ABSTRACT

BURNETTE, SAMARA FLEMING. Resiliency in Physics: The Lived Experiences of African-American Women Who Completed Doctoral Physics Programs. (Under the direction of Dr. Paul Bitting.)

Currently, little is known about African-American women with doctoral degrees in physics. This study examined the lived experiences of African-American women who completed doctoral programs in physics. Due to factors of race and gender, African-American women automatically enter a double-bind in science, technology, engineering, and mathematics (STEM) fields (Malcom, Hall, & Brown, 1976; Ong, Wright, Espinsoa, & Orfield, 2011) and therefore, they automatically assume risk for attrition when entering into an androcentric and White graduate program in physics. However, literature on educational resilience has never examined how these women make it through to completion in doctoral physics programs. Using an interpretive phenomenological approach, this study is designed to further investigate the lived experiences of African-American women who graduated from doctoral physics programs.

The selected participants included a purposeful sample of five African-American women who had completed a doctorate degree in physics since the 1980s from American doctoral institutions. Data collection consisted of a nine-question background survey, documentation, and semi-structured interviews conducted throughout a one month period. Interviews, lasting no less than 90 minutes, were digitally recorded and transcribed. To ensure validity of findings, triangulation and member checking were utilized.

Within this study, the findings answered four overarching questions. These questions surrounded the lived experiences of the participants and how they initially became interested in physics as well as experiences from their undergraduate years. Also, six doctoral obstacles became apparent. These obstacles included gender, race, autonomy, assertiveness, forming

study-groups, and passing qualifying and defense exams. How participants overcame these obstacles were revealed through four emergent themes surrounding the social and literal meanings of pluralism. These themes emerged from the data that linked the doctoral resiliency of at least three of the five participants and were categorized as: 1) Forming pluralistic peer connections; 2) Acquiring pluralistic laboratory skills; 3) Utilizing pluralistic problem-solving; and 4) Forming pluralistic support connections.

Based on the results of the study, a process paradigm became evident along with three salient conclusions. First, African-American women who want to pursue a doctorate degree must interact with a diverse group of peers and faculty to overcome programmatic challenges, such as the ones previously mentioned. Second, these women must be creative when facing foreseen challenges and utilize strategic problem-solving, even a multi-layered strategy, such as acquiring multiple laboratory skill sets to overcome bias outside of the confines of their doctoral physics programs. Lastly, protective factors have limitation based upon situation and setting. These same protective factors may be unprotecting, or produce negative consequences, if utilized improperly.

Suggestions for future research included more in-depth studies of African-American women in physics. First, researchers may want to explore graduate program resiliency utilizing a larger population of African-American women in physics. Next, research on understanding the role of the NSBP in the retention of African-American women in graduate programs in physics may be insightful. Also, studies may be conducted to explore how African-American women in doctoral physics programs partner with foreign nationals, especially the Chinese, to be successful. Lastly, researchers may want to examine life after acquiring the doctoral degree for African-American women in physics.

Resiliency in Physics: The Lived Experiences of African-American Women Who Completed Doctoral Physics Programs

by
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DEDICATION

This dissertation is dedicated to my parents who instilled in me a love for God, faith as a grain of mustard seed, and a solid work ethic. This document is also dedicated to anyone who ever hoped for something, but had no idea how to attain it.

BIOGRAPHY

Samara Fleming Burnette was born in New Haven, Connecticut, on February 12, 1974. The third child of five in a religious and working-class family, she was taught the importance of keeping God first in everything and having a solid work ethic through daily lessons in a homeschool curriculum. These seminal teachings have remained with Samara throughout her career endeavors and educational pursuits. She was homeschooled until she entered into the sixth grade at Speight Middle School after moving to Wilson, North Carolina.

Once she entered the public school system, she realized that her thirst for knowledge was recognized by both students and teachers. She excelled in public school, receiving academic awards through high school and graduating fourth in her class of 200 students. After graduating from E.T. Beddingfield High School in June 1992, she entered into North Carolina (NC) State University as a political science major, but changed her major twice and finally graduated in less than four years with a Bachelor of Arts degree in English in December 1995. While at NC State University, Samara worked as a work-study student, which inspired a love for the institution.

Upon graduating with her undergraduate degree, she applied for a full-time position with the Office of the Provost. In March 1996, she became the academic policy specialist for NC State University and editor of the Handbook for Advising and Teaching and the Faculty Handbook. During this period, she also was responsible for transitioning many paper-based communications onto the World Wide Web, including 26 university standing committees and

other administrative and ad hoc committees. Samara also worked with the Committee on Committees, which provided oversight to the numerous committees at NC State University. During this time, she continued exploring higher education options until she chose a master's program in public administration in January 2001.

In July 2004, Samara began a new position in the Division of Enrollment Management and Services as the first student retention coordinator for NC State University. After graduating with a Master of Public Administration in December 2004, Samara transferred into a new division in June 2005, but she retained her title in the newly reorganized Division of Undergraduate Academic Programs. She began facilitating the newly formed Advisory Council for the Enhancement of Student Success (ACESS), which was a large institutional council charged by the provost to examine the institutional perspective on student success by bringing together colleges and administrative offices around campus. Though she began taking classes in 2006, Samara was fully accepted into the Educational Research and Policy Analysis program in August 2007. Due to pending budgetary constraints in December 2008, Samara was moved to the Office of Advising Support, Information, and Services (OASIS) for six months in January 2009 after which she enrolled in her doctoral studies full-time under the advising leadership of Dr. Paul Bitting.

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Special thanks go out to friends as well. I especially like to thank Susan Grant for unselfishly editing parts of this dissertation at a moment's notice. You have saved my butt more than once! I would also like to thank Dr. Erin Robinson for her suggestions when preparing for my defense. I cannot forget to thank Dr. Stephanie Freeman for her tireless calls to pray and offer thanks to God for our progress. Girl, God is faithful!!! Also, thanks go out to friends that have inspired me with their doctoral journey or who have cheered me on during my journey: Dr. Frank Abrams, Dr. Thomas Conway, Virginia Howell, Judy Austin, Dr. Jeni O. Corn, Amy Shue Hays, Dr. Jamila Smith Simpson, Dr. Karrie Dixon, Alecia Matthews, Dr. Kelly Laraway, Dr. Makia Tillman, Evelyn Clegg, Jennie LaMonte, Myron and Lottise Murray, Maya and Lennart Arends, Peter Zambito, LaTricia Townsend,

Deborah Harvey Mathes, Dr. K. Renee Horton, and Dr. Willyetta Brown-Mitchell, who inspired me with the idea to research this topic in the first place.

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CHAPTER 1: INTRODUCTION

This study seeks to fill a gap in contemporary research examining the intersection of gender and race in graduate-level physics. The presence, or lack thereof, of women in the science, technology, engineering, and mathematics (STEM) pipeline is concerning to many educational researchers (Hanson, 2006; Hill, Corbett, & St. Rose, 2010; Ong, Wright, Espinosa, & Orfield, 2011; Perna, Lundy-Wagner, Drezner, Gasman, Yoon, Bose, & Gary, 2009). Today, women make up about 20 percent of doctoral recipients in science and engineering, which is substantial progress from 40 years ago (Hill, Corbett, & St. Rose, 2010). However, there is still a substantial amount of progress to be had in graduating doctoral women in these fields, particularly in recruiting, retaining, and graduating African-American women in doctoral physics.

Since the first African-American woman earned a doctoral degree in physics in 1972, fewer than 100 African-American women have followed in her footsteps (Ivie & Ray, 2005; National Society of Black Physicists, n.d.; Physicists of the African Diaspora, 1997). Though African-American women make up a little more than 6 percent of the United States' population, they earn less than 1 percent of the doctoral degrees in physics each year (Ivie & Ray, 2005; NSF, 2011). In their American Instittute of Physics (AIP) report, Ivie and Ray (2005) state that "during the twenty-eight year period [between] 1976 [and] 2003,just 35 African-American women earned PhDs in physics" (p. 17). The current trend for African-American women doctoral physics recipients reveals little hope of reaching parity in the near future. Between 1998 and 2008, 33 African-American women completed their doctoral

degree in physics within the United States (M. Fiegener, personal communication, May 26, 2011). During this same time period, 20 times more African-American women were enrolled in graduate-level physics (NSF, 2012). Though most of these women were no doubt enrolled in masters programs, a little more than 130 earned their master's degrees during this time (NSF, 2012). Consequently, an astounding number of African-American women who enroll in graduate physics programs are not resilient to doctoral completion. However, Ivie (2010) stated it best, "the numbers alone do not adequately portray the day-to-day inequality that women of color experience in physics" (p. 3). Therefore, investigating the lived experiences of these women will more accurately portray the daily inequalities these women face.

The intersection of gender and race automatically inducts these African-American women, and other women of color pursuing STEM fields within the United States, into a double-bind (Malcom, Hall, & Brown, 1976; Ong, 2005; Ong, Wright, Espinosa, & Orfield, 2011). The double-bind, which Ong, et al. (2011) explains as "the unique challenges minority women face as they simultaneously experience sexism and racism in their STEM careers," increases their risk for failure within these fields (p. 175). Malcom, Hall, and Brown (1976) first introduced the "double bind" in a manuscript report subtitled, *The Price of Being a Minority Woman in Science*. The report was summarized in the foreword of the document as follows:

> A small but significant meeting of thirty scientists took place in December 1975. The specialness of this meeting was that for the first time in America, minority women in science, engineering, medicine and dentistry met together

> to discuss their unique position as the most underrepresented and probably over-selected group in the scientific disciplines. These Black, Mexican-American, Native American, and Puerto Rican women were involved in … the "pure" and applied sciences, with a wide range of ages and experiences and diverse backgrounds and cultures, we shared a common bond; and a special and warm sense of sisterhood sprang from this. Generation gaps did not divide us, nor did our varied vocations, nor our cultural diversity. The common ties were those of the double oppression of sex and race or ethnicity plus the third oppression in the chosen career, science. … Our mission … was clear. We wanted to find out how and why we had made it and others had been left behind; how our sisters had handled personal and societal problems from childhood until present. (p. ix)

This report had 70 pages of what participants deciphered were the "reasons for [their] small numbers, relative invisibility, and exclusion from mainstream science" (Malcom, Hall, & Brown, 1976, p. ix). This group also took decided action and "outlined a blueprint for change" (Malcom, Hall, & Brown, 1976, p. ix), but presenters at the 2011 *Harvard Educational Review* summer symposium on "Unraveling the Double Bind," all agree that after 35 years, not much changed regarding representation; however, present obstacles are more subtle in terms of support, competence, and isolation.

Yet, despite the oppression that puts them at risk for failure, a number of these women were successful through completion (Malcom, Hall, & Brown, 1976). Like them,

there are a scant number of African-American women who share in their double bind and are resilient through doctoral completion in physics. This investigation focuses on them, their lived experiences, and any takeaways that will encourage other African-American women to persevere when pursuing doctoral physics.

Therefore, the next section begins this investigation by stating the main tenets of the problem, which is followed by the purpose statement and research questions. The theoretical framework follows these sections to provide the main perspective of this study. Finally, the study's significance and definitional terms are stated.

