect course topics with applications that would be of interest to their students. In her graduate program, she felt that this was not the case. She described the disconnect between coursework and real-world applications, saying

> …I'm sitting in these classes and I'm going to these meetings and sitting in these [research presentations] thinking 'this doesn't mean anything to me'. I understand the importance of this research but this doesn't connect to my life. I don't feel like this changes anyone else's lives in a direct sense of things.

Dawn shared feeling a disconnect between her undergraduate coursework and her current position – "I know I have all this knowledge, and I know all these formulas most of the time, but when it comes down to everyday living, I can't say that I can just recall some of my learning and say, 'Okay, this is that.'"

Transitioning from HBCUs to TWIs

The majority of women interviewed for this study attended HBCUs for their undergraduate degrees. Several participants went on to pursue graduate degrees at TWIs, and recognized distinct differences in their experiences in each environment. Students who attended HBCUs reported small undergraduate classes, often with fewer than 10 students in upper level courses. Felicia described her undergraduate physics courses, saying

> …. Physics was much more intimate, because I was one of the only people. So the professors, I believe….were very cultivating, and that's what I liked. Like, it was a lot of attention on me, and that was a good feeling.

She recognized the drastic difference between the size of undergraduate courses at her undergraduate HBCU, and courses at her graduate TWI:

> The introductory classes were much bigger. But, I mean, where I'm at now, at [a TWI], these undergraduate courses – the introductory courses of physics have, like, 400 students in it. So where I'm at – where I was, at [an HBCU], introductory courses had maybe 30.

> There wasn't that many of us. So that was real nice. Like, the professor was in your face. You know, it was better.

Several participants mentioned that despite earning high grades in their undergraduate majors at HBCUs, they felt academically underprepared for their graduate programs. They felt pushed/challenged, but not on issues that would be most relevant for graduate study. Jackie described this type of experience, sharing that her professors often pushed her to answer questions and solve problems quickly, but she did not learn how those concepts fit together, or how to apply them until she got to graduate school. In other instances, they felt that they did not have exposure to the same research techniques and equipment as their peers from TWIs with more financial resources. Patrice felt that she did not have as much hands-on research experience as her peers from TWIs, due to limited funding at her school. She described these disparities:

> So I didn't personally feel prepared going to grad school …even though it's small and you have intimate time with your teachers, there still things that you miss being at a large university and then having more funding. Like some of the projects that we did, especially in our physics class experiments where we were watching the video of them doing it and these are like older videos versus other places who had the funding and they had bigger departments, they actually had those resources. So they are actually hands on, doing these experiences whereas we were just watching a video and rewinding it…

Outside of the classroom setting, students who attended HBCUs for their undergraduate degrees felt that they were afforded more opportunities to build personal and professional relationships with faculty. Alicia described hurdles undergraduate students in her graduate TWI had to overcome to have an opportunity to join research teams in their program. Alicia recalled one student who contacted every faculty member in her department trying to get an opportunity to engage in undergraduate research. Ultimately, only one professor was willing to give her an opportunity to work on his team. She described her own experience as just the opposite – faculty at her HBCU encouraged her and other students in her program to get involved with their research projects, as well as research opportunities at other institutions. She said

> …I was more well-rounded; like the research experiences I got. I started doing research I guess the summer after my freshman year…And I had research like all three years. I had an internship at [a TWI]. And so when people saw that, they were like, "Oh, my God. She's done so much research."

She also felt that attending an HBCU equipped her with experience in taking a leadership role in presenting research, saying "… I think [my undergraduate HBCU] did prepare me for I guess being able to present research, being able to present my ideas clearly, and be confident about those ideas." This served Alicia well in her graduate degree program, as she was able to write a proposal to secure fellowship funding. Dawn also shared that professors in her undergraduate department supported her in pursuing research and internship opportunities that ultimately helped her get exposure in physics and refine her interests.

Most of the participants who attended HBCUs described keeping in touch with faculty and mentors from their undergraduate programs, whereas the students who attended TWIs seemed less inclined to do so. For most of the students who attended HBCUs, their undergraduate professors were a source of support into their graduate programs. The one outlier was Jackie, who felt wronged by professors in her program and intentionally distanced herself from her department. Among the students who attended TWIs, Whitney and Karen both had one or two supportive professors with whom they kept in contact, but seemed to have no interest in further communication with others in their departments. The students' interest in continuing relationships beyond requirements to complete their degree programs is consistent with their descriptions of relationships with faculty as undergraduate students.

In spite of positive reflections on their experiences at HBCUs, many of the women who attended these institutions for their undergraduate degrees felt that they lacked some the academic preparation that their peers who attended TWIs had. They described tradeoffs between having access to state of the art equipment and renowned scholars at a TWI, versus having supportive faculty and more opportunities to get research and internship experiences at an HBCU. In nearly every case, the women who attended HBCUs did not regret their decisions, but identified ways in which their alma maters could better prepare future students in STEM.

Analysis of Findings Related to Preparing for Graduate School

In transitioning to graduate programs, nearly every participant experienced periods of disrupted science identities. Family, mentors, and undergraduate professors were instrumental in their abilities to recover from these setbacks. Several women in the study began Ph.D. programs, but faced major hurdles to completing them. For example, four participants shared that they did not pass their qualifying exams in their first attempt. Although this may not be uncommon in STEM doctoral programs, the women sensed that their advisors were not supportive in helping them prepare, and in some cases encouraged them to leave their program before completing the degree. In one case, a participant left her program with a Master's degree. Another participant considered stopping at a Master's degree, and one woman's advisor pushed her to leave her program with a Master's degree. The women perceived that other students were offered more support prior to qualifiers, and in the event that they did not pass them, professors reached out to help them prepare them for a second attempt.

In other cases, the women faced major issues in their personal lives that took their attention away from their studies. Two participants lost a parent during their graduate programs, and had to take time off to take care of family business. Several women experienced a major disappointment in a particular graduate program. They chose a Masters/PhD. Bridge program based on the premise that they would be guaranteed admission to a Ph.D. program, but after enrolling found that the program did not offer what they were promised. They ultimately left with Masters degrees or transferred to other graduate programs. To protect the participants' identities, these incidents are not matched with case profiles.

Participants shared some interesting insights into their transitions from HBCUs as undergraduates to TWIs as graduate students. They described moving from supportive departments at HBCUS to TWIs where they felt isolated and discouraged by faculty and peers. Other researchers have identified students' difficulty in transitioning from undergraduate STEM programs at HBCUs to graduate programs at TWIs (Joseph, 2007; MacLachlan, 2006; Ong et al., 2011). Specifically, existing studies have noted academic challenges and social isolation in the TWI environment. Findings from this study build on the existing literature, and provide additional insight into the experiences of Black women who transition from HBCUs to TWIs. Women in this study experienced the same challenges cited in other studies, but they also noted that their undergraduate experiences at HBCUs afforded them opportunities that they may not have gotten in other institutions. They developed close relationships with professors, and had opportunities to engage in research and conference presentations. In several cases, faculty mentors from participants' undergraduate HBCUs were critical sources of support in their graduate programs. These professors provided guidance and academic assistance to the women in the absence of supportive faculty in their new departments. These findings may help STEM departments at HBCUs develop additional measures to prepare their students for graduate programs at other institutions. Findings from this work may also help TWIs identify areas in which they can better support incoming students from HBCUs.

Being a Black Woman in Physics

Several participants described their unique experiences and perspectives as Black women in physics. They perceived that their identities as Black women affected their interactions with faculty and peers in physics. They also felt that as Black women in physics, they had to 'represent' other Black women, and serve as role models for a younger generation of Black girls. Finally, the women in this study refused to forfeit other commitments and interests for physics. They worked to weave physics into their lives, rather than sacrifice their personal lives for physics.

Black Women and Interactions with Faculty and Peers

Nearly all of the women felt that their identity as Black women affected their interactions with peers and faculty. Karen discussed one international faculty member who went off in rants during class about women's roles in society. Although she never had a personal conflict with this professor, she sensed that he had some negative views about women and their abilities, and minimized one on one contact with him. Similarly, Latasha spoke about an international professor in her department who seemed to grade women's work more harshly than his male students. She and other women in his courses also observed that he talked down to women in his class and seemed to feel the need to assert himself as an authority to women. When the women questioned him, he would respond saying "I have tenure, and so what can you do?"

In her focus group interview, Felicia shared that she felt her male professors and peers were sometimes confused or intimidated by her as a Black woman, saying, "…sometimes I feel threatened like they do wanna keep me down because I'm female and maybe that whole race/gender and, you know, I'm a triple threat." Similarly, Felicia described being careful to be professional around her male professors and peers, so as not to be perceived as getting unfair advantages as a woman: "I guess it's my experience with males, it's knowing how to approach them and knowing how to speak with them properly, knowing how personal you can get with them and keeping it on a professional level." Karen also recalled peers in her department who dealt with sexual harassment from men in her program. To avoid having these types of issues herself, she distanced herself from peers:

> …It's physical boundaries, behaviors, things that are said, things that are done; every level. ….I guess that's why most of my relationships with the peers have just been on a school basis… I'm just keeping my relationships with those people professional so that I don't have to deal on a social level and have to encounter those problems. So in a way it's been separating myself from my peers…

Karen attributed her difficulty in finding mentors to her race and gender,

> … I felt like I stuck out in two ways; that I was a female in physics and that I was a Black female in physics. I always felt like I don't know if it was more on my end that I felt strange – strange from them, or if they felt the same way about me. So at first I had a hard time finding the mentorship that I really wanted to have.

Whitney also had a series of negative interactions with peers and faculty that she perceived to be a direct consequence of being a Black woman. At one point, she described her experience to a group of peers, saying "I feel like people don't talk to me because of my race, I feel really isolated in my classes, I feel like people assume that I'm not intelligent…" Whitney had a negative interaction with one of her professors, and felt that he made unfair criticisms and belittled her in the presence of other faculty from her department. She believed that his behavior was fueled in part because she was a Black woman, and she was even more disappointed that no other faculty members intervened on her behalf, saying, "I felt like nobody was defending me."

"Representing" Black Women/Proving

The women's perceptions of their professors' and peers' attitudes about them as Black women often resulted in a sense of needing to prove their abilities or 'represent' Black women collectively. Dawn described a persistent feeling that she has to prove herself among her STEM colleagues: "There's always this challenge of you have to constantly prove yourself, and it can become exhausting at times because you have to validate your existence or validate why you're here." Annie experienced similar scrutiny as one of the only Black women in her classes at a TWI, which made her feel more hesitant about seeking assistance or clarification in class:

> I think, maybe, that's where some of the hesitation came from in terms of wanting to ask questions or feeling like I couldn't ask a question in class at Georgia Tech. I think I started to notice that we weren't all the same in class, and I think I felt self-conscious…

Karen also described her concerns that as a Black woman in physics her peers and professors may see her as a token or novelty, rather than a competent scientist: "I worry that my presence there means more to people. Like, oh, you're here, because you look good on paper….'cause you look good for the department or something and not really based on any type of credentials or something like that." She shared that on some occasions when she opened up to peers about her concerns with finding a job, they responded by saying "oh, you're an African-American female scientist, they'll hire you anywhere." She felt that in making these types of comments, her peers downplayed her accomplishments. She said, "it's frustrating, 'cause I just feel like I'm being minimized, like my problems are being minimized just because of being female and African American." She joked that if being a Black woman was all she had to do to succeed, "I could have been asleep this whole time."