Problem Statement

African-American women in graduate school face an array of barriers on account of their race and gender. Gender and race bias continues to exist in STEM fields merely on account of the presence of minorities in these fields. According to Malcom (2006), "gender and race bias … is a graduate school reality that has to be managed" either by the student or the department and university (p. 47). Ong (2005) asserts that "physics profoundly contributes to the problem of exclusion" due to the poor ranking of the U.S. in preparing its female high school students for college physics majors (p. 596). Bug (2003) agrees with this assertion and argues that physics is fraught with White androcentric bias due to the exclusion of women and minorities. This exclusion is manifested at every level in physics for African Americans (Nelson & Brammer, 2010). The double-bind substantially decreases the likelihood that African-American women will earn their Ph.D.'s within physics simply on

account of their combined social legacies of disenfranchisement for women and slavery for African Americans in higher education (Arkbar, 1984; Solomon, 1985).

Barriers present on account of the relative absence of African-American women in physics are meaningful to this investigation. These barriers may be in terms of their interest in physics and the general culture of physics (Hanson, 2007; Hazari & Potvin, 2005; Ong, 2002; Ong, 2005). Other barriers are pulled from research on women of color in STEM (MacLachlan, 2006; Malcom, Hall, & Brown, 1976; Ong, et al., 2011) and barriers faced by African-American women in graduate education (Johnson-Bailey, 2004; Patton, 2009). Ong and colleagues (2011) developed a 36-page synthesis of 116 studies on women of color in STEM fields, which updates Malcom, Hall and Brown's (1976) report through providing what is empirically known concerning women of color in STEM fields in graduate and undergraduate programs. They identified "a large number of gaps in the literature" regarding women of color in STEM fields (Ong, et al., 2011, p. 199). In addition to updating past studies, they called for future scholars to examine "institutional characteristics and environments," funding influences, recruitment, retention, and diversity programs for this population, nontraditional pathways through graduate programs, mentoring, social climate, and family roles, among other things (Ong, et al., 2011, p. 199). Though they called for both qualitative and quantitative studies, they specified that these examinations be "more systematic and rigorous" (Ong, et al., 2011, p. 199).

Some researchers surmise the same obstacles present for women in STEM fields are also present for women of color in physics (Budil, et al., 2005; Zastavker, et al., 2009); and

consequently, African-American women in physics doctoral programs may be susceptible to unwelcoming departmental climates due to lack of support and social isolation from their departments, faculty, and peers. Yet, on account of the lack of empirical research in this area, it still may be argued that barriers common to women of color in some doctoral STEM fields may not be attributed to African-American women in physics doctoral programs.

Currently, little can be definitively said about the experiences of women of color in physics, especially at the graduate level. Ivie (2010) confirms that to a large extent, the experiences of women of color in physics are missing from studies regarding women in physics. Of the 116 studies, Ong and colleagues (2011) synthesized, only three empirical studies were identified at the graduate level in the physical sciences. Ivie (2010) acknowledged that she only knew of two researchers conducting research on women of color in areas of inequality in physics: Dr. Maria Ong, of Technical Education Research Centers (TERC), whose work is well represented in this investigation, and Dr. Sharon Fries-Britt, of the University of Maryland, whose recent work relates the educational experiences of African-American women in physics. The newsletter articles, dissertations, conference papers, and NPR transcripts (Budil, et al., 2005; Corley, 2009; Horton, 2010; Ivie, 2010; Ong, 2002; Zastavker, et al., 2009) suggesting that African-American women in physics programs are challenged to succeed are riveting; however, the extant empirical literature is nearly silent on these experiences of African-American women in physics doctoral programs. This current investigation is being done to identify the common or unique barriers present in the lived experience of a few African-American women who managed to succeed in doctoral

physics. Thus, this research will serve as additional verification of known STEM barriers and fill in the gap regarding barriers African-American women experience in doctoral physics programs.

In summary, the problem is that there is little empirical knowledge women of color in graduate STEM fields; consequently, very little empirical knowledge exists regarding how African-American women navigate through physics at the doctoral level to become successful or what critical experiences lead to their resiliency. Research must be done to provide context and detail to the experiences of these women and, if necessary, present resource and support structures for this population. The findings of this study are meant to fill this need.

Purpose of the Study / Research Questions

The purpose of this study is to showcase the lived experiences of African-American women in physics who completed their doctoral degrees. By providing detailed and in-depth description of these experiences, the researcher seeks to shed light on the challenges these women faced when they were enrolled in doctoral physics programs and strategies that they developed or utilized in order to be successful within these programs. In order to do this, the researcher utilizes qualitative phenomenological method with a constructivist worldview, which relates to the relativism of knowledge and meaning that individuals construct as they interact within the world (Creswell, 2009).

Qualitative research is best when striving to provide detailed description (Patton, 2002). Ivie (2010) affirms qualitative methods are best for studying African-American

women, stating that significance "…can only be gathered by studying women physicists of color at a more detailed level, perhaps using in-depth interviews and collecting data on facts other than representation" (p. 3). The researcher has chosen transcendental phenomenology to guide data acquisition and analysis. Creswell (2007) reveals that transcendental phenomenology focuses more on a description of experiences of the participants" than on the researcher's interpretations (p. 59).

Additionally, the goal of this study is to connect aspects of resiliency to the lived experiences of African-American women in these physics programs. Masten (1994) relates that the "rationale for examining resilience phenomena rests on the fundamental assumption that understanding how individuals overcome challenges to development and recover from trauma will reveal processes of adaptation that can guide intervention efforts with others at risk" (p. 3). The researcher hopes to contribute to the understanding of how African-American women experience doctoral physics programs in order to guide future interventions for them in terms of recruitment, retention, and graduation.

Hence, the purpose of this study is to understand and explore the resiliency of African-American women who graduated from doctoral physics programs, while guided by four overarching questions:

1. What are the lived experiences of African-American women who graduated from doctoral physics programs?
2. How do these African-American women who graduated from doctoral physics programs define resiliency?

3. What hindered the resiliency of African-American women who graduated from doctoral physics programs?
4. What facilitated the resiliency of African-American women who graduated from doctoral physics programs?

A theoretical framework of resiliency is also presented to guide how this study will be analyzed.

Theoretical Framework

Carlone and Johnson (2007) emphasized that "the literature about successful women of color in science needs a richer theoretical lens that takes into consideration the complex interplay between structure and agency and the ways these tensions play out over time (p. 1188). For this investigation, resiliency theory accomplishes this purpose. According to Morales and Trotman (2004), in order for resiliency to be present, there must be "obstacles, stress, and conflict" (p. 7). Therefore, there is a complex interplay between a double-bind agency (African-American woman) and a STEM higher education structure (doctoral physics).

Before discussing this framework, assumptions of what it means to be an African-American woman in a doctoral physics program must be brought to the forefront. First, this investigation assumes that African-American women are part of a "double minority" and are at risk in higher education (Jones & Watson, 1990). The second assumption is that participation within unwelcoming White, androcentric, physics environments present obstacles, stress, and challenge to African-American women on account of their race and

gender (Bug, 2003; Czujko, Ivie, & Stith, 2008; Malcom, 2006; Ong, 2005). Moore and Madison-Coleman (2005) argued that African-American women are the most targeted and oppressed group. The third assumption is lack of critical mass in physics at both the peer and faculty level presents tension with acquiring a science identity and puts African-American women at risk for attrition in this field (Carlone & Johnson, 2007; Czujko, Ivie, & Stith, 2008; Ong, 2002; Ong, 2005). With these assumptions revealed, this population aptly qualifies to be studied under the theoretical framework of resiliency. Thus, the risk criteria for this investigation are primarily based upon gender and race, but other risk statuses will not be excluded if they also emerge. For example, low-income students have been increasingly identified as a high-risk population; if financial barriers are present, these will factor into the criteria for risk; but socioeconomic status is not a primary criterion for this study.

Resiliency, defined by Masten, Best, and Garmezy (1990) as "the process of, or capacity for, outcome of successful adaptation despite challenging or threatening circumstances," is composed of internal and external factors (p. 426). Because of the research already done on African-American women in graduate STEM fields, it can easily be deduced that African-American women who participated in doctoral physics programs aptly satisfy criteria for stress and conflict. Empirical studies on this population put them at risk in terms of a variety of environmental protective factors in graduate school. On account of these environmental risk factors, Brown (2008) notes that African Americans are at risk for poor educational outcomes, such as graduation, in comparison to their White counterparts.

Resiliency research first followed a pathology-based model focused on deficits, but evolved into a wellness-based model based on strengths (Benard, 2004; Henderson & Milstein, 2003). This wellness approach now focuses on "competence, empowerment, and self-efficacy" (Henderson & Milstein, 2003). The basic question that comes out of resiliency research is why some individuals from high-risk circumstances or environments succeed while others fail (Thomsen, 2002; Werner & Smith, 1992). A high level of risk must be present for failure; individuals must surmount obstacles, cope with stress, and overcome conflict in order to gain success.

Resiliency is a process; and surmounting educational obstacles requires educational resiliency, which is likewise a process (Morales, 2000). Educational resiliency is defined as the "process and results that are part of the life story of an individual who has been successful, despite obstacles that prevent the majority of others from the same background from succeeding" (Morales & Trotman, 2004, p. 8). Within this process, there are protective factors, which are characteristics that enable students to be resilient (See Table I in Chapter 2).

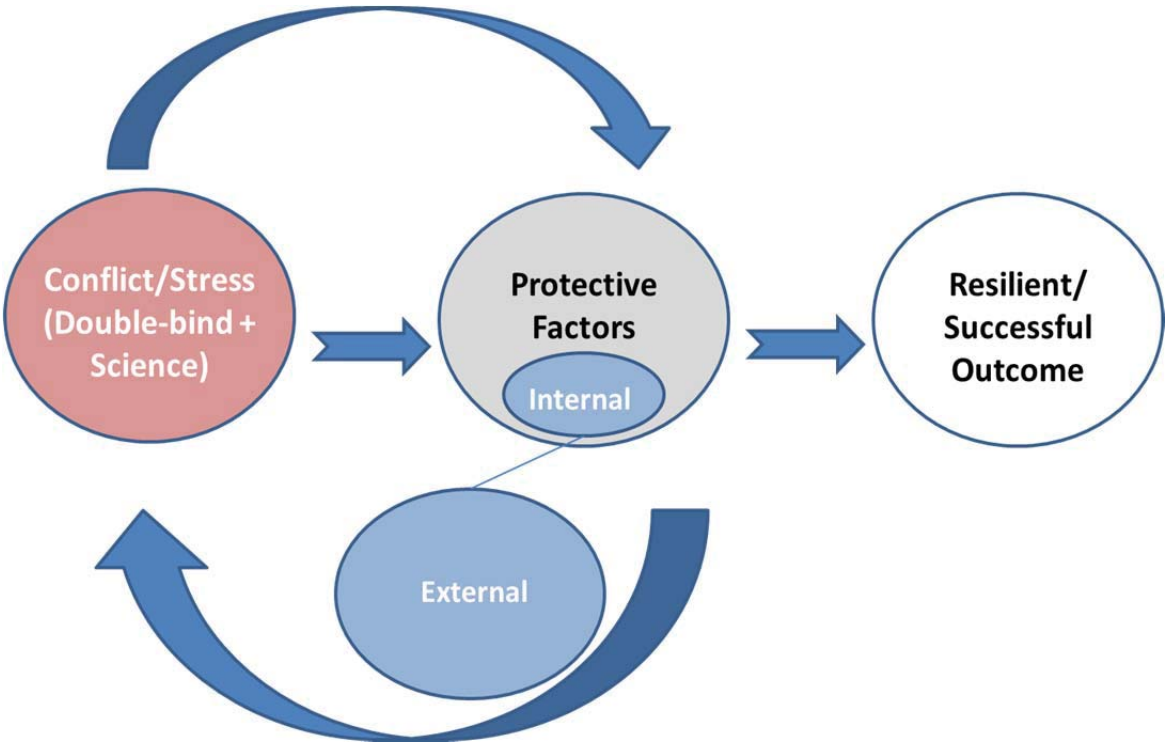

Figure 1: Process of Resiliency

Figure 1 above reveals how this process involves external and internal protective factors. Benard (2004) relates that resilience is a "dynamic and contextual process" where individuals recognize their assets and deficiencies (p. 37). Morales and Trotman (2004) suggests that these assets or deficiencies involve an individual's disposition, family, and environment. Hence, individuals adapt their behaviors to effectively function within a particular environment by utilizing protective factors to overcome conflict and stress. This process is on-going process, initiated by separate challenges that each individual encounters.