Most of the women in this study also described a sense of responsibility to 'represent' other Black women, or serve as a role model for the next generation of Black women in STEM. Alicia described this sense of responsibility as "weight". Whereas her White male peers had the luxury/privilege of solely focusing on being great physicists, she described staying committed to the cause of advancing other Black women in STEM along with being a good scientist herself:

> …It's like it's more work than a white male physicist – he just calls himself a physicist and so he doesn't have to worry about bringing up other white males. It's natural, right? And he doesn't have to do anything to try to right the wrongs of history and try to get more people involved, right? But, then I have this kind of other piece also that I have to worry about. I can't just worry about just my science; I have to also think about this other piece too.

Linking Physics with Other Interests

A number of participants had interests outside of physics, and described unique ways of connecting these interests with physics. They saw this as a clear difference between themselves and peers in their departments. The interviewees did not see their varying interests as contradictory or mutually exclusive. In several cases, the women perceived that their interests outside of physics made them more passionate about physics. For example, in both her focus group interview and follow-up interview, Felicia described physics as a way to grow closer to God, and develop a better understanding of his work. She said

> I'm a firm believer that physics is just studying the nature of God. And I think that, you know, physicists are often non-believers, and I want to be one of the believers who shows them that, you know, these answers that you guys are finding all point to God, and that's why I'm sticking with it.

She acknowledged stereotypes about physicists being 'dorks' who are disconnected from real-world issues, but felt that her spiritual view of science equipped her to address societal challenges:

> I feel like, with this subject, physics can – I know that physics can solve a lot of things that are going on in this world. And I feel like people have looked at physics like, "Okay, the people that study physics are like you know just dorks and disconnected from society and all they wanna do is go on their computers and do mathematical equations" but I feel like there's a deep connection between physics and our society because I feel like we're pioneers in changing the world ultimately.

Similarly, Jackie discussed her commitment to her mental and physical health despite a rigorous class and study schedule. She saw her health and her academic performance as complementing one another, and felt that she should not have to choose one over the other: "Doing what you love shouldn't mean sacrificing everything else that you love. You have to make time for everything."

Tensions between the women's academic pursuits and extracurricular interests typically stemmed from their peers and faculty in physics. Karen discussed the importance of her interests outside of physics, but found it difficult to connect with peers because they seemed to be solely focused on physics:

> I felt like I had a hard time connecting with the students there as well. So, I didn't feel like I really shared anything in common with the students. I felt like their whole world was physics and mine wasn't … I had stuff outside of physics that I was interested in and that I wanted to participate in.

Jackie shared her interest in having a family in addition to being a scientist, in spite of an undergraduate professor's advice to solely focus on physics. She described a tense conversation between them when she defended her choice to have a personal life outside of science, saying

> I'm sorry. I want to get married. I want to have kids. I don't see how hard that is to do all those things, and…He was like, "Look, I let all those things go so I could do this for the rest of my life," and I'm like, "That's *your* prerogative."

Alicia also described being a physicist, but not sacrificing her identity or other interests, saying "I guess physics has such a distinct culture and I feel like as a Black woman, that's also part of my identity as well. So, I try not to lose that identity in physics and still be able to have fun, and be cool, and all these things." Based on their connections between physics and other interests, it is clear that the Black women in this study do not see themselves solely as scientists. They recognize multiple talents and interests, and seek to develop them all.

Analysis of Findings Related to Being a Black Woman in Physics

As Black women in Physics, interviewees in this study saw their gender and ethnic identities as salient factor influencing their interactions with peers and faculty in their programs. Their comments underscored findings from other studies inferring that women of color experience discrimination and isolation based on their race and gender (Carlone & Johnson, 2007; Fries-Britt & Holmes, 2012; Justin-Johnson, 2004; Ong et al., 2011; Sosnowski, 2002). Participants commonly described these types of experiences in settings with predominantly White, International and male peers and professors. In this study, the women's identities also shaped their academic and career interests, which were often geared toward addressing societal challenges or educating underrepresented populations. This finding supports existing knowledge about women's altruistic aims in science (Carlone & Johnson, 2007; Hanson, 2009; Modi et al., 2012).

As Black women, in physics, participants frequently dealt with peers and professors who doubted their competence. They responded by working to disprove these negative perceptions.   The women's comments about feeling pressured to 'prove' themselves are related to research on 'stereotype threat' (Steele & Aronson, 1995). Steele & Aronson (1995) define stereotype threat as "being at risk of confirming, as a self-characteristic, a negative stereotype about one's group".   Steele & Aronson assert that negative stereotypes about a group (such as people with a shared racial/ethnic background and women) can negatively impact the performance of students from these populations.   In contrast, students perform better when they are unaware of negative stereotypes, or are exposed to encouraging messages about their abilities (Steele & Aronson, 1995).

The women's desire to be physicists without sacrificing other interests is consistent with literature on Black women suggesting that Black women have historically juggled multiple responsibilities, and constantly master multiple roles (Gutman, 1976; Hill, 1971; Kane, 2000; Parks, 2010). In many cases, these roles seem to contradict one another, however Black women have a unique ability to blur boundaries and transcend what others may perceive to be limitations. Similarly, the women in this study refused to be academically and personally limited to physics. They excelled in physics among peers who seemed completely immersed in the topic, yet maintained their involvement in activities that were meaningful to them. In some cases, they developed alternative understandings of physics that blended their multiple interests. All of the women maintained close ties to their families throughout their undergraduate and graduate programs, and sought to have families of their own.

Summary of Findings

The purpose of this chapter was to identify and analyze findings related to Black women's undergraduate classroom experiences in physics and other STEM courses, based on 11 individual interviews. Themes related to the theoretical framework included *Pre-College Preparation, Undergraduate Experiences,* and *Science Identity*. Emerging themes included *Perceptions of Physics/STEM Culture, Preparation for Graduate Programs and Careers,* and *Being a Black Woman in Physics*. The next chapter will address implications for policy and practice, a discussion of theoretical frameworks, limitations, and areas for future research.

Chapter 6: Discussion, Implications, Conclusion

This chapter begins with a summary and discussion of findings outlined in Chapters Four and Five. Next is a discussion of findings from this study, and their connection with existing literature and theories. I will then revisit theoretical frameworks used in this study, and identify additional frameworks that may offer additional insights. Implications for policy and practice at the individual, departmental, and national level will also be presented. Finally, the chapter will conclude with a discussion of limitations of the study and areas for future research.

The purpose of this study was to develop an understanding of African-American women's perceptions of their undergraduate STEM classroom experiences. Participants also identified classroom experiences that contributed to their persistence and degree completion in their undergraduate majors. Using qualitative methodology, I sought to address the following research question and sub-questions:

1. How do African-American women perceive the climate and interactions with peers and faculty in undergraduate STEM classrooms?
    a. How did they attempt to succeed in these environments?
    b. What classroom interactions and experiences did African American women perceive supported their persistence in their majors?
    c. How do they perceive that classroom experiences and interactions influenced their identities as scientists?

d. How did classroom interactions compare with interactions with faculty and peers outside of the classroom? (i.e. laboratories, social settings, office hours, etc)

Findings from this study will provide insight into the ways in which participants connected their personal identities as Black women with their academic and professional identities as scientists. Although the classroom experience was the focal point of this study, additional questions about other influences on their persistence in STEM including pre-college preparation, family support, and extracurricular experiences were included. Questions about these other topics provided valuable information about the students' individual backgrounds, and helped contextualize their perceptions, beliefs, and perspectives.

Participants in this study took part in focus groups with a research team led by Dr. Sharon Fries-Britt between the years of 2005-2009 at annual meetings of the National Society of Black and Hispanic Physicists. During this time, all of the participants were current undergraduate or graduate students in physics or other STEM majors. Data were collected through focus group interviews, individual follow-up interviews, and demographic questionnaires. The sample consisted of 31 self-identified African-American women who majored in physics and related STEM majors. The sample includes women who participated in focus groups at annual meetings of the National Society of Black and Hispanic Physicists between the years of 2005 and 2009.

This study was designed as a multi-case study based on individual interviews with African-American women from the NSBP focus groups. Their focus group comments were used to identify themes to be incorporated into follow-up interview questions and data analysis. An integrated theoretical framework also informed the study. The integrated framework was based on Carlone & Johnson's (2007) Grounded Model of Science Identity for Women of Color, Bandura's (1977) Self-Efficacy, and Cabrera et al.'s (2001) Teaching for Professional Competence Model. The integrated framework incorporates individual and institutional-level characteristics and experiences that contribute to career and degree outcomes for Black women in physics.

In 2012 and 2013, African-American women from the focus groups were invited to participate in individual interviews focused on their undergraduate classroom experiences. Individual follow-up interviews were conducted with 11 of these women, selected based on their availability and willingness to participate in interviews. All of the 11 women interviewed completed their undergraduate degrees in physics, and enrolled in graduate degree programs in physics or related disciplines. Several participants were still enrolled in graduate programs at the time of their individual interviews.

Discussion of Findings

How do African-American women perceive the climate and interactions with peers and faculty in undergraduate STEM classrooms?

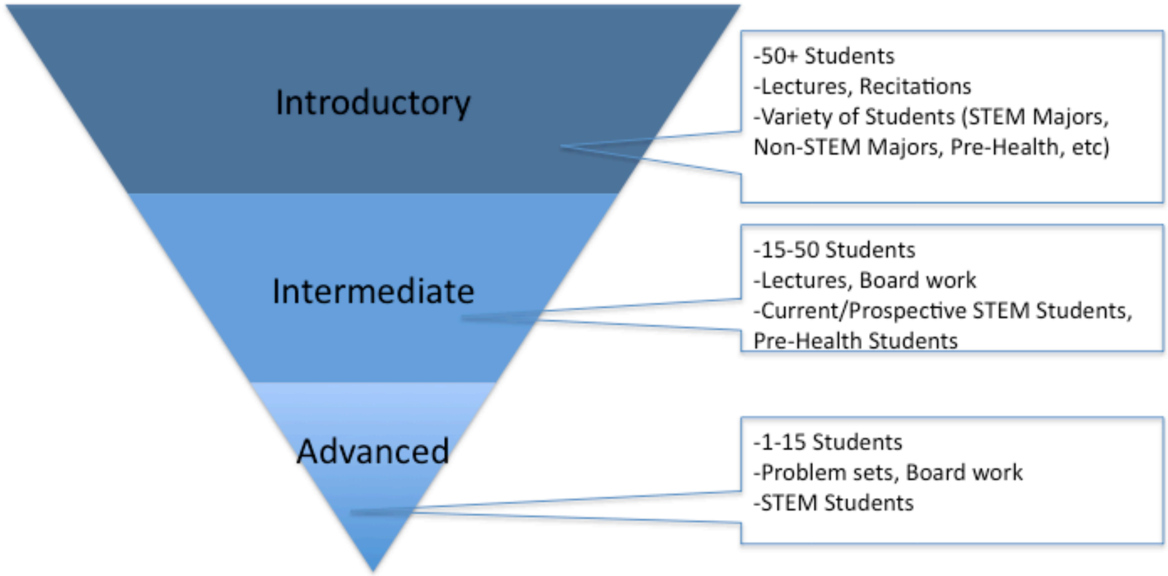
The women in this study perceived a range of climates in STEM classrooms, depending on the course, professor, and institution they attended. All participants described drawbacks of large introductory classes. In these larger classes, the women felt that professors had a tendency to lecture without engaging students. They also perceived that professors were not interested in connecting with students because many of them were there solely to fulfill general education or medical school admission requirements. These findings are consistent with literature identifying problems in introductory STEM courses, such as ineffective pedagogical practices and measures intended to "weed out" students (Johnson, 2005; Seymour & Hewitt, 1997).