How African-American women surmount obstacles, stress, and conflict in doctoral physics programs are the main takeaways of this study.

Significance of the Study

This study has significance relating to theory, research, and practice. Beginning with theory, each of these areas of significance is highlighted categorically as they relate to African-American women who completed doctoral physics programs.

Theory

The use of the resiliency theory is significant to this investigation on doctoral women in physics. The resiliency theory has been used in primary and secondary education, but has rarely been used in postsecondary study (Morales & Trotman, 2004). Although this framework has been used at the postsecondary level, it has yet to be utilized to investigate and study successful African-American women who were resilient in physics doctoral programs. Utilizing the resiliency theory within this higher education classification produces an understanding that resiliency is an on-going process and that anyone can be successful in doctoral physics if they develop and utilize the right protective factors to succeed.

Research

This study is also significant because it will add to the existing body of knowledge on African-American women in physics. Research on the challenges these women face, on strategies they develop to overcome these challenges, and on other aspects of this population of women at the doctoral level in physics are particularly significant given the White,

androcentric dominance of physics. Therefore, this research may begin to provide answers empirically on this population once excluded from mainstream physics.

To date, information on how African-American women wade through the myriad of obstacles in doctoral physics programs is still relatively hidden. Many researchers cite the importance and demand of role models, mentors, and many other forms of support for minority populations (Chubin, 2007; Ivie, 2010; Malcom, 2006; Malcom, Hall, & Brown, 1976; Nelson & Brammer, 2010; Ong, et al., 2011; Zastavker et al., 2009), but often this information is expressed in the aggregate. Hanson (2004) mentions that the difficulty in studying African-American women in STEM fields is that disaggregated information on subset populations are hard to come by. She mentions the "…data are often provided for race groups and gender groups, but not for race/gender subgroups" and "even when subgroups are mentioned, the information provided is often minimal" (Hanson, 2004, p. 97). Consequently, crucial information concerning this population is yet unconfirmed; and this investigation will assist in filling in the gap in this area.

In a similar vein, there are hardly any studies related to African-American women physicists, meaning those who have already completed their doctorates (Czujko, Ivie, & Stith, 2008), and this study will add to this research. Wini Warren (1999), author of *Black Women Scientist in the United States*, concretely expresses that the impetus for her book was the fact that African-American women scientists suffer from "historical neglect" (p. xi). Perna and her colleagues (2009) relate that the study of African-American women in STEM fields is ripe for investigation because of the dearth of research on this population. Based on

this neglect and exclusion in extant research, this study will inform the present literature on African-American women who earned their doctoral degrees in physics.

Practice

How this study informs practice is also significant. First, STEM fields are an important part of the United States' economic success, national security, and scientific leadership in the world (Burke, 2007; Perna, Lundy-Wagner, Drezner, Gasman, Yoon, Bose, & Gary, 2009). Today's global society now includes numerous economic competitors for the U.S. from ever-expanding knowledge markets around the world: Canada, China, France, Germany, Hong Kong, India, Japan, and others (Burke, 2007). With such heightened competition, the U.S. must use all of its human resources to regain dominance in education and economics and to continue to ensure its national security (Burke, 2007; Darling-Hammond & Wood, 2008; Perna et al., 2009). All minorities and, salient to this investigation, African-American women, are among the vital resources currently being underutilized, undervalued, and underrepresented in STEM fields.

Secondly, particularly in physics at the doctoral level, the number of African-American women who have earned their Ph.D.'s remains under 100 since 1972; and there is a need to increase graduate outcomes for this population (Ivie & Ray, 2005; M. Fiegener, personal communication, May 26, 2011). Higher education produces the opportunity for individuals in today's society to increase earning potential and improve the quality of life (Baum & Ma, 2007). Czujko, Ivie, and Stith (2008) contend that completing a doctoral degree provides access to the highly coveted jobs in science, from faculty member to

researcher. Physics graduates learn analytical and problem-solving skills that make them highly competitive for a vast range of employment options, ranging from governmental and industrial labs to Wall Street, which include high-paying jobs even in a slow economy (American Physical Society, 2011). Additionally, they relate that jobs requiring a doctoral science degree "offer a great deal of autonomy and the ability to control one's own research agenda" (Czujko, Ivie, & Stith, 2008, p. 17). These researchers assert that this is especially true in physics because it is generally assumed that a physicist has earned a doctoral degree (Czujko, Ivie, & Stith, 2008). However, equal doctoral graduate outcomes in this field have not yet been achieved for African-American women (Nelson & Brammer, 2010; Czujko, Ivie, & Stith, 2008).

Lastly, increased graduation outcomes for African-American women are crucial in gaining a diverse qualified employment pool for academia (Turner, Gonzales, & Wood, 2008). This is important to the production of African-American women doctoral candidates because this adds to the role models and mentors for this population (Czujko, Ivie, & Stith, 2008; Ivie, 2010; Justin-Bailey, 2004). According to the latest 2010 report by the American Association of University Women, all women are substantially underrepresented within three disciplines: 1) computer science, 2) engineering, and 3) physics (Hill, Corbett, & St. Rose, 2010). They report that though women make up 18 percent of the physical science faculty, the numbers of "women from underrepresented racial-ethnic backgrounds" are often "too low to report" (Hill, Corbett, & St. Rose, 2010, pp. 15, 17). Consequently, a pipeline must be

created which infuses diversity into the physical sciences, and specifically into the field of physics to likely increase the success of other aspiring African-American women in physics.

Definition of Terms

Key terms used throughout this study are defined below, in alphabetical order for quick reference:

At-risk (high risk): populations who are extensions of high-risk populations in the society as a whole – females, minorities, the disabled, and the economically disadvantaged (Jones & Watson, 1990, p. 3).

Double-bind: the unique challenges minority women face as they simultaneously experience sexism and racism in their STEM careers (Ong, Wright, Espinosa, & Orfield, 2011, p. 175).

Educational resiliency: the process and results that are part of the life story of an individual who has been successful, despite obstacles that prevent the majority of others from the same background from succeeding (Morales & Trotman, 2004, p. 8).

Protective factors: influences that modify, ameliorate, or alter a person's response to some environmental hazard that predisposes a maladaptive outcome (Rutters, 1985, p. 600).

Resiliency: the ability or process of remaining *in-tact* in the midst of potentially and often destructive environmental factors (Morales & Trotman, 2004, p. vii).

Chapter Summary

African-American women are scarce in graduate-level physics programs and have not made much progress in securing Ph.D.'s in this field to date. On account of few African-

American women participating and graduating in doctoral physics programs, they no doubt meet a variety of obstacles and experience a great amount of stress. These women quite possibly have no viable network of women who look like them to serve support structures (MacLachlan, 2006; Malcom, 2006; Malcom, Hall, & Brown, 1976; Nelson & Brammer, 2010; Ong, et al., 2011). Despite these challenges, some are resilient. This phenomenon is explored within this investigation. Understanding the resiliency of African-American women who have completed doctoral physics programs will quite possibly lead to interventions that will help build bridges to this field for other aspiring African-American women physicists.

CHAPTER 2: LITERATURE REVIEW

It has only been 40 years since the first African-American woman completed a doctoral degree in physics, but still very little is empirically known regarding their experiences in these programs. Most of the literature regarding their experiences is provided through anecdotal reports, articles, and conference papers. However, current studies that pertain to the African-American women in physics are found at the undergraduate level and these are often aggregated via racial (African Americans) or minority gender group (women of color, minority women, and underrepresented minority women). Also, studies describing the experiences of women of color in science, technology, engineering, and mathematics (STEM) disciplines are pertinent to this investigation as physics is a subset field within this category. In addition to these studies, studies pertaining to African-American women at the doctoral level also provide perspective for this investigation.

Therefore, this chapter will provide a historical backdrop to African-American women in science followed by an overview of the current empirical studies on African-American women in physics. This review showcases an array of information that may determine the persistence of African-American women in physics, such as the numeric landscape of African-American women in physics, the baccalaureate origins of doctoral recipients for this population, and challenges to women of color in science. Following these discussions, a rendering of studies specific to African-American women in doctoral programs will be presented. Lastly, this review will end with the resiliency theoretical foundation, which will provide perspective to this investigation.

Historical Foundation for African-American Women in Science

In her book, *Sisters in Science*, Diann Jordan (2006) presents a concise historical summary of African-American women in American science (See pp. 2-26) along with a timeline of the historical events affecting their presence in these disciplines (See pp. 27-37). Jordan (2006) provides the rationale for the historical introduction by stating, " In order to understand the current plight of black women in the sciences and engineering, it is important to have a historical perspective of how both their race and gender impacted their development in science" (p. 2). Jordan (2006) reveals that historically, on account of their race and gender, the "whole idea of educating African American women before the Civil war was not even entertained" (p. 3).

Jordan (2006) begins her historical account by relating that slavery and poverty provided major barriers to obtaining an education prior to the Civil War. One major barrier significant to slavery was that African-American women were not considered fully human. Lincoln and Mamiya (2003) relate that the United States' Constitution defined African-American women as three-fifths of a human being during slavery (p. 4). Jones (2010) points out lawful disenfranchisements regarding slavery; and she discloses that "all slaves were barred by law from owning property or acquiring literacy skills" (p. 13). Fordham (1993) provides a summary of Davis' 1971 article on *Reflections on the Black Woman's Role in the Community of Slaves* to relate the historical status of the African-American woman:

> …African-American women bring … a history of womanhood that differs from that of white or any other American women. African-American

> women's history stands in striking contrast to that generally associated with white womanhood and includes (1) more than 200 years in which their status as women was annulled, compelling them to function in ways that were virtually indistinguishable from their male slave counterparts; (2) systemic absence of protection by African-American and all other American men; (3) construction of a new definition of what it means to be female out of the stigma associated with the black experience and the virtue and purity affiliated with white womanhood; and (4) hard work (including slave and domestic labor), perseverance, assertiveness, and self-reliance. In other words, the history of African-American males and females includes an extended period when gender differences were minimized, resulting in a kind of "deformed equality" … or, as Cary (1991) describes it, a period when African-American females were "officially" classified as the "neutered 'Other'. " (p. 8)

This status, with its social, economic, and educational origins in America, placed African-American women at a disadvantage even upon Emancipation. Jordan (2006) contends that even after the slaves were freed, "black women still earned little or no wages for farm work and unskilled labor jobs" (p. 2). Thus, on account of their newly found freedom, African-American women were inducted into an oppressive gender-based social order, which caused them to lag behind African-American men in higher education pursuits.

After the Civil War, African-American men managed to gain entrance into the science disciplines. Jordan (2006) highlights the black educational institutions as instrumental to this development. African-American women also entered higher education during this time, but they neither entered science fields nor graduate education.

Though Mary Jane Patterson became the first African-American woman to earn her bachelor of science degree in English from Oberlin College in 1862, it would not be until 1921 before the first three African-American women earned their Ph.D. in economics, English, and German; this is irrespective of the first African-American physician (M.D.), Rebecca Lee, in 1864 (Jordan, 2006). Warren (1999) describes various African-American women earning degrees in medicine in the late 1800s and Jordan (2006) posits that these women were the first to gain a foothold in science. However, Jordan (2006) reveals that the door opened in the 1930s and 1940s for seven African-American women doctoral recipients in biology, botany, chemistry, and mathematics. However, the doors did not fully open for all fields until the 1950s and 1960s, when African-American women began earning bachelor degrees in the various fields traditionally dominated by men. Jordan (2006) states that the African-American women did not begin earning engineering doctoral degrees until 50 years after the first African-American man received his engineering doctorate in 1925.

Mickens (2002) and Malcom (2006) relate that Edward Bouchet was the first African-American man to receive his doctoral degree in physics from Yale University in 1876. Willie Hobbs Moore became the first African-American woman to earn her doctoral degree in physics in 1972 from the University of Michigan at Ann Arbor (National Society of Black

Physicists, n.d.; Physicists of the African Diaspora, 1997). The almost 100 year lag between the two definitely lends credence to the argument that physics is a traditionally male discipline and that African-American women pursuing doctoral degrees are still "pioneers" within these fields (Horton, 2010).

In summary, during the late 19th Century, graduate education was considered "an accomplishment suited for men" (Perkins, 2009, p. 54). African-American women were absent from science fields on account of their historical legacy of slavery and oppressive gender disenfranchisements. This brief historical account provides a backdrop regarding why today's "pioneers" may still face barriers within this field after years of exclusion.

African-American Women in Physics

Following the Civil Rights Movement of the 1960s, African Americans have increasingly gained access to physics, but barriers to their success are thought to be prominent simply because of the low rate of enrollment and completion (Ivie & Ray, 2005; Ivie, 2010; Ong, 2005). Malcom (2006) argues that though focused efforts have increased gender diversity in physics, there is still more work to do in terms of the minority presence in physics. African-American men have taken a substantial lead over their female counterparts in terms of enrollment and completion. This lead is so dramatic that even *The Journal of Blacks in Higher Education* (2001) concluded that "black women … continue to avoid the academic study of physics" (p. 80). Malcom (2006) argues that though women have been making progress in physics for more than 30 years, the numbers of minority women in physics were not affected by the push to bring more women into this field.

The latest enrollment and graduation numbers reveal the dismal presence and success of African-American women in physics. As Hanson (2006) reveals, it is sometimes extremely difficult to acquire adequate information on African-American women in the sciences due to the way these data are often aggregated. In terms of this investigation, acquiring adequate numbers on doctoral enrollment proved to be impossible. The National Science Foundation (NSF, 2008b) graduate enrollment data table (Table 3-2) does not separate the number of African-American women in doctoral physics programs from the number of African-American women in master's physics programs. However, these data tables do break down the numbers of doctoral graduates by race and gender.

NSF enrollment numbers confirm Ivie and Ray's (2005) assertion of the dismal presence of African-American women in physics. At the bachelor level, 1.5 percent of African-American women intended to major in an undergraduate physical science major (NSF, 2008a). Ivie and Ray's (2005) report relate that on average about 56 African-American women out of 3800 students earn their bachelors of science (B.S.) degrees in physics each year within the United States. In physics, African-American men dominate their racial subgroup at the graduate level, outnumbering their female counterparts almost three to one in enrollment (NSF, 2008b). In 2008, 215 African Americans were enrolled in graduate physics programs at doctoral institutions, with 170 African-American males enrolled and only 45 African-American women enrolled (NSF, 2008b). That same year, 15 African Americans earned doctoral degrees in physics, with African-American women earning one-fifth within their racial subgroup (NSF, 2008c). Ivie and Ray (2005) confirm

that African-American women earn less than three doctoral degrees in physics in the United States each year (p. 17). A ten-year trend (1998-2008) by the National Science Foundation of African-American women doctoral recipients in graduate physics by specialized field does not appear to be linear (See Appendix E). Instead, the number for African-American women doctoral recipients fluctuates, reaching a three-year high of five from 2002-2005, and declining back to three by 2008. Coincidentally, between 2000 and 2004, Florida A&M had joined Howard, Hampton, and Alabama A&M in granting doctoral degrees in physics (Czujko, Ivie, & Stith, 2008).

Based upon the above enrollment and graduation facts, it is quite easy to conclude that "in a decade … essentially no progress had been made in the number of African-American … Ph.D. recipients" (Bug, 2003, p. 882). Ivie and Ray (2005) suggest that the low enrollment of women of color in physics is probably based upon their low baccalaureate attainment in physics. Hanson (2004) also contends that though African-American women show an early interest in the sciences, their interest in physics remains substantially low through high school. Ivie (2010) presents a description of the physics pipeline for women of color inclusive of the physics academe:

> At the beginning of the academic pipeline, there is only a trickle of women of color into physics, and the numbers don't improve farther along. For comparison, approximately 5000 people, mostly white male US citizens, earn bachelor's degrees in physics annually. In 2007, only 181 women of color (including Asian American women) earned bachelor's degrees in physics. In

> … 33 years …, more than 35,000 people have earned physics PhDs in the US, but only 111 under-represented minority women have done so. In all 800 physics and astronomy departments in the US …, there are approximately 9100 fulltime equivalent faculty positions, but there are only 29 black women … on physics faculties. (pp. 1, 3)

Ivie (2010) concludes that as double minorities, the experiences of women of color in the academe are likely unique from that of a man's or a White woman's experiences as they "may be subject to inequities in hiring, salary, promotions, etc." (p. 3).

Data presented in Nelson and Brammer's (2010) study affirm Ivie's data for African American faculty. In their study, they indicate that African Americans make up less than 1 percent (0.7%) of the faculty in the top 100 physics departments across the United States, with their highest representation at the assistant professor level (Nelson & Brammer, 2010). A 2008 AIP report on untapped talent showcased that 64 African American faculty members resided in 185 doctoral physics departments in 2004 within the U.S., and of that number, a significant concentration (28) worked primarily at three HBCUs: Hampton, Howard, and Florida A&M (Czujko, Ivie, & Stith, 2008). Czujko, Ivie, and Stith (2008) uncovered that "only 30 other PhD-granting physics departments had any African American faculty members, and most of these had only one" (p. 21).

Consequently, African-American women are absent from departmental faculty rosters in physics (Ivie, 2010; Nelson & Brammer, 2010). Nelson and Brammer's (2010) study showcased that "the number of Black female professors in [the] physical sciences … is near

zero" (p. 16). Their study specified only one African-American woman on the faculty in the top 100 physics departments across the United States in 2007 (Nelson & Brammer, 2010, p. 8). Still, regardless of gender, Mulvey and Nicholson (2006) showcased that underrepresented minority populations account for less than 5 percent of faculty members in the "top 50" U.S. physics departments.

Dearth of Studies on African-American Women in Physics

There are a limited number of empirical studies detailing the experiences of African-American women in physics. Empirical studies of any racial minority in physics programs at any level are likewise extremely limited. Three empirical studies regarding the experience women of color in physics have surfaced within the last decade by two contemporary researchers, Ong (2002; 2005) and Fries-Britt and Holmes (2012). Inclusive of women of color is another empirical study by Fries-Britt, Younger, and Hall (2010), which investigates the experiences of students of color in physics. Ong's (2002) dissertation was part of an on-going study, funded by the National Science Foundation, regarding how women of color form their science identities to succeed in physics programs at a research institution; this study begins this section.

In her dissertation, Ong (2002) longitudinally studied undergraduate women (freshmen, sophomores, junior, and seniors) of color succeeding in physics using social practice theory. Six out of eight of these women of color went on to pursue doctoral degrees in physics. Though this study mostly derives its information from the undergraduate years, Ong (2002) also pulls from their graduate experiences when extending social practice theory

to include the body as a visible and performance aspect within a membership community. Ong (2002) proposes that "the body, as a primary indicator of race/ethnicity and gender, is profoundly used as a source of information for who can do science and how it may be practiced" (Ong, 2002, p. 36). Ong (2002) relates that the body is the medium from which science identities are altered, displayed, and learned. Hence, she utilized race, gender, physics culture, and academic achievements to study her central questions related to why few women of color enter physics and what conditions are present to enable those who achieve degrees to be successful (Ong, 2002, p. 10). She found that by the time women of color graduate from their undergraduate programs, they have experienced "as traditional outsiders, some exclusion, isolation, and aggression" (Ong, 2002, p. 127) through what she terms as follows:

- "Dealing with Gendered Condescension," and "Ventriloquated Thoughts and the Hidden Language of Race in Science," which shows how scientific competence is negated for women of color within the physics discourse;
- "Masking the Female Body," "Appropriating Whiteness," and "Sacrificial Labor and 'Invisible Work'," which display how women of color use fragmentation to succeed in physics; and
- "Performing Masculinity in Speech and Mannerism," which reveals how women of color develop a cultural strategy of multiplicity to combine the dissonance of their identities as women, minorities, and physicists.

Because these elements follow them into their graduate careers, these women of color must "develop the insight necessary to act against" social borders that challenge their success by engaging in strategies, such as fragmentation or multiplicity, to be successful (Ong, 2002, p. 127). Ong (2002) credits "teaching, role modeling, mentoring, and curricular and pedagogical reform" as the enabler of their undergraduate success (p. 127).

Ong (2005), in her eight-year longitudinal study on body projects for women of color in physics, updates her dissertation, and to some extent clarifies it, by examining three realms of "ordinary" within science, gender, and race using body theory. Though her investigation included the same pool of women of color as in her above dissertation, her findings present the progressive process women of color assume to mediate barriers to their scientific competence and membership by performances. Ong (2005) finds that women of color overcome prevalent stereotypes regarding race and gender to persist in the White, androcentric physics field through engaging in bodily projects, which either 1) allow them to approximate "ordinariness through fragmentation" performed via strategies of racial or gendered passing, or 2) allow them to reject these strategies in acceptance of multiplicity of identities which utilize "stereotype manipulation or performances of superiority" (Ong, 2005, p. 593). Ong (2005) suggests that practices of multiplicity may cause self- harm under particular circumstances, but "multiplicity empowers marginalized members more than does fragmentation" (p. 600).

For instance, Kendra, an undergraduate and the only African-American woman in the study, used loudness and humor as performances to succeed in her department. As the only

African-American woman in her department, she often received clues that she did not belong, which led her to reject notions of an ordinary physicist and embrace her multiplicity by her "deliberate self-presentation," which she "performed … through her deliberate self-stylization, including her choice of dressing in Kente cloth, her hairstyle, and even her speech and mannerisms" (p. 607). Ong (2005) relates that Kendra's progressive visual and oratory performances rendered her a spectacle, which garnered the acceptance of her faculty and peers because they saw her as "a recognizable and comprehensible stereotype," which is less threatening to "local membership boundaries in physics" (p. 608). However, Elena, a Latina graduate student, engaged in fragmentation by temporarily modifying both her speech and dress to appear ordinary among her male laboratory peers. In this way, Ong (2005) relates that a woman succeeds in science "by appropriating the masculine behaviors of the science world (i.e., process) communicates to others that she has acquired the "proper" scientist identity" (p. 601).