In large lectures, most of the women in this study felt hesitant about being vocal in class, out of fear that they may embarrass themselves or get negative responses from professors. Many of the participants attended HBCUs with relatively small physics departments. As they progressed in their majors, the women described having far fewer people in their classes, and having much more individual attention from professors. When taught by supportive professors, these small classes helped the women learn the material. Although most perceived that they benefitted from smaller courses, being alone or one of two or three students in a given course proved problematic. In some instances, participants described having too much individual attention from professors who would belittle and discourage them. This was a unique finding that was not present in existing literature about women of color in STEM. Given eight of the women's experiences attending HBCUs, they were more likely than other STEM students to be the sole student (or one of very few students) in their physics and other STEM courses.

Participants' classroom interactions with faculty and peers also varied depending upon the size of the class, professor, and institution. In most cases, the women felt that their identities as Black women shaped their interactions with others in their program. As undergraduates, all of the participants were aware that Black women were rare in physics. They felt hyper-visible, yet isolated in some cases, and sensed that they were constantly assessed by peers and faculty based on their race and gender. Many of the women described working to ensure that they did not live up to any negative stereotypes about women or minorities. Their perceptions of stereotypes and efforts to disprove them underscore research related to stereotype threat (Steele, 1999). In TWI environments, the women had a distinctly more difficult time making connections with peers and faculty.

Throughout their discussions of their STEM classroom experiences, the participants in this study loosely described a continuum of class sizes, teaching methods, and student composition from their introductory coursework through their advanced STEM courses (Figure 5). They described feeling most engaged in intermediate and advanced courses where class sizes were smaller, and they received more feedback and interaction with faculty. They faced their greatest difficulties navigating introductory courses with large numbers of students, and advanced courses where they felt they received too much individual scrutiny. This finding is consistent with other research on classroom interactions and optimal environments for STEM student learning (Terenzini et al., 2001).

Figure 5: Continuum of Undergraduate STEM Coursework



Another common theme was perceptions of an unwritten, yet pervasive culture in their departments across a range of institution types and geographic regions. The women in this study perceived that a culture of physics and STEM influenced their professors' behaviors, and shaped their classroom interactions. Several researchers have identified elements of STEM culture (Kuhn, 1962; Ong, 2005; Ong et al., 2011; Traweek, 1988). This study provides new insights into Black women's perception of a common culture and expectations in a specific STEM discipline – physics. In addition to themes of competition and meritocracy in literature about STEM culture, the women noted that the physics community is relatively small. For that reason, they were cautious about maintaining positive relationships with faculty, and leaned on mentors to help the gain entry into networks that would help them advance in their studies and careers. They also perceived that they were expected to solely devote their time and energy to physics, and described feeling limited by binaries of ‘right and wrong’ approaches to solving problems in their physics work.

How did undergraduate African-American women attempt to succeed in these environments?

The women in this study described multiple strategies to succeed in their undergraduate STEM classroom settings. In all cases they sought out resources, including peer networks, professors’ office hours, Teaching Assistants, and study groups. In some instances, they described strategies for seeking assistance when dealing with difficult professors, such as bringing a classmate along to office hours for support.

Many of the women had a core group of one to three peers in their programs that served as a source of support. They studied together, helped one another in class, and often forged friendships outside of class. In the absence of supportive peers, women relied on family and mentors for support, and focused their attention on reasons why they chose to study physics. The women often pursued physics for altruistic reasons or based on a love of science. They felt that courses taught ineffectively, departmental politics, and negative interactions were distractions from their greater purpose in their field of study. Revisiting their personal interests and purpose motivated them to persist. The women’s recurring assessment of their interests seems to be a unique theme in the experiences of this population of students. Findings related to support from peers, family, and mentors are consistent with literature on minority student persistence in STEM majors (Espinosa, 2009; Fries-Britt et al., 2010; Hrabowski, 2003; Hrabowski & Maton, 1995; Russell & Atwater, 2005; Smith & Hasfaus, 1998). Several studies have noted that families, peers, and mentors encourage women of color to persist in STEM, and provide support that may be lacking in their departments (Andrade, 2007; Carlone & Johnson, 2007; Ellington, 2006; Espinosa, 2009; Fries-Britt & Holmes, 2012; Grandy, 1998; Griffin et al., 2010; Justin-Johnson, 2004; Russell & Atwater, 2005; Tate & Linn, 2005).

The women in this study also sought out opportunities to engage in physics research and internships outside of the classroom. Therefore, their perspectives about physics were not limited to interactions with faculty and peers on their own campus. When they had negative classroom experiences, several participants drew from positive co-curricular experiences as reassurance that they were capable and still had a passion for physics.

Despite seeking out opportunities to develop skills in physics, the women in this study rejected what they perceived to be the dominant culture of physics. They described sensing that they were expected to dedicate all of their time and energy to their academic work, and sacrifice their other interests for physics. They also felt that they were constantly expected to prove their competence to peers and professors in their field of study. They were able to push back against this culture by observing mentors who managed to be outstanding physicists while juggling family responsibilities and other interests. They also maintained connections with family, friends, and mentors outside of their undergraduate institutions who helped keep them grounded. Finally, they sought out opportunities outside of their own universities through internships, conferences, and research experiences that exposed them to a variety of people and careers in physics. Given the women's experiences, their perceptions of physics as a field of study and a career path was not limited to their undergraduate programs and courses.

What classroom interactions and experiences did African American women perceive supported their persistence in their majors?

The Black women in this study identified a number of individuals and classroom experiences that supported their persistence in physics majors. The women excelled when they felt that they were valued and respected as scientists by professors and peers. They felt that this was demonstrated in classroom settings when they were invited to contribute with questions, discussions, or solving problems. These findings also support existing literature that identifies high-impact pedagogical practices for students in STEM, such as collaborative learning practices (Cabrera et al., 2002), problem-based learning (Lipson et al., 2012), and active learning (Pascarella & Terenzini, 2005).

Professors played a major part in creating supportive classroom environments, but peer behaviors also played a role. Specifically, the women benefitted from being in classes and study groups with peers who freely shared knowledge and saw their physics courses as a collective effort instead of an individual competition. The women also excelled in environments where they were not expected to be experts or always get "right" answers. They appreciated courses where questions were welcomed, and professors sought curiosity and effort over perfection. These findings support research on women's ways of knowing (Belenky et al., 1986), and supportive STEM environments for Black women in STEM (Perna et al., 2009; Carlone & Johnson, 2007; Fries-Britt & Holmes, 2012).

Participants consistently mentioned at least one or two professors who not only engaged them in class, but also made efforts to get to know their interests and supported their goals outside of class. These professors helped develop their academic skills and helped them see ways in which pursuing physics could fit into their lives (without sacrificing their other interests). Most importantly, these professors helped the women navigate the physics community by preparing them academically, helping them attend conferences, and recommending them for graduate programs and other opportunities. Faculty mentors who help students excel in the classroom, as well as in their larger field of study have been frequently cited as contributing to minority students' persistence in STEM (Alfred et al., 2005; Ellington, 2006; Fries-Britt et al., 2010; Griffin et al., 2010; NRC, 20006; Schimmel, 2000; Whitten et al., 2004). Faculty mentorship was critical for women in physics due to the small community of scholars in the discipline.

How do African-American women perceive that undergraduate classroom experiences and interactions influenced their identities as scientists?

During the individual interviews, participants described themselves as competent scientists, and recalled being "good at" science and math from a young age. In the undergraduate environment, these positive perceptions of their abilities helped them persist through difficult or isolating class settings. The women also identified professors who recognized their talents and went out of their way to support and mentor them.

Participants were asked to recall instances in which they felt the most competent as scientists, as well as when they felt the most discouraged. In nearly every case, the women referenced academic experiences. Therefore, it seems that the classroom experience played a central role in African-American women's science identity development. They felt the most competent when they had opportunities to demonstrate their abilities among other physicists or peers. The women described experiences when they identified successful solutions to problems in classes and labs, earned high grades on assignments, or fully understood lessons taught in class. These positive experiences enabled the women to feel that they "belonged" in physics, and empowered them to pursue other opportunities outside of the classroom, such as internships, research, and publishing journal articles. Participants' descriptions of their competence and performance in classes support findings by Carlone & Johnson (2007) that suggest that these experiences contribute to women of color's identities as scientists. However, findings from this research emphasize the importance of the classroom context in Black women's science identity development.

Other classroom interactions built the women's self-efficacy by providing encouragement and vicarious experiences. Verbal affirmations and recognition from professors provided a boost to the women's perceptions of their abilities in science. Having women and minority professors resonated with participants, and made a career in physics seem more like a realistic goal in their own lives. These findings support existing research on self-efficacy (Bandura, 1977) and stereotype inoculation (Stout et al., 2011). Stout et al., (2011) assert that exposure to female and minority professors and professionals in STEM counteract the effects of negative stereotypes among women and underrepresented minority students.

It is important to note that all of the women's classroom experiences were not positive. Several participants described classroom interactions that contributed to disrupted science identities. Isolation from peers, invisibility, and negative comments from professors discouraged the women, however they relied on their positive experiences and supportive mentors to persist.

How did classroom interactions compare with interactions with faculty and peers outside of the classroom? (i.e. social settings, office hours, etc)

Participants described interactions with individual faculty members in the classroom as mostly consistent with their interactions in other settings such as office hours. The women in the study noted some increased pressure in classrooms to avoid embarrassing themselves in front of their peers. In most cases, they mentioned less personal interaction with professors in lecture settings.

Despite mixed perceptions of interactions with faculty inside and outside of the classroom context, nine participants identified at least one undergraduate faculty member who they perceived as supportive in their department. These professors developed personal relationships with students, ensured that they had access to resources such as lounge space and scholarships, and used their connections in the field to help students secure summer research opportunities. These professors also took an interest in supporting the women's pursuit of graduate study, and offered guidance in the process of finding and applying to programs. This type of personal interaction often began with a professor noticing students' potential in the classroom setting, then extended into a professional or collegial relationship outside of the classroom.

Participants also described consistent interactions with peers inside and outside of the classroom. Peers who were not interested in collaborating in class were also unlikely to offer the women assistance in study groups outside of class. Similarly, peers who showed an interest in working with the women in class commonly became friends and study partners outside of class. Particularly in HBCUs or smaller institutions, the women described close-knit communities of physics majors who took courses together, studied together, and had a shared understanding of the rigors of their major. These findings support literature citing peer support in HBCUs and women's colleges as contributing to women's success in STEM majors in these settings (Justin-Johnson, 2004; Lent et al., 2005; Perna et al., 2009).

What are key factors in persistence and degree attainment among African American women in STEM?

Participants in this study identified several factors in their persistence and degree attainment. Several women described having a personal belief in a greater purpose for their life, and pursuing physics was simply a means of fulfilling their purpose. For example, several participants felt that their purpose was to teach and mentor other Black women with an interest in STEM. They felt that they were to lead by example in their own studies and careers. Similarly, several participants mentioned their faith as a means of understanding their purpose and dealing with setbacks. All of the women described varying levels of an intrinsic passion for science and mathematics, and throughout their undergraduate experience they sought opportunities to feed their interest. This frequently took the form of seeking different types of experience in the sciences, such as research, internships, and teaching.

Another common factor in the women's persistence was support from family, friends, professors, and mentors. The women also shared insightful examples of the types of support that enabled them to be successful in undergraduate physics programs. Specifically, they benefitted from professors who sought to get to know them outside of the academic context, and faculty and mentors who helped them make connections in their field. Friends and family members provided invaluable encouragement and social support.