In their five-year qualitative study with the National Society of Black Physicists (NSBP) and the National Society of Hispanic Physicists (NSHP), Fries-Britt, Younger, and Hall (2010) examined the academic, racial, and social experiences of 110 students of color succeeding (35% women) in undergraduate physics. They had three main findings: 1) interactions with faculty matter; 2) peers make a difference in persistence; and 3) the proving process transitions into graduate study (Fries-Britt, Younger, & Hall, 2010). Students at minority-serving institutions (MSIs) often had positive interactions with faculty than students at predominantly White institutions (PWIs). Undergraduate peers within the physics

programs at MSIs were mostly supportive and helpful, but students attending PWIs had a different experience, especially if the program was large. Smaller programs tended to be more intimate and supportive. However, students of color in graduate physics programs felt that they were in a "never-ending proving process," especially if they came from a HBCU (Fries-Britt, Younger, & Hall, 2010, p. 79). These students revealed that "their enrollment in graduate-level physics programs at PWIs was questioned because of the institutions at which they earned their baccalaureate degree" (Fries-Britt, Younger, & Hall, 2010, p. 79).

Also pertinent to this investigation, Fries-Britt, Younger, and Hall (2010) cited other key findings related to science motivation, parental influence, and exposure to science activities. Students of color developed an early interest in science on account of parents and K-12 teachers who encouraged them to pursue these fields. Some students of color had at least one parent who was a scientist while others had parents who involved them in science activities.

Recently, Fries-Britt and Holmes (2012) performed a five-year qualitative study focusing on the experiences of 39 African-American women (18 undergraduate and 21 graduate students) enrolled in physics programs. Though these African-American women felt as if they were adequately prepared to be successful, they were challenged in establishing connections with faculty and peers, especially male peers. These women reported being intellectually stereotyped as inferior to their male faculty and peers, and at times they perceived the academic or laboratory help from them as "over-compensating or babying," which made them feel less than an equal peer (Fries-Britt & Holmes, 2012, p. 210). They

also desired a connection with female scientists to encourage them and transmit how to successfully navigate through these disciplines. Fries-Britt and Holmes (2012) reveal that female faculty members, especially those few of the same race, "tended to support their interest in science as well as other activities and understood their need to nurture other parts of their lives" (p. 211). Graduate women felt that a balance between their careers, family, and community were important to their success in physics. They were also aware that being an African-American woman in physics was important. Fries-Britt and Holmes (2012) note that these women were "keenly aware of being a scientist and they worked hard to accomplish the important steps that demonstrated mastery as scientists" (p. 212).

A few limitations are present within these studies. First, all of these studies mostly encompass experiences at the undergraduate level. Fries-Britt, Younger, and Hall's (2010) study does not wholly transfer to African-American women, even at the undergraduate level, on account of the racial aggregation of their participants. Though Ong (2002; 2005) clearly specifies ethnicity/race of her participants, only one out of the 10 women of color participating in her study is identified as an African American. These critiques are important to this investigation because they correspond to the striking argument Leggon (2010) makes concerning the inappropriateness of aggregation when studying intersections of race, ethnicity, gender, and science:

> Disaggregating gender by race and ethnicity should not create dichotomous categories, such as women and minority women or women and women of color. These dichotomies suggest that the term women refers to women who

> are non-Hispanic and White. Moreover, the terms minority women and women of color hide important racial/ethnic differences among women. The effects of the confluence of race/ethnicity and gender are greater than the sum of the effects of the individual components. In other words, the results from the intersection of race, ethnicity, and gender are not additive but synergistic: Race/ethnicity influences how gender is experienced, and gender influences how race/ethnicity is experienced. For that reason, race/ethnicity data must be disaggregated by gender, and gender data must be disaggregated by race and ethnicity. (p. 1020)

Though Ong's (2002; 2005) studies involved graduate women of color in physics, none of these women were African-American women. However, Fries-Britt and Holmes' (2012) study specifically examined undergraduate- and graduate-level African-American women in physics, but the study's findings left the reader to distinguished between these classifications. It was also not clear whether the 21 graduate African-American women in this study were doctoral students in physics. These limitations further contribute to a gap in knowledge concerning the experiences of African-American women in doctoral physics programs.

Baccalaureate Origins of African-American Women in Physics

Researchers have supported the claim that HBCUs are important producers of African American doctoral recipients (Chubin, 2007; Czujko, Ivie, & Stith, 2008; Fries-Britt & Holmes, 2012; Joseph, 2007; MacLachlan, 2006; Malcom, 2006). Ong and colleagues (2011) communicate women of color entering STEM graduate programs must be

academically prepared to be successful in graduate school. Preparing for graduate school takes place at the undergraduate level. Though Miyake, Kost-Smith, Finkelstein, Pollock, Cohen, and Ito (2010) reveal physics is challenging at both the undergraduate and graduate levels, Ong and her colleagues (2011) convey that many African-American women have attended supportive HBCUs, which encourage their success in the physical sciences.

In her article on diversity in physics, Malcom (2006) relates that underrepresented minority baccalaureate degree recipients in physics disproportionately originate from HBCUs and Hispanic-serving institutions. In his article on African Americans in doctoral STEM programs, Chubin (2007) revealed that "HBCUs dominate the undergraduate origins of African-American doctoral production" (p. 97). Swail, Redd, and Perna (2003) also noted that though HBCUs only account for 4 percent of the four-year colleges and universities, they have a legacy of educating African Americans that would not otherwise gain access to education and graduate 28 percent of the African-American undergraduates in the United States.

Likewise, in their qualitative case study examining how Spelman College helped African-American women to successfully progress in STEM fields, Perna, Lundy-Wagner, Drezner, Gasman, Yoon, Bose, and Gary (2009) posit that "HBCUs are important producers of African Americans in STEM fields" and that they are even likely to enroll in a graduate program in STEM following their undergraduate majors (Perna et al, 2009, p. 5). These researchers relate that HBCUs instill a strong work ethic into their students, which Hanson (2006) contends is tied to the persistence of African-American women in STEM disciplines.

Perna et al. (2009) found that African-American women attending Spelman College report having positive experiences, which developed in them both a high self-efficacy and self-confidence to compete in science. A student participant within the study summed up the environment at Spelman, by saying, "It is just an environment where you're set up to succeed" (Perna et al., 2009, p. 11). Jordan (2006) also relates that HBCUs nurture the self-confidence of African-American women in science.

Malcom (2006) also suggests that HBCUs, as well as other minority-serving institutions, positively influence student potential, student capacity, learning environment, curricular activities, and expectations. Malcolm mentions that in a 2005 talk-back session with "newly minted African American Ph.D.'s" who were Packard Scholars, the scholars "contrasted the communities of the black colleges with those of their graduate schools and noted that the HBCUs gave them confidence, encouragement, and tangible proof that African Americans could succeed in science" (p. 47). Fries-Britt & Holmes (2012) relate HBCUs as environments where African-American women in physics thrive. These foundational experiences are important to perseverance in science.

In contrast to these positive undergraduate experiences, Joseph's (2007) ethnographic dissertation study of six African-American women graduate students in mathematics and chemistry programs at PWIs found that some African-American women in her study were stunned at the difficulty and challenges that awaited them. She relates that these women thought they had been adequately prepared for the transition from the HBCU to a PWI (Joseph, 2007). Joseph (2007) recounts that, "They did not know that the lack of advanced

courses, the lack of sophisticated equipment at their undergraduate institution, their gender and the color of their skin would place them in a precarious spot in graduate school" (p. 195). Similarly, MacLachlan (2006) found that the African-American women in her study transitioning from HBCUs had difficulties once enrolled at PWIs. Thus, the quality of academic preparation may vary across HBCUs.

A recent study by Czujko, Ivie, and Stith (2008) suggests that HBCUs dominate as physics doctoral producers. They contend that "Alabama A&M …is among the largest producers of African American physics PhDs even though it is relatively new -- awarding its first PhD only about 15 years ago" (Czujko, Ivie, & Stith, 2008, p. 19). These researchers demonstrate the significance of this production by reporting that even "the largest producers of African American physics PhDs averaged less than one per year over three decades"(Czujko, Ivie, & Stith, 2008, p. 19). This information relates to all African Americans in doctoral physics, indicating that those who attend PWIs may be significantly at a disadvantage when pursuing a doctoral degree in physics.

This section reports the overwhelming undergraduate HBCU origins of many African-American women in graduate science. While HBCUs create positive undergraduate experiences for these students, once they transition to PWIs for graduate school, the experience for African-American women may not be as positive. HBCUs are also important to the production of many of the African American physics doctoral recipients. Consequently, Fries-Britt and Holmes (2012) suggest African-American women in physics

may be at-risk for failure in highly competitive, unsupportive, predominantly White environments.

Challenges to African-American Women in Science

This section highlights some main challenges for women of color in science, which may also pertain to African-American women physics. The information from this section is not wholly derived from empirical studies, but some of the information was collected from anecdotal articles, AIP reports, and other sources. Three prominent challenges frequently surface: 1) science identity; 2) isolation; and 3) stereotypes. Connected to these challenges are the challenges of support systems, which Zastavker, et al. (2009) relate are connected to challenges all women encounter in physics. These include an array of barriers, including "unfriendly climate, … absence of role models, … and the intrinsic masculinity of the scientific enterprise" (Zastavker et al., 2009, p. 190).

Science Identity

In examining identity, this review will reveal what seems to be an inherent dissonance between African-American women and their identity with the masculine discipline of physics. Based upon the enrollment numbers in physics at both the baccalaureate and graduate level, it can be safely concluded that African-American women exclude themselves from participation in physics (Czujko, Ivie, & Stith, 2008; Ivie, 2010; Ivie& Ray, 2005; Hanson, 2006; Malcom, 2006). The reason for their self-exclusion, may hinge on how they identify as a physicist. In her study of women, science, and academia, Fox (2001) contends that "in and out of science, women are usually characterized as different from the masculine

norm" and thus "…sense a contradiction … in participating in science" (p. 662). Relating how undergraduate women of color in physics sense their fit and competence in the major, Ong (2005) points to dominate images of ordinary White male scientists, which often effectively discourages many bright and competent women and underrepresented minorities from deeming physics as an option. Ong (2005) posits that "…women of color who pursue science careers often perceive that their corporeal appearances stand at unfavorable odds with their identity claims as scientists;" and she concludes that "being seen simultaneously as ordinary women, minorities, and scientists sometimes requires creative and painfully contradictory practices and performances" (Ong, 2005, p. 596).

Lack of female role models, especially same-race female role models, may highly contribute to the scant presence of African-American women in physics. Malcom (2006) notes that women tend to gravitate into more feminine fields, like biology and chemistry. Both biology and chemistry tend to have a critical mass of women and/or minority women (Hill, Corbett, & St. Rose, 2010). Simmons and Grant (2008) suggest that African-American women in doctoral programs need the support from an African-American female mentor to effectively persist. The ability to see oneself as a physicist as a result of having adequate role models provides credence to Jordan's (2006) contention that "image is everything" and that African-American women share in the responsibility of making themselves visible by tapping into media outlets (p. 22). Jordan (2006) concludes because women in general are not recognized as scientists, African-American women will have more difficulty being recognized as such.