Discussion of Findings

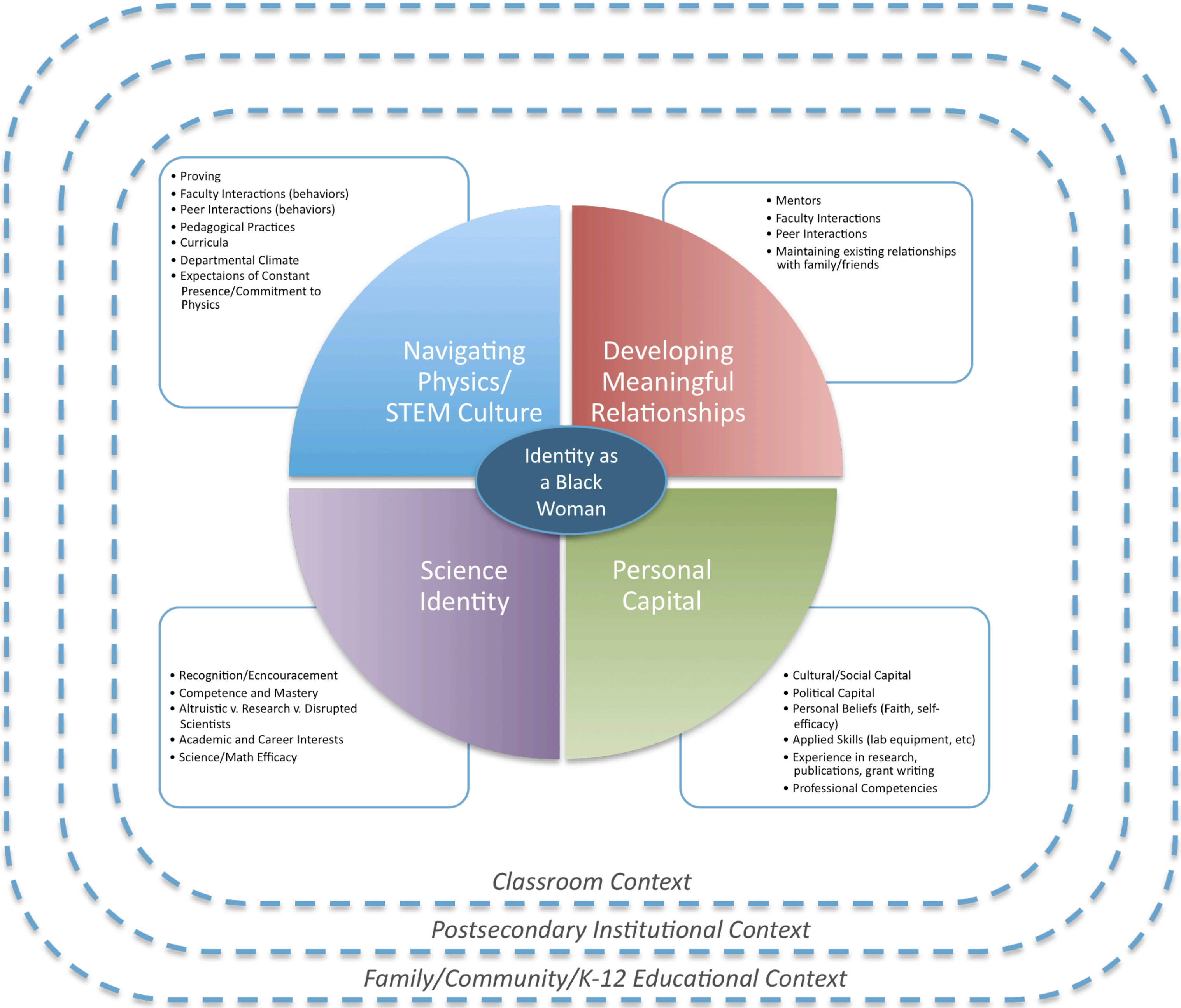
Findings from this study confirmed that among this group women, their identities as Black women affected all aspects of their undergraduate classroom experiences in physics. Specifically, they perceived that their race and gender influenced their interactions with peers and faculty in their departments. Their identity as Black women was also a major part of their identities as scientists, and influenced their career and degree aspirations. Although they frequently perceived that their identities as Black women were burdensome in their interactions with colleagues, it also empowered them to reject expectations that they should solely devote themselves to physics.

It is important to note that some of the findings from this work related to classroom interactions are relevant to student populations beyond African-American women. However, negative interactions and practices seem to have a disproportionately damaging impact on African-American women in STEM. If we seek to increase the STEM enrollment and persistence of this population, these are areas that must be addressed. Furthermore, interventions to improve the STEM climate for this population will likely benefit other groups as well.

Based on the theoretical frameworks and their individual and focus group interviews, I identified four areas in which Black women must develop in order to be successful in undergraduate physics classrooms. Given the women's persistence through graduate programs, these findings are also rooted in their perceptions of skills necessary to be successful beyond the undergraduate classroom context. These four areas include: *Navigating Physics/STEM Culture, Developing Meaningful Relationships, Science Identity, and Personal Capital.* The four areas are depicted in a model summarizing the study's findings (Figure 6). The model incorporates the four themes, with Black women's identity at the center. Identity as a Black woman influenced the women's perceptions of the physics climate, shaped their science identity, served as a source of capital, and affected their ability to develop meaningful relationships. Therefore, identity as a Black woman overlaps with all four areas related to women's success in physics majors.

Participants' experiences were influenced by varying characteristics of their undergraduate STEM classes, as well as their undergraduate institutions, K-12 education, and family backgrounds. These environments shaped their experiences, and their identities as Black women and scientists. Therefore, the model is also nested in classroom, institutional and Family/Community/K-12 Educational contexts represented by dotted lines.

Figure 6: Model of Undergraduate Achievement for Black Women in Physics



Discussion of Theoretical Frameworks

This research was guided by several models that address the role of the classroom context in student outcomes, and minority women's experiences in STEM.

These models included Cabrera et al.'s Teaching for Professional Competence Model (2001), Carlone & Johnson's Grounded Model of Science Identity Development (2007), and Bandura's Self-Efficacy (1977). These three models were useful in identifying the pre-college characteristics, learning environments, and interpersonal interactions that supported Black women's persistence in STEM majors. Elements from the three frameworks were incorporated into an integrated framework that guided this work.

Carlone Johnson's (2007) Grounded Model of Science Identity was most useful in developing an understanding of the women's experiences in physics. However, based on insights from participants, African-American women's experiences may vary slightly from those depicted in the model. Specifically, the model seems to imply that "women's current science identities are fixed, that they have 'achieved' a particular science identity" (Carlone & Johnson, 2007, p.1208). Carlone & Johnson acknowledged this limitation, but recommended further study to determine the ways in women's trajectories and identities may change over time. This research builds upon their work, providing evidence that this group of Black women in physics engaged in a constant process of assessing their interests and abilities, which determined their science identity at a given point in time. Nearly every participant experienced periods of disrupted science identity, but this was not a permanent state for any participant. Instead, the women engaged in processes of re-assessing their interests and drawing support from mentors and family to move back into seeing themselves as capable physicists.

The aforementioned frameworks provided valuable insights into the classroom experiences of Black women in physics, however several themes emerged that were not fully addressed in the integrated theoretical framework. Therefore, three additional relevant frameworks were identified during data analysis. These frameworks include Intersectionality and Black Feminist Thought, Stereotype Threat (Steele, 1999), and Social/Cultural Capital.

Intersectionality and Black Feminist Thought

Intersectionality is the concept of interlocking identities and oppressions attached to those identities. Intersection encompasses "the processes through which multiple social identities converge and ultimately shape individual and collective experiences" (Shields, 2008 as cited in Museus & Griffin, 2011). Several scholars have posited that Black women's experiences are situated in at the intersection of two powerful systems of oppression: race and gender (Hill-Collins, 1990, 1998, 2002; Howard-Hamilton, 2003; Parks, 2010). In this study, the women's interests and perspectives were influenced by both their race and gender identities. As Black women in physics, participants in this study dealt with stigmas attached to both women and Black students, and they spoke about themselves as Black women, rather than just 'women' or 'Black students'.

Hill Collin's work on *Black Feminist Thought* (1990, 1998, 2002) extends the concept of intersectionality to explore the unique ways in which Black women create and validate knowledge. She posits that Black women have been subject to being "outsiders within", in the sense that they are invited into spaces traditionally dominated by white males, but remain outsiders because their voices and perspectives are not prominent in these spaces (Hill-Collins, 2002). As students in a discipline where there are very few other Black women, the women in this study often shared experiences in line with the “outsider within” concept.

Hill-Collins also argues that the politics of race and gender influence the creation and interpretation of knowledge. She posits that in seeking knowledge, Black women value lived experience over objectified positions, and prefer to engage in dialog over debate. She also asserts that Black women see all knowledge as value-laden, and knowledge should be balanced with compassion and empathy for other perspectives. Finally, Hill-Collins (2002), suggests that given the value-laden nature of knowledge, Black women feel a sense of personal responsibility for the implications and repercussions of the knowledge they attain and create. Hill-Collins draws contrasts between these ways of knowing and the types of knowledge that are valued in Eurocentric learning contexts (i.e. objective, separated from social and cultural influences). In this study, the women described physics and other STEM courses as spaces in which knowledge was presented as objective, and professors had specific methods of solving problems that they expected all students to follow. Considering the regimented processes and norms participants in this study perceived in physics, it is likely that the women experienced tensions between their preferred ways of knowing, and those valued in their academic programs.

Stereotype Threat

Steele (1999) defines stereotype threat as “a situational threat—a threat in the air that, in general form, can affect the members of any group about whom a negative stereotype exists. Where bad stereotypes about these groups apply, members of these groups can fear being reduced to that stereotype. And for those who identify with the domain to which the stereotype is relevant, this predicament can be self-threatening" (Steele, 1999, p. 614). All of the women in this study were aware of negative stereotypes about women and minorities' academic abilities. These stereotypes were exacerbated in the physics context, where women and minorities are severely underrepresented. They felt that as Black women they were working to disprove multiple negative stereotypes perpetuated by professors and peers.

A number of researchers have tested the effects of stereotype threat in academic settings with women and minorities in STEM (Aronson et al., 1999, 2002; Good, et al.,1999, 2003; Inzlicht and Ben-Zeev, 2000). Students consistently show diminished performance on tests and exams after they are exposed to negative stereotypes about their respective in-groups. In contrast, when students are presented with positive reinforcement about their potential to succeed in a given course or assignments, their performance on tests and exams are comparable to those of control groups (Good et al., 2003). It seems that positive recognition from significant others and exposure to environments that minimized exposure to negative stereotypes about women and minorities in physics may have helped women in this study overcome the effects of stereotype threat. Given the qualitative nature of this study, it was not possible to measure the effects of stereotype threats on participants' academic performance. It was clear that participants were aware of negative stereotypes about Black women in the sciences; therefore a deeper investigation into the effects of stereotype threat on Black women's performance in STEM may provide valuable insights.

Social/Cultural Capital

Two additional frameworks that may be helpful in understanding the experiences of high-achieving Black women in physics are those of social and cultural capital (Bills, 2000; Bourdieu, 1986; Coleman, 1988). Pascarella et al. (2004) posit that social capital "resides in relationships among individuals that facilitate transaction and the transmission of different resources". Thus, social capital encompasses benefits accumulated based on relationships with other people. Similarly, Cultural Capital is the "degree of ease and familiarity that one has with the 'dominant' culture of a society" (Bills, 2000, p.90). Therefore, cultural capital includes skills, knowledge, education and other advantages that help advance one's interests.