Complementing Ong's (2005) qualitative longitudinal study of how undergraduate women of color view their identities in physics, some researchers have found that women of color succeed in STEM disciplines despite prevalent scientific identities. In their qualitative study examining the science identities of 15 women of color in undergraduate and graduate science, Carlone and Johnson (2007) examined how a basic science identity model, consisting of competence, performance, and recognition, interacts with a student's racial, ethnic, and gender identity to create a cultural production of what a scientist really is. Though Hazari and Potvin (2005) argue that physics has an inherent masculine and cultural bias, Carlone and Johnson (2007) found that successful women of color unconsciously reject the traditional masculine and racial norm of science and actively form science identities for themselves that help them to effectively mitigate the negative barriers they encounter (Carlone & Johnson, 2007). In her dissertation, Ong (2002) addresses how minority women form science identities to be successful. She reveals that women of color who are determined to be successful in physics go well beyond the average male and non-minority undergraduate or graduate student to willingly participate in "a practice of sacrificial labor" (p. 61). She explains that they saw the extra time they invested on homework problems or in the laboratory as compensation for what they lacked as individuals. Ong (2002) contends these sacrificial investments are mostly "invisible" work; and states that:

> These women clocked 13-16 hour days on a regular basis, and much of this work was not publicly advertised or acknowledged, since they hid the extra

> hours they worked and organized themselves to appear as if they are keeping on par with their White male counterparts in the laboratory. (p. 63)

Thus, it seems that women of color intentionally stress themselves to create science identities in physics. However, Ong (2002) notes that this extra investment in physics increased their confidence and their ability to succeed.

Isolation

African-American female physicists have noted their isolation while enrolled in physics program (Corley, 2009; Horton, 2010; Nealy, 2008; Ong, 2002; Ong, 2005). The isolation African-American women experience in physics is common through the other male-dominated sciences of computer science and engineering (Hill, Corbett, & St. Rose, 2010). In a 2009 National Public Radio (NPR) interview, Dr. Shirley Jackson related her experience as being the second African-American woman to earn her doctoral degree in physics within the United States and the first to earn this degree from the Massachusetts Institute of Technology (MIT) located in Cambridge, Massachusetts (Corley, 2009). In this interview, Dr. Jackson pointed to social isolation as the biggest issue of her graduate tenure (Corley, 2009). Other anecdotal reports from science magazines and newsletter articles also relate that social isolation plays a huge part in the experiences of African-American women in graduate school (Nealy, 2008; Horton, 2010).

In *A Fascination for Physics* (Nealy, 2008), Dr. Nadya Mason, an African-American "wife, mother, and master physicist" and "emerging…leader in her field," speaks of her isolation in terms of faculty and peers in her field (p. 26). She states:

> Before you consciously realize it, you are looking for role models around you. …In college you look for people who look like you or act like you or share similar interests as you for affirmation that you are interested in a field where you will be supported and thrive, because others have come before you and thrived. (p. 26)

Though Dr. Mason never found the collegiate mentor she was seeking, she is aware of the importance of being visible to other women of color. She acknowledges that as a faculty member she is now maintaining a high enough profile so that she can connect with other young women in physics. Like Dr. Mason, Dr. Elaine Lalanne, in Horton's (2010) article examining how African-American women are still the "firsts" to earn doctoral degrees from their respective universities, mentions that she also felt isolated in her doctoral physics program for two years until students sharing her cultural distinction joined her program. Dr. Lalanne mentions that her African American adviser, who was also the chair of her department, was "instrumental in [her] success in making it through the program" (p. 4).

The isolation reported in the above anecdotal accounts may directly pertain to the absence of a critical mass of women peers and faculty within physics departments (Flam, 1991). Malcom, Hall, and Brown (1976) contend that an African-American woman who is the only representative of her racial/ethnic group in a graduate program may feel exclusion within that environment. However, many minority women find it hard to connect with their graduate peers (MacLachlan, 2006). Etkowitz, Kemelgor, Neuschatz, Uzzi, and Alonzo's (1994) quantitative study, looking at 30 science departments in the disciplines of biology,

chemistry, physics, computer science, and electrical engineering, also found that a lack of critical mass contributes to the isolation minority women feel within these disciplines. Lott, Gardner, and Powers (2009) affirm why a critical mass for minorities is important: "When students, such as women and students of color, are surrounded by a critical mass of others who are like them, they tend to be retained and finish at higher levels than students who are relatively isolated demographically" (p. 262).

According to Chubin (2007), in graduate-level STEM fields where African Americans may be the only representative of their race, they are often encouraged to take on extra responsibilities. Chubin (2007) contends that African-American students are often burdened with recruiting other African-American students to doctoral programs at predominantly White institutions and they are also disproportionately asked to sit on various committees because of their race. Accepting many of these responsibilities may set them up for failure due to the extended time commitments necessary to complete these duties (Chubin, 2007).

MacLachlan's (2006) qualitative study of 63 ethnically diverse women, including 10 African-American women, participating in STEM graduate education found that one African-American woman felt as if she was always "under surveillance by fellow graduate students" (p. 241). This feeling may lead African-American women to be paranoid regarding their interactions with their peers, which may place them at risk for failure if coping strategies are not developed. Supporting this research, Johnson-Bailey's (2004) study of the experiences of ten graduate level African-American women within the College of

Education at a predominantly White research institution revealed that feelings of self-doubt and isolation were the challenges to their persistence. Their concerns related to not being included in campus activities, being deliberately excluded from formal and informal departmental networks, such as study groups, research projects, opportunities for publication, and social events. Ong et al. (2011) backs up this claim, relating that these supports are necessary to the success of women of color.

In her intro, Jordan (2006) coined the syndrome of "isolation within isolation" (p. 24). She reports that African-American women must create their own system of support because they are isolated from what she terms "mainstream" scientists (Jordan, 2006, p. 24). She writes:

> Some black women scientists must deal with the isolation from "mainstream" scientists and engineers as well as some distance from scientists of her race (black men, for any number of reasons) and of her own gender (white women and other minority women). This leads some black women scientists to experience what I coin as an "isolation within isolation" syndrome. (p. 24)

Thus, Jordan argues that even when African-American male counterparts are present within a STEM field, they may not fill the isolation void, but contribute to it.

Isolation may be on account of the competition for graduate resources within some STEM departments. Chubin (2007) also relates that sometimes departmental politics encourage a competitive spirit that is hazardous to the success of the few African Americans within STEM graduate programs. This type of competition may, as Chubin (2007) argues,

pit minority peers against one another for funding and mentorship. Dean and Fleckenstein (2007) maintain that supportive peers are crucial to success in STEM disciplines, especially within the graduate environment, and Mwenda (2010), in her dissertation on minorities in STEM doctoral programs, adds that "peers provide implicit knowledge that [minority] students need to navigate departmental requirements and culture" (p. 31). Thus, isolation may be the greatest barrier to the experience of African-American women in doctoral science programs.

Stereotypes

In her longitudinal study on 10 women of color in physics, Ong (2005) relates that the experiences of African-Americans and women create vulnerability in their perception of being judged according to prevailing societal stereotypes. The culture of physics is inherently masculine (Hazari & Potvin, 2005; Ong, 2005). Miyake, et al. (2010) describe physics as a challenging subject for undergraduate and graduate college students. They cite that "learning the [physics] material in lectures and textbooks and demonstrating understanding on exams put substantial pressure on students," which very often produces the stereotype that men excel women at math and science (Miyake, et al., 2010, p. 1235). Adding to this stereotype, Ong (2005) indicates that there is a prevalent belief that "blacks and women have inferior intellect" (Ong, 2005, p. 603).

In her book, *Why Are All the Black Kids Sitting Together in The Cafeteria?" and Other Conversations About Race*, Beverly Tatum (2003) also states that "Blacks have historically been characterized as less intelligent than Whites, and women have been viewed

as less emotionally stable than men" (p. 23). In a later book, *Can We Talk About Race? and Other Conversations in an Era of School Resegregation*, Tatum (2007) points out heredity arguments of intelligence have deeply influenced the American educational system and have had a psychological impact that is often manifested in student behavior. She states:

> Some African American students may have come to believe that high academic achievement in school is territory reserved for White students. Certainly the curriculum, devoid of Black role models, and the demographics of the tracking pattern in many schools, heavily skewed in favor of White students, would support that conclusion. Some African American students may actively choose to distance themselves from "White" behaviors, meanwhile embracing "Black" behaviors as defined by the popular culture as an expression of "authentic "Blackness," for example, behaviors that may run counter to school success. (Tatum, 2007, p. 58)

Tatum follows this argument with how an awareness of societal assumptions can lead to the debilitating phenomenon of stereotype threat, which is defined as "the threat of being viewed through the lens of a negative stereotype, or the fear of doing something that would inadvertently confirm that stereotype" (Steele, Reisz, Williams, & Kawakami, 2007, p. 163).

Steele and Aronson (1995) performed four studies to examine stereotype threat for African American college students. In this study, they defined stereotype threat as "being at risk of confirming, as self-characteristic, a negative stereotype about one's group" (Steele & Aronson, 1995, p. 797). Participants included African-American and White Stanford

undergraduates, taking a timed test (25-30 minutes) from the verbal Graduate Record Examination (GRE), under three testing conditions. Two conditions were not race-prime, but one condition was described as a "diagnostic of intellectual ability, thus making the racial stereotype about intellectual ability relevant to Black participants' performance and establishing for them the threat of fulfilling it" (Steele & Aronson, 1995, p. 799). In three of these studies, the timed tests were followed by a version of the Spielberger State Anxiety Inventory (STAI), which had been adequately researched to detect anxiety. Steele and Aronson found that for African-American students the race-prime "evaluative pressure [of] stereotype threat causes an impairment of both accuracy and speed of performance" due to self-doubt, stereotype avoidance, and self-handicapping (p. 802). What Steele and Aronson (1995) suggest is that for African-American students, there is both an individual and a collective self, which may heighten their self-awareness when performing in classrooms, particularly at predominantly White campuses because they see themselves as representative of the abilities of African Americans in general instead of abilities uniquely their own (Steele & Aronson, 1995). They conclude that collectively, "these experiments show that stereotype threat—established by quite subtle instructional differences—can impair the intellectual test performance of Black students, and that lifting it can dramatically improve that performance" (Steele & Aronson, 1995, p. 808).

Supporting Steel and Aronson's (1995) findings, Ong (2005) reveals that "women of color who persevere in physics … [take] action to disprove stereotypes that call into question their scientific or academic competence" (p. 603). While Ong's study involves women of

color mostly in undergraduate physics, this threat can easily be transferred to the masculine enterprise of graduate-level physics (Perkins, 2009). Souto-Manning and Ray (2007) also supports that graduate education, which is the "traditional academic scholar-in-training" is "constructed as white, male, middle-class, childless, or married with minimal childcare responsibilities" (p. 286). Thus, stereotype threat may be compounded in graduate education and scientific disciplines due to the androcentric nature of both enterprises.

Jordan (2006) confirms that the legacies of African-American women regarding slavery and their exclusion from educational pursuits may lead others to negatively perceive African-American women in science. MacLachlan's (2006) study also revealed that women of color reported feeling as if they didn't belong in their graduate programs even more than their White female counterparts. Johnson-Bailey's (2004) narrative study on African-American women in graduate programs at a major research university found that they "continuously struggled with the issue of whether or not their work was as good as that of White students" and that interactions with faculty or peers often made them second-guess their abilities (p. 342). Consequently, African-American women in physics may be vulnerable to negative assumptions of their intellectual and biological abilities due to mainstream beliefs.