Aside from their academic abilities, the women in this study discussed having access to information, social and professional networks, and financial resources to support their education. At the K-12 level, family members, mentors, and school counselors provided information about undergraduate programs and the college application process. When the women enrolled in their undergraduate programs, their peers, professors, and other staff members shared information about courses, financial resources, and opportunities in their field. Some professors used their personal contacts to help the women secure summer research opportunities and gain admittance to graduate programs. Based on comments from focus groups and interviews, it is clear that social/cultural capital that supported their long-term involvement and persistence in physics.

Implications for Policy and Practice

Findings from this research have the potential to inform education policy and classroom-based practices in physics departments. Although this research is primarily focused on physics, implications may be relevant to other STEM majors.

Undergraduate Classroom Practices

Undergraduate institutions, physics departments, and professors have opportunities to maximize upon African-American women's interests in physics. The women in this study thrived in environments where peers where encouraged to work with one another to learn material. Professors often set the tone for this by organizing study groups, engaging students in group assignments during classes, and ensuring that their departments had communal spaces reserved for physics students to study and work together. These high-impact practices are supported in literature about minority women in STEM (Carlone & Johnson, 2007; Perna et al., 2009; Fries-Britt et al., 2010). Physics professors who wish to develop a greater sense of community in their departments may consider these types of measures to do so.

The women in this study also sought to connect their course material from course to course, and to societal issues. In many cases, they sensed that their professors had not come together to review their department's curricula to identify gaps in material, yet as students, they were still expected to readily make connections. This was frustrating for women in this study, and they perceived that they were frequently blamed for curricular issues beyond their control. Departmental reviews of curricula may help identify and address gaps in course content within physics majors.

The women also expressed a consistent interest in seeing linkages between their course concepts and societal challenges. This served as a way for them to see the importance of their discipline, and also helped them identify potential career paths. Several researchers have noted that women often have an interest in using science for altruistic aims (Carlone & Johnson, 2007; Hanson, 2009; Johnson, 2007); therefore making these connections clear in the classroom setting would benefit women with altruistic science identities.

Nearly all of the women in this study described varying levels of anxiety about speaking in front of their peers and professors in the classroom setting. They felt that they were being constantly assessed, and attempted to avoid perpetuating negative stereotypes by giving incorrect answers in class. In other cases, professors had aggressive reactions to the women's 'wrong' answers in class and office hours. The women's anxiety often carried over into their interactions with faculty outside of the classroom setting. By comparison, the women describe their non-STEM classes as spaces in which multiple perspectives and approaches were welcomed. Professors in other departments gave them an opportunity to explain their responses, which made them more willing to publicly contribute to class discussions. Given the frequency of this theme among the women, it may be helpful for physics faculty to assess their responses to 'incorrect' or unexpected answers in their classes. Naturally, some non-physics courses are more discussion-based which makes it easier to engage students in discussions. However physicists may be able to make minor adjustments to their courses to facilitate discussions and minimize students' angst about responding to questions. Specifically, physics professors can and ask questions that emphasize the process for coming to an answer, rather than solely focusing on the "right" or "wrong" final answer.

Several students described environments, pedagogical practices, and grading practices that helped reduce their anxiety about responding to questions. Through their comments, participants identified several practical ways professors and departments encouraged classroom participation. First, participants in this study seemed to thrive in smaller class settings, where they had more one on one time with their professors, and felt less anxiety about speaking in front of a large group of peers. One participant recalled a physics professor who would give short multiple-choice quizzes in each class, based on the previous lecture and homework assignment. This particular professor would give full credit when students chose one correct answer. He would also allow students to choose more than one answer, and would give partial if the correct answer was selected. Another participant described a professor's use of "clickers" to get a sense of students' comprehension of the material he taught throughout class. This enabled all students to participate and check their understanding, without feeling pressure to get the "right" answer in front of the entire class. It also enabled the professor to see on which topics his students needed more instruction.

In participants' comments, they recognized their professors' multiple roles as researchers and teachers. In the classroom, the women responded most favorably to professors who simply sought to get to know their interests and learning styles, rather than relying upon "canned" lectures. They viewed lectures without personal interaction as being indicative of professors' indifference in their success in their subject. In addition to developing personal connections with students, professional development programs that introduce innovative teaching practices may also help STEM professors engage students in the classroom setting.

Infusing Conversations about Diversity into Physics

When asked about a culture of physics, nearly all participants noted that they perceived an avoidance of conversations about race and gender in their departments. The women saw their race and gender as having a heavy influence on their academic experiences; therefore they seemed to struggle with attempting to ignore these major parts of their identity in conversations with peers and faculty. Research on minority students at the K-12 level indicates that culturally-relevant pedagogy may help engage more diverse groups of students in STEM (Denson et al., 2010; Ladson-Billings, 1995; Lipman, 1995; Tate, 1994). Ladson-Billings (1995) identifies three criteria for educators to implement culturally relevant pedagogy: (1) Ability to develop students academically, (2) Value skills that students bring from their home culture, and build on them in classroom settings, and (3) Develop students' critical competence by helping them recognize, critique, and address social inequities. A number of researchers have identified specific classroom practices consistent with culturally relevant pedagogy, including involving students in knowledge construction, examining course topics from multiple perspectives, tailoring lessons to student interests, and tapping into family and community resources (Villegas & Lucas, 2002; Irvine & Armento, 2000).

Despite consistent findings related to the effectiveness of culturally relevant pedagogy at the K-12 level, there has been much less research on ways to make

STEM education more culturally-relevant at the postsecondary level. Although conversations about race and gender may not easily align with physics course topics, departments can show their interest in these topics by hosting symposia addressing the intersections of race/gender and physics, guest speakers, and ensuring that work by physicists from diverse backgrounds is represented in courses.

The women's perceptions of avoidance of conversations about race and gender in their STEM courses also served to silence some participants in these settings. Being ingrained in a "culture of no culture" minimized their experiences shaped by their own race and gender. This also made it difficult for some of the women to express concerns when they felt that they were discriminated against based on their race and/or gender. They felt that they were led to believe that in order to be successful in physics, they were expected to behave like other physicists, and forfeit many of the interests that they valued as African-American women.

Advising and Mentoring

From their focus group and interview comments, participants provided a description of the types of advising and mentoring that supported their persistence in their field. They benefitted most from advisors and mentors who sought a deeper understanding of their individual interests and personalities. These advisors and mentors often invited the women to engage with them outside of the context of classes and office hours. They invited the women to their homes, attended conferences with them, and made time to have open conversations with them about their concerns, long-term goals, and postgraduate opportunities. Through their positive mentoring and advising relationships, the women in this study saw examples of professors who were both accomplished scientists, and had outside interests such as families and traveling.

In contrast, they identified faculty behaviors that discouraged them or made them doubt themselves.   Several participants encountered professors who seemed dismissive when they sought assistance outside of class.   They often described this as "difficulty in connecting". In some cases, the women's advisors would indirectly suggest that they were not cut out for physics, despite their satisfactory academic performance. The women described occurrences when advisors would say that they should consider another profession unrelated to physics, or declined to serve as a reference for admission to graduate programs. This made the women feel that they were being assessed differently from their peers, who they perceived were solely assessed on their academic performance. From these comments, it was clear that the women sought advisors who would share advice and resources to help them succeed in physics, instead of attempting to re-route them into another field of study.

The women's stories also suggest that they appreciated advisors and mentors who did not attempt to make them completely sacrifice other parts of their lives for physics. They valued seeing other sides of their mentors' lives, beyond their research.   In contrast, it seemed like several faculty mentors were attempting to make the women replicate their own experiences in physics.   Professors did this by referencing their own sacrifices for physics (such as forfeiting having a family) and suggesting that the women do the same. None of the women in this study were willing to completely give up other parts of their lives for physics, and they all had a sense of personal efficacy that enabled them to hold fast to the belief that they could manage to reach both their academic and professional goals.

Existing literature on Black women's mentoring relationships provide insight into the types of connections that support their persistence (Alfred et al., 2005; Burlew & Johnson, 2002; Collins, 2000; Foster, 1993; Fries-Britt & Turner-Kelly, 2005; Fries-Britt et al., 2010; Griffin et al., 2010; Guiffrida, 2005; Maton et al., 2000; Ong, 2002; Seymour & Hewitt, 1997). Consistent themes in this study and the mentoring literature include benefits from mentors who hold high standards for mentees, seek to get to know their individual interests, and offer guidance for academic and professional success. Students also benefitted from mentors who were willing to share their own experiences in relating to their mentees. Participants in this study specified that they needed mentors most in navigating the politics of their departments and the larger physics community.

Some researchers have suggested women of color accrue additional benefits from interacting with mentors from shared gender and racial backgrounds (Brown, 2000; Guiffrida, 2005). Several of the women in this study identified mentors who were international faculty, males, or White women. In some cases, the women perceived that these individuals were more supportive than other Black and female faculty members in their departments. These experiences indicate that mentors' interest in their success and willingness to support them were even more important than sharing the same race or gender. Considering the dearth of Black women as physics professors, it is imperative that male faculty and professors from other racial/ethnic backgrounds mentor talented Black women in physics programs.

Developing personal relationships with this population of students and helping them navigate physics departments are critical elements of forging these mentoring relationships.

In order to effectively mentor women in physics, it is important for professors and other STEM professionals to invest time in understanding the needs of their students. Departmental assessments of mentoring must also extend beyond quantitative measures of hours spent with students or the number of advising meetings (Griffin et al., 2010). Instead, departments should seek to assess the quality of those interactions, and ensure that professors are aware of ways to engage their protégés in meaningful ways.

Graduate School Preparation

All of the women in this study earned their undergraduate degrees in physics and went on to pursue graduate degrees. Although the focus of this study was the undergraduate classroom experience, the women tended to describe their undergraduate classroom experiences in comparison to those of their graduate programs. They also discussed the ways in which they went about choosing graduate programs, and undergraduate experiences that influenced their decisions.

Although there is a wealth of knowledge and research centered on the undergraduate college choice process (Cabrera & La Nasa, 2000; Hossler & Gallagher, 1987; McDonough et al., 1997; Perna 2000, 2006), much less attention has been devoted to the college choice process for graduate students (Kallio, 1995). The undergraduate college choice process is commonly described in three phases: identification, search, and choice. At each phase, students draw from a number of sources of information to identify institutions that will be meet their social, academic, and financial needs. Findings from this study exposed a similar process as participants sought admission to graduate degree programs, however there were some distinct differences in their graduate program choice processes relative to the undergraduate college choice literature.

There are unique considerations for students in STEM, such as identifying an advisor/research project, securing funding in one's own department, and understanding key benchmarks such as qualifying exams. Whereas decisions about undergraduate college choice often begin around the eighth grade (Cabrera & LaNasa, 2000), the women's interest in pursuing graduate degrees in physics or related disciplines often began later, in their undergraduate degree programs. They all had research experiences, internships, or teaching opportunities that sparked a desire to study physics beyond their undergraduate programs. In several cases, faculty advisors and mentors suggested that the women apply to graduate school. In other instances, the women met recruiters from graduate programs at physics or STEM-based conferences. One major difference in the women's choices about graduate programs was the relative lack of family involvement compared to the undergraduate college choice process. In this study, the women's information about graduate programs came solely from the physics community through mentors, recruitment at conferences, and academic programs. This has important implications for professors and other mentors' recognition of talent and encouragement of underrepresented minorities and women to further their education in physics.

Without recognition and encouragement from meaningful others in science, many of the women in this study may not have gone on to pursue graduate degrees.

All but one of the participants in this study also described experiencing difficult transitions into graduate programs academically and socially. They often felt behind their peers academically, and had difficulty in identifying advisors and mentors to help navigate their graduate programs. Several other researchers have noted challenges in minority women's transitions from undergraduate to graduate programs in STEM (Herzig, 2004; Joseph, 2007; Ong et al., 2011; MacLachlan, 2006). These challenges were even more pronounced when students transitioned from supportive environments at HBCUs, to more isolating TWI departments (Joseph, 2007; MacLachlan, 2006). None of the women in this study anticipated these challenges in their graduate programs. Therefore, opportunities to interact with students and faculty in prospective graduate programs as undergraduates may have helped the women make more informed decisions about their graduate programs. Graduate programs could also facilitate this process by offering prospective students opportunities to engage in summer research and courses at their institutions.

Several participants who attended HBCUs as undergraduates described leaning on their undergraduate professors and mentors for support in their graduate programs. This was largely due to the fact that women perceived a lack of support in their graduate programs. This finding suggests that maintaining ties with undergraduate faculty may yield benefits for Black women in graduate programs. Formally engaging professors' from women's undergraduate institutions as committee members for qualifying exams, theses and dissertations may help ease

Black women's transitions into graduate programs. In spite of their willingness to help their former students, the women's undergraduate mentors may be sacrificing time that could otherwise be spent with current students advancing their own careers. Assessing mentoring activity past the undergraduate program and factoring students' post-graduate activities into faculty promotion and tenure may be a way to support extended faculty involvement with students.

Education Policy

This study provides valuable insight into programs and experiences that support the persistence and degree completion of Black women in physics. Beginning well before their college years, each of the women recalled positive experiences with K-12 teachers and science-based extracurricular programs. Their experiences bring to bear the importance of K-12 teachers who can engage diverse groups of students in STEM subjects (Brown, 2002; Fries-Britt et al., 2010, 2012; Hanson, 2009; Ladson-Billings, 1995). Colleges of education should consider reviewing teacher training programs to ensure that future STEM teachers are knowledgeable about a variety of teaching practices to suit a range of student interests. K-12 schools and STEM departments should also review their curricula to identify subjects and activities that could engage Black girls and other underrepresented students early. Furthermore, teacher preparation programs at the postsecondary level should emphasize future educators' role in identifying and developing STEM talent in their students. Creating awareness about K-12 teachers' roles as mentors, providing recognition to talented students, and providing opportunities for students to demonstrate their abilities science and mathematics could lead to positive long-term outcomes for African-American girls with an interest in STEM subjects. Several women described being exposed to role models who were professionals in STEM-based careers. Therefore, there may also be opportunities to make clear linkages between K-12 STEM coursework and real-world applications through school-sponsored guest speakers, lab activities, and field trips to shadow professionals in STEM.

At the high school level, the women all took rigorous science and math courses. Several participants attended college preparatory high schools, and two participants attended high schools with a math and science focus. These academic environments enabled the women to become confident in their math and science abilities, and master skills that would benefit them in college-level math and science courses. Despite taking the most rigorous courses available to them, some of the women still faced difficulty in adjusting to their undergraduate courses. Undergraduate STEM departments and secondary schools should assess the alignment of their coursework to ensure that students transition from one level to the next seamlessly.

For first-generation college students, college preparatory high schools were invaluable sources of information about the college application process, financial aid, and scholarships. They had guidance counselors and college counselors who were very involved in their college choice process, and made sure that they were aware of deadlines and funding opportunities. First-generation participants noted that in spite of this support there were still college expenses that they did not expect, such as airfare to travel home for holidays and mandatory student fees. Research on first-generation students identifies a lack of understanding of financial obligations as one obstacle for this population of students (Davis, 2012; Engle et al., 2006). Implementation of comprehensive college access programs that support students beyond choosing a college, and continue to offer support and guidance through their undergraduate degree programs would be beneficial to this population of students.

Findings from this study also shed light on the need for more longitudinal data about undergraduate outcomes and students' educational trajectories. Specifically, data showing critical points at which students leave physics and other STEM majors would enable researchers and practitioners to concentrate their efforts on courses and students supports at those times. Using this type of data on a campus level, educators would also be able to identify particular courses and instructors that have poor outcomes among students, and direct attention to improving those courses.

The women's descriptions of their experiences in graduate programs indicates a need more information about graduate degree program outcomes that is readily accessible to prospective students. It also seemed that they were unaware of viable career options for physicists. A few of the women applied to graduate degree programs based on information from recruiters, or their positive reputation in the physics community. However, as students in these programs, they perceived a lack of support from faculty and barriers to degree completion. More information about student outcomes of degree completion, time to degree, and student experiences would have helped the women make more informed decisions about their graduate studies.

Similarly, several of the participants attended graduate bridge programs that were marketed as direct paths into Ph.D. programs. However, for the women and other students in these programs, they were disappointed to find that many students did not successfully transition into doctoral programs. They felt that if they had access to more information about program outcomes, such as rates of successful entry into Ph.D. programs, they would have sought direct admission into doctoral programs after completing their undergraduate degrees.

Nearly half of the women pursued physics in part because of the availability of funds to support their educational expenses. They were strong in their science and math courses, but were often choosing between physics and other majors. The women were aware of scholarship programs for STEM students, and in several instances chose physics over other options in order to be eligible for these funds. Minority and first-generation students are particularly sensitive to the costs of college attendance, and factor expenses into their decisions about colleges to attend (Engle et al., 2006; Lohfink & Paulsen, 2006; Saint John et al., 2005; Somers et al., 2004). Findings from this study also indicate that some groups of students may consider the availability of financial support in decisions about degree programs and majors to pursue.

Several interviewees shared that they worked part-time or work-study jobs to support themselves as undergraduates. Two of these participants described drastically different undergraduate work experiences. Latasha received work-study funding to work in a lab in her department. She was able to earn money while gaining experience in a physics research setting. Whitney worked multiple off-campus jobs, which took up a great deal of her time and prevented her from participating in study groups with her peers. Despite the benefits of work-study for undergraduate students (Cabrera et al., 2005), funding for these programs has consistently declined in recent years (Baum et al., 2012). Policymakers and postsecondary institutions should consider more sustainable support for programs that use financial aid as a means to recruit and retain Black women in STEM. Specifically, work-study placements in STEM labs or other academic settings would serve the dual purpose of providing financial support and giving students invaluable experience in their discipline. Scholarships, grants, and other financial support in exchange for STEM-based research or work would be equally beneficial to students. These types of funding opportunities help students focus on their academic responsibilities and remain engaged in their field of study.

In recent years, there has been a decline in student enrollments and degree completion rates in physics (Mangan, 2011; Mulvey & Nicholson, 2012; Williams, 2010). Researchers have attributed this decline to several factors, including a lack of student awareness about physics as a field of study and physics-related professions, and policies at the institutional and state level that jeopardize physics programs (Mulvey & Nicholson, 2012). The declines in physics enrollments and degree-granting programs shed light on the need for greater efforts to expose K-12 students to academic and professional opportunities in physics. Investments in outreach programs led by postsecondary physics departments may encourage more students to consider physics as a college major.

At the state and institutional level, it is apparent that policies that establish minimum numbers of student enrollments and degrees as a way to assess programs' viability pose a direct threat to degree-granting physics programs. In 2011, the Texas Higher Education Coordinating Board (THECB) implemented a policy introducing strict enrollment guidelines for postsecondary degree programs. Programs with fewer than five students enrolled were deemed "underperforming", and faced elimination or consolidation with other programs (Mangan, 2011). Several other states have implemented similar policies, including Georgia, Kentucky, Louisiana, and North Carolina (Mangan, 2011). These policies are particularly problematic for physics departments at HBCUs, as these institutions are often smaller than their counterparts in TWIs (Williams, 2010). As evidenced in this study, a number of HBCUs also participate in joint degree programs in which students attend more than one physics program during the completion of their degree. If the standards set in Texas were implemented nationwide, "526 of the roughly 760 physics departments in the US would be shuttered. All but 2 of the 34 HBCU physics programs would be closed. A third of underrepresented minorities and women studying physics would have their programs eliminated. Physics training would be increasingly concentrated in larger elite universities with very adverse effects on the future scientific workforce." (NSBP, 2011) Amid calls for expanding STEM literacy and investing in STEM talent, enacting policies that would eliminate postsecondary physics programs seems counterproductive. As states and institutions consider ways to make postsecondary institutions financially sound, it is important to consider ramifications of proposed policies. Nuances of specific disciplines and institutions should be factored in to any policies, and fields that serve national interests should be preserved.

Areas for Future Research

Faculty and Institutional Perspectives

Despite the importance of African-American undergraduates' perceptions of STEM classroom interactions, faculty members and institutions play an integral role in setting the tone for these environments. Future research should examine faculty perspectives on pedagogical practices, teaching philosophies, and curricula. Institutional perspectives could also provide insight into factors affecting class sizes, faculty recruitment and training, and the availability of funding to support STEM departments and students. In classrooms where Black women have excelled in physics, departments and professors may have insights about programs and incentives to further improve supports for underrepresented students. Balancing Black women's perceptions of their academic experiences with faculty and institutional perspectives would provide a more comprehensive understanding of contexts that support or hinder degree completion among this population of students. Professors may also be able to provide information about policies or other expectations that prevent them from doing more to provide the mentorship and guidance that many African-American women in STEM seek.

Graduate Experiences

Despite this study's focus on undergraduate classroom experiences, all of the women had attended graduate programs. The women made comparisons between their undergraduate and graduate programs, and described challenges they faced with peers and faculty in these contexts. From their comments, it seems that their obstacles in graduate programs were even more pronounced than in undergraduate programs. Therefore, future studies on African-American women's graduate classroom experiences, peer interactions, and faculty interactions may build upon this work.

The women in this study also described their processes for identifying and selecting graduate programs. Considering the fact that all of the women in the follow-up interviews attended graduate programs, they all had two, and in some cases three different college choice processes. Existing college choice literature primarily focuses on college choice at the undergraduate level (Cabrera & La Nasa, 2000; Hossler & Gallagher, 1987; McDonough et al., 1997; Perna 2000, 2006). However, the women's experiences show that similar considerations are taken into account when choosing a graduate degree program. Future studies should delve deeper into these processes, and ways in which more African-American women can be recruited into graduate programs.

From the women's comments, it is also clear that all physics graduate programs that succeed at recruiting Black women do not retain them. Therefore, future research should be conducted to identify structures and practices that lead to successful graduate degree completion among this population of students. Furthermore, many of the individual interviewees were still enrolled in graduate programs. They shared valuable insights about their undergraduate experiences, and were able to identify experiences that had lasting effects on their success. A future study with the same women after they have completed their graduate degrees may provide additional understanding about their graduate experiences and career pursuits.

Link Qualitative and Quantitative Data

Findings from this study revealed themes that seem to have implications reaching far beyond the 31 NSBP focus group participants and 11 individual interviewees. This research could be coupled with quantitative data to develop a more complete picture of Black women's progression through physics majors. Specifically, longitudinal, quantitative data about their pre-college education and coursework, points when they leave physics majors (i.e. specific courses with high failure rates), interest/enrollment in graduate degree programs, and career choices should be linked with qualitative research such as this. Similarly, more qualitative research could help policymakers and practitioners understand student experiences/perspectives behind existing quantitative data about Black women in physics and other STEM majors.