Still other stereotypes exist specifically concerning African-American women. Fordham and Ogbu (1986) found that African-American women are an oftentimes distinguished as loud, which is considered a masculine characteristic. In a predominantly White environment, loudness may even be construed to mean other things. According to

Cousins (1999), within the educational environment, being loud may connote "licentiousness, social backwardness, and a general lack of appropriate values and taste, especially when this behavior was practiced in public," and even more so when done in the company of mainstream culture (p. 308).

Support Systems

Ong and colleagues listed three main support systems that must be in place for women of color to persevere in STEM graduate programs. These supports systems include family support, faculty support, and peer support. Monetary support was also listed as it directly relates to persistence in STEM fields.

Family Support. Ong and her colleagues (2011) relate that family support is important to the persistence of graduate women of color in STEM programs because they instill a strong religious and emotional means to overcoming adversity. MacLachlan (2006) also relates that the women of color in her study "enjoyed very strong support systems provided by their families, including parents with virtually no education who sustained them through school" (p. 239). Hanson (2007) contends the "high positive self-concept found among minority youth under conditions of economic and social oppression is based in a distinctive minority community, church, and family system that has historically provided a positive support system and encouraged children to be positive and proud" (p. 28). Hanson (2007) also reveals that African-American women are raised in families that encourage them to be assertive and confident in order that they not be stifled by prevailing chauvinistic sex roles in employment.

As mentioned by Fries-Britt, Younger, and Hall (2010), family is also often the first to instill an interest in science. Hanson (2007) points out using qualitative and quantitative data from the Knowledge Networks panel that African-American families may instill an independent spirit within their children that allows "young women to go into an area where so many of them do not feel welcome" (p. 24). Fries-Britt, Younger, and Hall (2010) contend that parents introduce their children to science activities and encourage their resilience in these activities. Hanson (2007) found African-American women were influenced by encouraging words and efforts to make science fun. Thus, though families may not be scientifically inclined, they may be able to encourage strong character traits in their daughters as well as instill a strong work ethic and interest in STEM disciplines.

Faculty Support. Positive relationships with faculty are crucial in graduate programs. In his article regarding African American graduate students in STEM programs, Chubin (2007) relates that "role models matter " for African Americans in graduate education (p. 99). "For women of color doctoral students in STEM, their mentors often played important roles in women's decisions to attend graduate school, choose a particular doctoral program, and/or to stay or leave their programs" (Ong, et al., 2011, p. 27). In her study on women of color in graduate STEM programs, MacLachlan (2006) found that graduate mentorships enabled women of color to both be successful and professional through encouraging independence and self-reliance, which is helpful to developing confidence.

Mentors are important because Grant and Simmons (2008) assert that African-American female faculty members are in demand as mentors for graduate African-American

women within any discipline, but especially those which are traditionally male-dominated. However, Ong and her colleagues (2011) affirm that "all women of color … are severely underrepresented as STEM faculty, particularly at the associate and full professor ranks" (p. 189). In fact, in their qualitative study examining the perceived effects of gender on faculty interactions by female graduate students in upper- and lower-level graduate programs, Schroeder and Mynatt (1993) found that the supporting and nurturing atmosphere provided by female major professors and also the quality of interaction were instrumental regarding the retention and post-graduation success of female students regardless of race.

As stated in previous sections of this dissertation, African Americans are scarce on physics faculties. It is highly likely that "most physics students of all races will never see an African American physics professor in the classroom" (Czujko, Ivie, & Stith, 2008, p. 21). Consequently African-American graduate students may never be connected with an African American mentor regardless of gender. This may highly affect their ability to succeed in physics, especially if their undergraduate origins were at an HBCU.

Peer Support. Having supportive peer relationships is pertinent to persistence, but most women of color lack a true connection to their peers in graduate STEM programs. MacLachlan (2006) reveals that over half of the women of color in her study wished they had known how to interact effectively with their male peers. She reports that women of color in STEM graduate programs associated problems with racism and sexism with male graduate colleagues. In fact, the African-American women in her study did not feel at ease with their fellow graduate students (MacLachlan, 2006). Joseph's (2007) study confirmed this

revelation when she found that especially in "predominantly White" graduate programs, African-American women felt that "meeting people and finding their place in the department was difficult" and took a great deal of effort (p. 195). Fries-Britt and Holmes (2012) related that African-American women within predominantly White environments, saw them as "more competitive, where students cluster into groups and were less inclined to offer assistance to one another" (p. 209). Chubin (2007) article suggests that African-American women in doctoral STEM programs at PWIs often seek out fellow members of their racial group to study with and exchange course notes. He shares how two African-American females within a graduate STEM classroom utilized the strategy of divide and conquer, which was to intentionally separate into different study groups and bring information back to each other, in order to fill in gaps and understand difficult course material. Thus, peer support may also challenge African-American women in doctoral physics programs.

Monetary Support. Like many of the other tenets of this investigation, not much research has been done in the area of women of color participating in STEM disciplinary areas and funding. In the empirical synthesis section on graduate studies, Ong and colleagues (2011) related the works of Hall (1981), Brown (1995), and Sosnowski (2002) that women of color indicate a high need for financial aid but may be unsure of the application processes, and that they are often discriminated against in fellowship rankings. This follows Malcom, Hall, and Brown's (1976) conclusion that financial support is important and that women of color should be made aware of them and how to apply for them.

In a recent dissertation examining the role of financial support and relationships with faculty and peers for minority students in STEM doctoral programs, Mwenda (2010) found that most minority students are offered fellowships combined with teaching and research assistantships and loans. In her study, Mwenda's (2010) data was inconclusive regarding which financial support packages were more effective for retention in graduate school. Instead, fellowships and teaching and research assistantships seemed to provide a connection to the graduate program; and fellowships offer networking opportunities which may be more meaningful latter on due to opportunities to present at outside networking events, such as conferences (Mwenda, 2010).

African-American Women in Doctoral Programs

Also pertinent to African-American women who participated in doctoral physics are studies relating the experiences of African-American women in doctoral programs regardless of major. These studies relate challenges that may also pertain to African-American women in physics through showcasing support system challenges at this classification, identity challenges, and challenges concerning isolation. Though no direct tie exists to doctoral physics, these studies also provide perspective into how African-American women cope in doctoral programs despite these challenges.

Johnson-Bailey (2004) study of the experiences of ten graduate level African-American women within the College of Education at a predominantly White research institution revealed that feelings of self-doubt and isolation were the challenges to their persistence. Their concerns related to not being included in campus activities, being

deliberately excluded from formal and informal departmental networks, such as study groups, research projects, opportunities for publication, and social events. Many African-American women in Johnson-Bailey's (2004) study revealed that they were not satisfied with their advisers, who are faculty that are assigned to them. These students reported that at times they were misadvised by their departmental advisers regarding when to take certain courses. They revealed that if they had followed the course selection advice given by these advisers within their first year of graduate school, then they would have failed to persist within the program due to the difficulty of the course content.

In her qualitative study, Patton (2009) examined the unique mentoring experiences of eight African-American graduate women in predominantly White college environments. Each participant recognized the need for a mentor, especially an African-American female mentor because of the collective or common bonds between their perspectives (Patton, 2009). This finding related to their ability to trust and relate to the mentor as a member of the family. Most of these African-American doctoral graduate students likened their African-American female mentor to their mothers or family members (Patton, 2009). Another finding was that when departmental mentors did not fit the ideal mentor description, then an external mentor from the family, soror community, or church would be enlisted to aid in psychosocial support and encouragement (Patton, 2009). Interestingly, this study encompassed a range of academic disciplines, including business, education, humanities, law, and science; but only the science graduate student indicated that she neither had a

departmental mentor or an African-American female mentor. A limitation to this study is that Patton does not give any indication of how this student faired through degree completion.

Resiliency Theory

The resiliency theory is used in this investigation to relate the experiences of African-American women physics doctoral recipients. Masten, Best, and Garmezy (1990) define resiliency as the "process of, or capacity for, outcome of successful adaptation despite challenging or threatening circumstances" (p. 426). Resiliency was also defined by Morales and Trotman, (2004) as the "ability or process of remaining *in-tact* in the midst of potentially and often destructive environmental factors (p. vii). In the last 20 years, resiliency has evolved from a pathology-based approach into a wellness approach, focusing on "competence, empowerment, and self-efficacy" (Henderson & Milstein, 2003).

The basic question that comes out of resiliency research is why some individuals from high-risk circumstances or environments succeed while others fail (Thomsen, 2002; Werner & Smith, 1992). In order for resiliency to be present, there must be "obstacles, stress, and conflict" (Morales & Trotman, 2004, p. 7). A high level of risk must be present for failure; individuals must surmount obstacles, cope with stress, and overcome conflict in order to gain success.

In higher education, there are already predefined at-risk populations. Even if these groups do not self-identify as at-risk or high-risk, these populations are thought to be at risk as a direct result of the social legacies that accompany them within the United States. According to Jones and Watson (1990), populations who are at-risk or high-risk in higher

education are extensions of high-risk populations in the society as a whole – females, minorities, the disabled, and the economically disadvantaged" (p. 3).

African-American women are at risk due to their socio-historical legacies of slavery and disenfranchisement. Though the yoke of both of these legacies have lawfully been released since the mid to late 19th Century, these legacies have lingered in educational fields, historically dominated by men within the United States (Adair, 2002; Glazner-Raymo, 2002; Glazner-Raymo, 2008; Jordan, 2006). In general, African Americans are at risk for poor developmental outcomes in comparison to their White counterparts (Brown, 2008). African Americans are more likely to confront poverty, reside in underprivileged neighborhoods, lack substantial financial resources, and more likely to suffer from health problems (Brown, 2008; Taylor 1994). Thereby, societal extensions of being both a minority and a female appropriately constitute an at-risk population for African-American women because of inherent discrimination regarding gender and race.

Educational Resiliency

Morales and Trotman (2004) transitioned the resiliency framework to higher education by focusing on the educational resiliency of 19 low-income African-American and Hispanic exemplary students, as they transitioned from high school to college. Educational resiliency is defined as the "process and results that are part of the life story of an individual who has been successful, despite obstacles that prevent the majority of others from the same background from succeeding" (Morales & Trotman, 2004, p. 8). They utilize the resiliency cycle model, which is based upon an undergraduate student success model known as the

Personal Academic Cycle for Excellence (PACE) method, which is part of a student's academic resiliency, meaning "academic achievement in the classroom by students who fit *vulnerable* criteria," (Morales & Trotman, 2004, p. 9). Educational resiliency of students is often based upon their academic resiliency, which creates milestones of success per course taken.

Protective Factors

Researchers relate that individuals utilize protective factors to overcome conflict and stress (Benard, 2004; Morales & Trotman, 2004). In a survey of resilience research for over the past 20 years, Benard (2004) relates the proactive factors of caring and support, high expectations, and participation or contribution. She also connects personal aspects of social competence, problem-solving, autonomy, and sense of purpose as protective factors (Benard, 2004). Written from a practitioner's lens of what educators can do to enhance the resiliency of their students, Thomsen (2002) posits resiliency is both constitutionally and environmentally cultivated. These factors of success are influenced by three components. Morales and Trotman's (2004) resiliency study of undergraduate students of color notes that disposition, family, and environment serve as a triad of components to analyze the lives of high risk students with respect to their academic achievement, regardless of negative background factors. Brown, D'Emidio-Caston, and Benard (2001) confirm that dispositional individual attributes could be "enhanced with the proper environment" (p. 16). Thomsen (2002) contends that "[a]s educators, it is our responsibility to assist students in finding their

own strengths and recognizing their own resilience so that, when faced with life's challenges, they can draw from them" (p.171).