Replication with Other Populations and STEM Disciplines

This study explored the undergraduate classroom experiences of Black women in physics. The findings from this work have implications for students of other races/ethnicities, and students in STEM disciplines other than physics. Future studies could provide more detailed insights into the experiences of women from other racial/ethnic backgrounds. Given their unique social contexts, there may be different factors that affect their interest and persistence in their field. Similarly, given the variety of STEM disciplines (Appendix A), there may be differences in departmental cultures, faculty attitudes, and student perceptions across different STEM majors. Existing literature is commonly based on studies that examined STEM majors in aggregate (Carlone & Johnson, 2007; Museus et al., 2011; Ong et al., 2011; Perna et al., 2009; Seymour & Hewitt, 1997). More studies in the context of specific disciplines such as physics, biology, computer science, chemistry, and engineering would provide valuable insight into similarities and differences in students' perceptions across these areas of study.

Limitations

Despite the strengths of this study (diverse institution types, wide geographical range, data collection and analysis over time) there are several limitations. First, students' comments in 2005-2009 focus groups cannot be directly linked to their demographic forms. Although this was initially beneficial in terms of maintaining students' anonymity, it made it more difficult to match student attributes with their responses to focus group questions in both phases of data analysis. In some cases (11), students attended the conference multiple times, and participated in the focus groups more than once. Unless a participant explicitly stated that they attended the conference multiple times, it was sometimes difficult to determine repeat attendees. Follow-up interview questions helped identify which African-American women attended the conference multiple times.

Another limitation of the study is my limited interaction with participants. Data analyses were based upon student responses in one-time focus groups and conference proceedings over a four-day period, as well as one-on-one interviews that in most cases were conducted via videoconference. Although the conference context enabled the development of a diverse sample, participants were not observed in classroom settings over an extended period of time. All participants in individual interviews graduated from their undergraduate programs, therefore their descriptions of their undergraduate classroom experiences were based on their memories. Although their comments give insight into people and practices that were most impactful long-term, some other details about their experiences may have been forgotten and omitted from the study.

Finally, this study is limited to the perceptions of participants. To fully understand the culture within undergraduate physics departments, it would be important to examine the context by conducting classroom observations and incorporating voices of professors and administrators. This study is centered on students' perceptions of their experiences in physics, therefore professors were not interviewed. With this in mind, there may be explanations for professors' behavior or classroom practices that are left untold. Regardless of professors' intentions, it is important to recognize the ways in which faculty behaviors are actually perceived by students.

Conclusion

Amongst ongoing calls for more STEM graduates for the workforce, economy, and innovation in the United States, it is increasingly important for STEM educators and policymakers to develop a more nuanced understanding of students' pathways to STEM degrees. This study addresses this need by studying patterns of success among an underrepresented population of students, African-American women. This study also focuses on one particular STEM discipline: Physics.

This study also sheds light on the importance of research on the educational experiences African-American women. In recent years, numerous education researchers have focused their attention on issues affecting African-American males, due to their relatively low enrollment and degree completion rates in higher education (Cuyjet, 2006; Harper, 2013; Palmer & Young, 2009; Strayhorn, 2008). Findings from this study show that African-American women also face major obstacles and challenges in their academic pursuits. Understanding these circumstances may help educators, researchers, and policymakers improve African American women's outcomes in fields where they are underrepresented, such as physics. Findings related to women's strategies to persist in spite of difficulties might also be beneficial to other underrepresented groups.

Data representing educational patterns in STEM education shed light on gaps in the postsecondary enrollment and degree completion of African-American women across disciplines. Despite expressing interest in science and mathematics before college, many underrepresented students leave STEM majors to pursue other fields of study after their first few semesters of college (Hanson, 2009; Hill et al., 2010). This research begins to develop an understanding of disciplinary cultures and behaviors that may deter Black women and other underrepresented groups from pursuing majors and careers in these fields. Modifying teaching and learning contexts is an essential aspect of ensuring a diverse pool of students with interest and talent in STEM enter the United States workforce. Just as they provided unique perspectives about what it means to be a scientist, these diverse groups have the potential to develop innovative solutions to problems, mentor future students in STEM, and help secure our country's economic future.

Appendices

Appendix A: NSF STEM Majors

NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOWSHIPS
http://www.nsf.gov/pubs/2011/nsf11582/nsf11582.htm#appendix

Fields of Study
Note: Applicants are reviewed in panels based on their primary Field of Study. The "other" field of study category should only be selected by applicants if the proposed field of study is not covered by one of the following fields, and should not be used to designate a field of study that is more specific than the fields listed.
CHEMISTRY
Chemical Catalysis
Chemical Measurement and Imaging
Chemical Structure, Dynamics, and Mechanism
Chemical Synthesis
Chemical Theory, Models and Computational Methods
Chemistry of Life Processes
Environmental Chemical Systems
Macromolecular, Supramolecular, and Nanochemistry
Sustainable Chemistry
Chemistry, other (specify)

COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE)
Algorithms and Theoretical Foundations
Communication and Information Theory
Computational Science and Engineering
Computer and Information Security
Computer Architecture
Computer Systems, Networking, and Embedded Systems
Databases
Data Mining and Information Retrieval
Graphics and Visualization
Human Computer Interaction
Informatics
Machine Learning
Natural Language Processing
Robotics and Computer Vision

Software Systems and Software Engineering
CISE, other (specify)

ENGINEERING
Aeronautical and Aerospace
Bioengineering
Biomedical
Chemical Engineering
Civil Engineering
Computer Engineering
Electrical and Electronic
Energy
Environmental
Industrial Engineering & Operations Research
Materials
Mechanical
Nuclear
Ocean
Optical Engineering
Polymer
Systems Engineering
Engineering, other (specify)

GEOSCIENCES
Atmospheric Chemistry
Aeronomy
Biogeochemistry
Biological Oceanography
Chemical Oceanography
Climate and Large-Scale Atmospheric Dynamics
Geobiology
Geochemistry
Geodynamics
Geophysics
Glaciology
Hydrology
Magnetospheric Physics
Marine Biology
Marine Geology and Geophysics
Paleoclimate
Paleontology and Paleobiology
Petrology
Physical and Dynamic Meteorology
Physical Oceanography
Sedimentary Geology
Solar Physics

Tectonics
Geosciences, other (specify)

LIFE SCIENCES
Biochemistry
Biophysics
Cell Biology
Developmental Biology
Ecology
Environmental Science
Evolutionary Biology
Genetics
Genomics
Microbiology
Molecular Biology
Neurosciences
Organismal Biology
Physiology
Proteomics
Structural Biology
Systematic Biology
Life Sciences, other (specify)

MATERIALS RESEARCH
Biomaterials
Ceramics
Chemistry of materials
Electronic materials
Materials theory
Metallic materials
Photonic materials
Physics of materials
Polymers
Materials Research, other (specify)

MATHEMATICAL SCIENCES
Algebra, Number Theory, and Combinatorics
Analysis
Applied Mathematics
Biostatistics
Computational and Data-enabled Science
Computational Mathematics
Computational Statistics
Geometric Analysis
Logic or Foundations of Mathematics
Mathematical Biology

Probability
Statistics
Topology
Mathematics, other (specify)

PHYSICS AND ASTRONOMY
Astronomy and Astrophysics
Atomic, Molecular and Optical Physics
Condensed Matter Physics
Nuclear
Particle Physics
Physics of Living Systems
Plasma
Solid State
Theoretical Physics
Physics, other (specify)

PSYCHOLOGY
Cognitive
Cognitive Neuroscience
Computational Psychology
Developmental
Experimental or Comparative
Industrial/Organizational
Neuropsychology
Perception and Psychophysics
Personality and Individual Differences
Physiological
Psycholinguistics
Quantitative
Social
Psychology, other (specify)

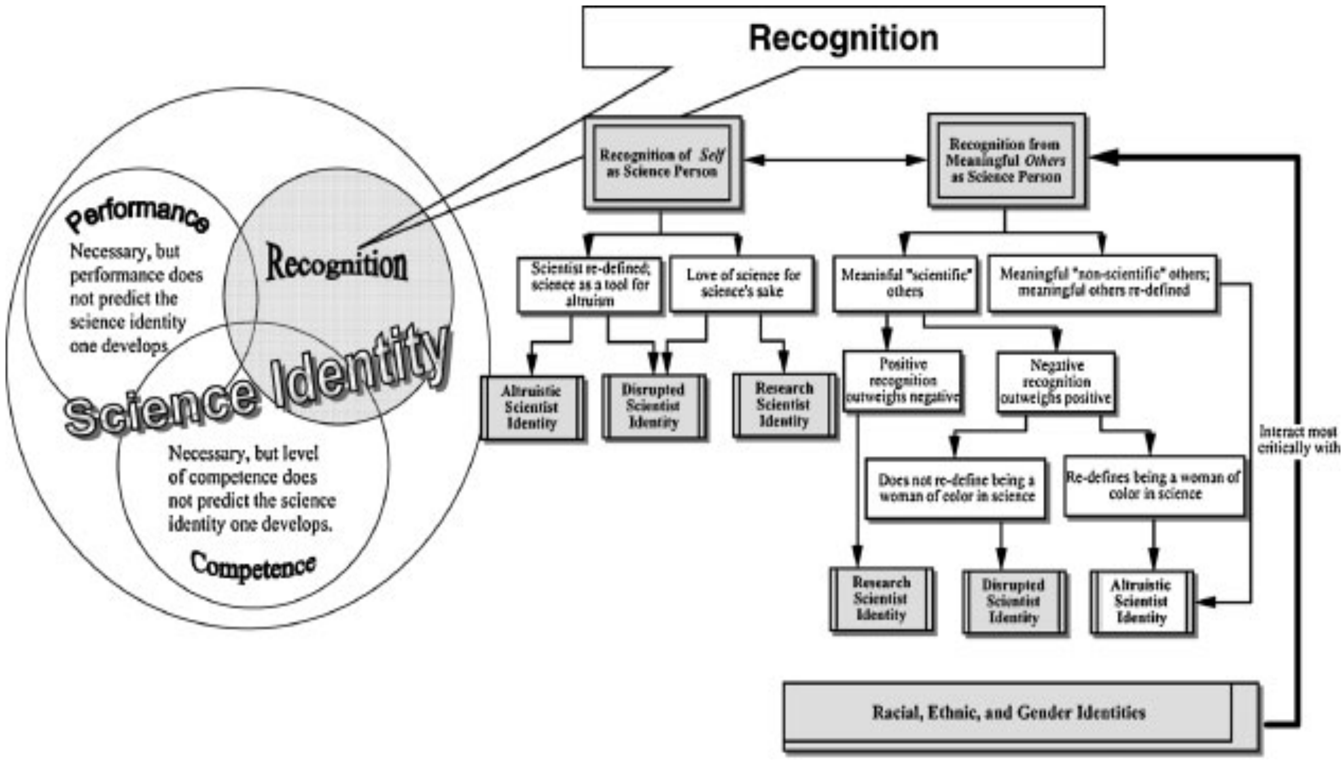
SOCIAL SCIENCES
Archaeology
Biological Anthropology
Cultural Anthropology
Anthropology, other
Communications
Decision Making and Risk analysis
Economics (except Business Administration)
Geography
History and Philosophy of Science
International Relations
Law and Social Science
Linguistics

Linguistic Anthropology
Medical Anthropology
Political Science
Public Policy
Science Policy
Sociology (except Social Work)
Urban and Regional Planning
Social Sciences, other (specify)

STEM EDUCATION AND LEARNING RESEARCH
Engineering Education
Mathematics Education
Science Education
Technology Education
STEM Education and Learning Research, other (specify)

Appendix B: Grounded Model of Science Identity for Women of Color

(Carlone & Johnson, 2007)



Appendix C: NSBP Demographic Form

2009 Joint Annual Conference of the National Society of Black Physicists and the National Society of Hispanic Physicists
Demographic Questionnaire
Focus Group Data
Spring 2009

Dear participant please complete this brief questionnaire by circling or checking the appropriate answers below. If you are uncomfortable sharing any parts of this information please leave the question blank. We ask that you do not sign this questionnaire.

1. What is your gender? a) Male b) Female
2. What is your age? _____
3. What is your country of origin? ____________
4. What is your parent's country of origin? _____________
5. What is your racial background?
   a) Black
   b) Latino/Hispanic
   c) Mixed race (please specify) _____________________
   f) Other (please specify) __________________________
6. What is your class rank?
   a) Freshman e) 1st year Grad student
   b) Sophomore f) 2nd year Grad student
   c) Junior g) 3rd year Grad student
   d) Senior or beyond h) 4th year and beyond
7. Please identity your institution affiliations
   Undergraduate institution (s)_______________________
   Graduate institution (s)__________________________
   Have you ever transferred institutions? ____ Yes ____No
   (*please describe which institutions you transferred to and from)*
8. What is your student status: a) Part-Time b) Full-Time
9. Which statement (s) best describe your work status (circle all that apply):
   a) Part time work less than 20 hours
   b) Part time work more than 20 hours
   c) Full time work
   d) Summer work only
   e) Not working
   f) Fellowships
   g) Teaching Assistant/Graduate Assistant

9. Where do you work? a) on campus b) off campus

10. How many hours do you spend per week working?
    a) 1-5   b) 6-10   c) 11-15   d) 15-20   e) 20-30   f) 30+   g) n/a

11. What is your mother's level of education?
    a. Elementary school only
    b. Junior high school only
    c. Some high school
    d. High school diploma
    e. Some college
    f. Bachelor's degree
    g. Associates degree
    h. Some graduate school
    i. Master's degree
    j. Ph.D. or professional degree

12. What is your father's level of education?
    a. Elementary school only
    b. Junior high school only
    c. Some high school
    d. High school diploma
    e. Some college
    f. Bachelor's degree
    g. Associates degree
    h. Some graduate school
    i. Master's degree
    j. Ph.D. or professional degree

13. What is your approximate combined yearly family income?
    a. under $20,000
    b. $20,000-$29,999
    c. $30,000-$49,999
    d. $50,000-$64,999
    e. $65,000-$79,999
    f. $80,000-$100,000
    g. $100,000-$150,000
    h. $150,000 and above

14. What type of high school did you attend? a) public b) private

15. What was the minority composition of your high school?
    a) <10% minority b) 10%-49% c) 50%-90% d) >90% minority

    Which minority group had the MOST representation at your high school?

    ____

16. What is (or was) the minority composition of your undergraduate institution?
    a. <10% minority b) 10%-49% c) 50%-90% d) >90% minority

Which minority group had the MOST representation at your undergraduate institution? _________________

Appendix D: NSBP Focus Group Questions

Focus Group Questions 2009 Joint Annual Conference of the National Society of Black Physicists and the National Society of Hispanic Physicists February 11-14, 2009

Pre-College Questions:

1. As a young child what inspired you to pursue science?

2. Can you identify a critical moment or time in your educational experience when you knew you wanted to be a scientists?

3. Was there a teacher or mentor who played an important role in developing your interest in science? If yes what did she do to inspire you?

4. Did you feel like you received a good educational foundation for the sciences? What was that foundation.

College Questions:

Role of faculty

1. Describe the type of interactions you have had with faculty in the classroom?
   - What behaviors are most important for faculty to demonstrate in the classroom?

2. What are the behaviors of faculty that matter most in your interactions?

3. Are there particular things that faculty do in the classroom that make you want to learn? If so what are those things?

4. Are there particular things that faculty do in the classroom that make you lose interest in learning? If so what are those things?

5. Have you had different experiences with minority and majority faculty? If so can you describe some of these differences?

6. What has motivated you to remain in the sciences?

Race & Motivation

7. Does race, culture or ethnicity factor into your motivation to succeed? If so how? If not why not?

8. Have you ever felt pressured to prove yourself based on your race, culture or ethnicity? If so describe a situation.

   - Has this ever happened in a classroom setting?

9. What do you believe are the advantages and disadvantages of attending a TWI versus an HBCU and/or HSI?

Diversity of the Program/Peers

10. Describe the diversity of your program and how this has shaped your educational experiences.

11. Describe the diversity of your closest group of peers and how this has shaped your educational experiences. (*this can be the group you study with or socialize with)*.

12. How well do you feel your program is preparing you?

Appendix E: Message to Potential Follow-up Interview Participants

Dear NSBP Member,

You are receiving this email because you are a self-identified African-American woman who participated in a focus group with Dr. Sharon Fries-Britt's research team between the years of 2005-2009 at an annual meeting of the National Society of Black/Hispanic Physicists.

I am inviting you to participate in another research project to explore the factors related to undergraduate persistence and success for African American women in Science, Technology, Engineering, and Mathematics (STEM) majors. This study will serve as the basis of my doctoral dissertation. I hope that findings from this research will inform college professors, administrators, and policymakers about African American women's perceptions of their classroom interactions and experiences in STEM, and the ways in which those interactions support or hinder their progress in their respective majors. It may also aid professors and other STEM instructors in the development of more inclusive and effective teaching practices.

This study will be conducted through 60-90 minute interviews. Ideally, the interviews will be conducted in person, but video conferencing software (ie: Skype) may be a viable alternative if participants are unable to meet in person. To supplement this data, we will review public university and departmental websites, and ask participants to share copies of course syllabi, transcripts, or other documents that they feel may provide insight into their undergraduate STEM courses. Participation in this study is completely voluntary, and all participant information shared will remain confidential.

If you have any questions, please contact me at kholmes@umd.edu. My advisor for this research is Dr. Sharon Fries-Britt and she can be contacted at sfries@umd.edu.

Thank you for your consideration,
Kimberly Holmes

Doctoral Candidate
Department of Counseling, Higher Education, and Special Education
University of Maryland

Appendix F: Follow-up Interview Protocol

1. Which year(s) did you attend the NSBP Conference?

2. Which year(s) did you participate in a focus group with the research team?

3. What was your undergraduate major when you attended the conference?

4. Did you complete your undergraduate degree?
    a. If so, what was your final major?

5. How did you develop an interest in STEM/Physics? How did you get to this point in your academic/professional life?

6. What did you do academically/professionally after your undergraduate years?

7. What do you recall about your undergraduate classroom experiences in STEM?
    a. What types of interactions do you recall with faculty in the classroom setting?
    b. What types of interactions do you recall with peers in the classroom setting?
    c. How did your STEM classroom experiences differ from those in other academic departments?
    d. Did they have any influence on your post-graduate interests and aspirations?

8. Do you feel that the things you learned in STEM courses were relevant to your career goals? Please explain.
    a. Do you believe that your professors understood your interests and goals? Please explain.

9. Describe a time when you felt the most accomplished/capable as a scientist.

10. Describe a time when you felt the most discouraged.

11. After completing your degree (or leaving your major), do you keep in touch with faculty, staff or students from your department?
    a. How would you describe your relationship with those individuals?
    b. Did they have any influence on your career/academic decisions after completing your program?

12. After completing your undergraduate degree, did you feel adequately prepared to go into the workforce or graduate school?

13. What does it mean to you to be an African-American woman (or Black, descendent of Africans) in physics (or STEM)?

14. In retrospect, what were the greatest influences on your decision to persist in your major (or change to another)?

15. Is there anything else you would like to share about your experience as a Black woman in Physics?

16. Do you know any other African-American women who participated in NSBP focus groups?

17.

Appendix G: NSBP Master NVIVO Coding List

1. Pre-College Experiences
a. K-12 Academic Experiences (e.g. classroom experiences; field trips; exposure to science)
b. K-12 Teacher (e.g. examples of interaction neg/pos; affirmed students abilities; encouraged their participation; how they taught the subject matter)
c. First generation (e.g. if parents have less than a BS/BA degree, first child to go to college - when in doubt, just label first generation)
d. Extracurricular Activities (e.g. camps, competitions, conferences, etc.)

2. Postsecondary Experiences
(e.g. comparisons and differences among institutions attended)
a. Undergraduate experiences
b. Graduate experiences
c. Post doc experiences

3. Race/Ethnicity/Cultural Identity/Issues
a. Underrepresented (e.g. Black, Hispanic/Latino)
b. Other (e.g. White or Multi-racial/ethnic student)
d. International or immigrant (e.g. dynamics and conflicts with this population - code with faculty interactions or peer interactions)
e. Proving Process (e.g. disproving stereotypes, exceeding expectations)
f. Racial Experiences (e.g. discrimination, biases, subtle attitudes "vibes")

4. Gender
a. Male
b. Female

5. Family Support
a. Parent expectations (e.g. things parents have said directly; their perceptions of parents expectation)
b. Parent occupation (e.g. mention jobs or careers, specific skills, access to resources based on job)
c. Parents education (e.g. degree attainment, field of study, unique skills and abilities, where parents went to school)
d. Siblings (e.g. siblings assisted them with college choice, provided general knowledge about college, career choices, wanting to be a role model for siblings)
e. Extended family (e.g. serving as a role model, provided general knowledge about college, career choices)

6. Faculty Interactions

a. Outside the classroom (e.g. faculty attended a student event/presentation; invited to faculty members house; socialized with faculty outside of the department)
b. Inside the classroom (e.g. responsiveness to questions, negative interactions, ways of engaging students)
c. Pedagogical Practices (e.g. style of teaching, class structure, interactive teaching methods, course content)
d. Students Perceptions of Faculty expectations (e.g. feedback about performance, statements about mastering the subject matter; workload; study habits)

7. Peer Interactions/Collegians
a. Support (e.g. helping with assignments; study groups, motivation and encouragement)
b. Conflict (e.g. overly competitive, challenges in group projects)
c. Minority peers
e. Non-minority peers

8. Institutional Factors
a. HBCUs
b. PWIs
c. HSIs
d. Resource Differences (e.g. lab experiences, money for school, fellowships, professional opportunities)
e. Campus Climate (e.g. mission, policies; how they describe the environment; demographics of student population/faculty)

9. Academic Program
(e.g. Physics, engineering, math, astronomy)
a. Courses (e.g. general discussion of classes)
b. Career or Degree aspirations (e.g. comments about their own career aspirations; comments from others about career and education plans)
c. Internships
d. Research opportunities
e. Sense of belonging (e.g. perceptions of social or academic "fit" with their department)
f. Staff (e.g. academic advisors, program coordinators, administrative assistants, etc)

10. Foreign-Born
(Immigrant/International students and faculty; to be double coded with other themes)

11. Financial Issues
a. Grants/funding
b. Employment
c. Family Resources

12. Mentors
(to code with faculty, peers and staff who provide academic or professional expertise)

13. Science Identity
a. Recognition (e.g. awards K-20; positive feedback from faculty or mentors in STEM field; Peer recognition of their abilities, publications)
b. Encouragement (e.g. verbal affirmation of abilities, others pushing them to succeed)
c. Self-Efficacy (e.g. perception of own abilities and potential, confidence in eventually grasp what's being taught)
d. Skill Development/Mastery (e.g. high scores on tests, familiarity with lab techniques or equipment)

14. Other/Miscellaneous

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