Protective factors are characteristics that enable students to be resilient through utilizing them as strongholds. Brown, D'Emidio-Caston, and Benard (2001) relate that connections within family and environment are the main source of advice and assistance for at-risks students. They reveal that "authentic sustained contact … properly acknowledges the value of caring as an explicit part of learning and developing" (Brown, et al., p. 49). This connectedness to the support of others is the key in developing or facilitating resilience; and thus "relationships are the medium for supporting thriving development" (Brown et al, 2001, p. 17).

In their book on resiliency in schools, Henderson and Milstein (2003) create a profile of an academically resilient student. This student is adept at decision-making, comfortable in the learning environment, caring, and involved. This student follows rules and encourages others. This student is also connected to at least one caring adult. Henderson and Milstein (2003) purport that above all these, the student must possess a high degree of "hopefulness" (p. 30). These factors make up the profile of what resilient students possess in their lives as they rise above negative circumstances to be successful in their academic lives. All in all, these studies suggest that individuals use internal and external protective factors as strongholds to success (see Table 1).

Table 1

Internal and External Protective Factors

Internal Protective Factors: Individual Characteristics that Facilitate Resiliency	Environmental Protective Factors: Characteristics of Families, Schools, Communities, and Peer Groups that Foster Resiliency
1. Gives of self in service to others and/or a cause	1. Promotes close bonds
2. Uses life skills, including good decision making, assertiveness, impulse control and problem-solving	2. Values and encourages education
3. Is sociable; has the ability to be a friend and form positive relationships	3. Uses high-warmth, low-criticism style of interaction
4. Has a sense of humor	4. Sets and enforces clear boundaries (rules, norms, laws)
5. Has an internal locus of control	5. Encourages supportive relationships with many caring others
6. Is autonomous; independent	6. Promotes sharing of responsibilities, service to others, "required helpfulness"
7. Has a positive view of personal future	7. Provides access to resources for meeting basic needs of housing, employment, health care, and recreation
8. Is flexible	8. Expresses high and realistic expectations for success
9. Has the capacity for and the connection to learning	9. Encourages goal setting and mastery
10. Is self-motivated	10. Encourages pro-social development of values and life skills
11. Has personal competence	11. Provides leadership, decision making, and other opportunities for meaningful participation
12. Has self-worth and self-confidence	12. Appreciates the unique talents of each individual

Source: Henderson & Milstein (2003), p. 18, edited

The Resiliency Process

Resiliency is process-laden. Benard (2004) transmits that resilience is a "dynamic and contextual process" where individuals recognize their assets and deficiencies (p. 37). In his study on the resiliency of undergraduate female students of color, Morales (2000) notes educational resiliency is also a process. In their book on students of color, Morales and Trotman (2004) argue protective factors present in resiliency literature have not focused on "specific processes by which the factors result in outstanding academic achievement" (p. 4). Morales & Trotman, (2004) describe an educational resiliency process encompassing a student's external and internal protective factors. These protective factors involve an individual's disposition, family, and environment, which allow a student to be successful (Morales & Trotman, 2004). Werner and Smith (1992) further support the process of resiliency by relating that "resilience is the response to a complete set of interactions involving person, social context, and opportunities" (p. 89).

Morales (2000) created a model from his examination of five minority Dominican American students from low socioeconomic backgrounds at New York University. Morales' (2000) study was qualitative and his population consisted of three females and two males. This model is an individualized process model that relates not only why but how high-risk students become successful in their educational pursuits. Morales (2000) describes the need for the resilience process model as essential to understanding the operation, sequence, and origins of resilience in students.

The sequential and cyclical nature of the resilience process has not received a great deal of attention in the resilience literature (Morales, 2000; Morales & Trotman, 2004). Morales (2000) conveys that this is because most resilience literature limits its focus to the identification of protective factors and does not thoroughly explore the process by which the protective factors lead to resilience. Morales (2000) posits that in order to acquire a thorough understanding of how protective factors operate, it is essential to pay close attention to "their sequence, their origins, and how they work with each other" (p. 18). Morales (2000) introduces the Resiliency Cycle, a five-step process that exhibits how students develop their resiliency:

1. The student realistically and effectively identifies/recognizes her or his major risk factors.
2. The student is able to manifest and/or seek out protective factors that have the potential to offset or mitigate the potentially negative effects of the perceived risk factors.
3. The protective factors work in concert to propel the student toward high academic achievement.
4. The student is able to recognize the value of the protective factors and continues to refine and implement them.
5. The consistent and continuous refinement and implementation of protective factors, along with the evolving vision of the student's desired destination,

> sustain the student's academic achievement as new academic challenges present themselves. (p. 11)

This five step process has not yet been transitioned to doctoral resiliency in physics. This study will utilize some steps within this process as a way to analyze the lived experiences of African-American women who graduated from doctoral physics programs.

Chapter Summary and Limitations

This chapter relates the historic legacy of African-American women in America and it also presents the reasons for their lag in doctoral physics programs. The current numeric landscape of African-American women was also discussed to show how scarce the presence of this population is in physics. Many African-American women finishing doctoral degrees in physics originate at HBCUs, which may increase their confidence to succeed but may lead to other challenges once these women enter predominantly White graduate environments, especially as African-American women often have unique experiences in graduate programs.

This chapter also related resiliency theory and how internal and external protective factors enable success. Success is often not instantaneous. Instead, success often comes through a cyclical process that entails identifying strengths and weaknesses and implementing strategies to become successful. Therefore, resiliency theory is utilized within this investigation to understand the success of African-American women who complete doctoral physics programs.

A major limitation of this literature survey is that few studies exist that simply focus on African-American women in doctoral physics programs. Instead, aggregation often

confounds their unique experiences in contemporary literature. Even though this survey of both empirical and non-empirical works is extensive, it primarily focuses on women of color in physics. When African-American women are the main focus, disaggregating graduate classification was a major problem. All of this points to a gap in available research and the need for more studies on African-American women in doctoral physics.

CHAPTER 3: METHODOLOGY

Within the United States, less than 100 African-American women have graduated with their doctoral degrees in physics since 1972. Extant literature is silent on how this population has managed to succeed despite persistent barriers in this highly White and androcentric field. The purpose of this phenomenological study is to understand the resiliency of African-American women who have completed doctoral physics programs. The research questions that guided this study were as follows:

1. What are the lived experiences of African-American women who graduated from doctoral physics programs?
2. How do these African-American women who graduated from doctoral physics programs define resiliency?
3. What hindered the resiliency of African-American women who graduated from doctoral physics programs?
4. What facilitated the resiliency of African-American women who graduated from doctoral physics programs?

This chapter describes how this study was conducted. The following sections present the design of the study, sample selection, data collection and analysis, issues of validity and reliability and the researcher's biases and assumptions as related to African-American women and their participation in doctoral physics programs.

Design of the Study

Within the past 20 years, qualitative research has gained prominence in research studies in the humanities and social sciences (Merriam, 2009). The philosophical underpinnings of qualitative research are connected to one's epistemological assumptions, meaning "assumptions about the nature of knowledge, truth, and methods that generates claims of knowledge and truth," ontological assumptions, meaning "what we take to be real and our way of being in and relating to the world," and axiological assumptions, or "what we value as reality, knowledge, and truth" (Piantanida & Garman, 2009, p. 8). Researchers who engage in qualitative research reject postpositivist deterministic notions of an objective reality and accept social constructivist views of reality based upon multiple perspectives, interpretation, and interaction (Creswell, 2009). Thus, qualitative inquiry allows researchers to explore and understand "the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2009, p. 4).

Qualitative researchers do not explore and understand meaning by adhering to the scientific procedure. Instead, qualitative methods are distinguished by three procedures for data collection: "(1) in-depth, open-ended interviews; (2) direct observation; and (3) written documents" (Patton, 2002, p. 4). These procedures facilitate a deep excavation beneath surface understandings of phenomena to allow for "voluminous raw data" that can be organized into "major themes, categories, and illustrative case examples" (Patton, 2002, p. 5). These procedures are often combined within a single study to establish its validity through triangulation.

While qualitative studies often use the same data collection methods, there are varying methodological traditions within qualitative inquiry. Patton (2002) related theoretical, pragmatic, and practical perspectives that inform qualitative inquiry. Creswell (2007) explored five theoretical perspectives (i.e., narrative research, phenomenology, grounded theory, ethnography, and case studies), which he termed approaches; while Merriam (2009) explored six "designs" (i.e., basic qualitative research, phenomenology, grounded theory, ethnography, narrative analysis, and critical qualitative studies). Merriam (2009) acknowledged that these "types of qualitative research" have "somewhat different focus, resulting in variations in how the research question might be asked, sample selection, data collection and analysis, and write-up" (p. 22).

Phenomenology

Phenomenology is a 20th century philosophy highly influenced by the German philosopher Edmund H. Husserl (Merriam, 2009; Moustakas, 1994; Patton, 2002). Patton (2002) revealed that phenomenology to Husserl meant "the study of how people describe things and experience them through their senses" (p. 105). Moustakas (1994) expressed that Husserl believed that all scientific knowledge was predicated on internal evidence, which must be acquired through intentionality, intuition, and intersubjectivity. Thus, Husserl's epistemological assumptions involved "the experiencing person and the connections between the human consciousness and the objects that exist in the material world" (Moustakas, 1994, p. 43). His more concise assumption as Patton (2002) put it was that "we can only know what we experience" (Patton, 2002, p. 105).

This philosophy ascribes a person's understanding primarily to sensory experience, which afterward must be described, explained, and interpreted in order for meaning to develop (Patton, 2002). Hegel (as cited in Moustakas, 2009) defined phenomenology as "knowledge as it appears to consciousness, the science of describing what one perceives, senses, and knows in one's immediate awareness and experience" (p. 26). Consequently, realities are derived from internal perceptions of ones lived experience and are the only "pure phenomena" (Groenewald, 2004, p. 4). Perceptions govern feelings, images, past meanings, and present experience (Moustakas, 1994).

Moustakas (1994) explained that individuals "bring to consciousness fresh perspectives, as knowledge is born that unites the past, present, and future and that increasingly expands and deepens what something is and means" (Moustakas, 1994, p. 53). Consciousness becomes "an absolute reality while what appears to the world is a product of learning" (Moustakas, 1994, p. 27). Within this consciousness, intentionality is central as it represents a reciprocal dependence of subject and world (Crotty, 1998). Crotty (1998) suggested that "objectivity and subjectivity need to be brought together and held together indissolubly" (p. 44). Thus, intentional interactions with the world evoke meaning for individuals.

Eichelberger (1989, as cited in Patton, 2002) suggested that though an individual's unique experiences are regarded as truth, the "philosophical basis of phenomenology … assumes a commonality in … human experiences and must use rigorously the method of bracketing to search for those commonalities" (p. 106). Patton (2002) offered another

phenomenological assumption that "there is an essence or essences to shared experiences" (p. 106). Researchers seek to understand experiences at a greater level of meaning than what can be derived from individual consciousness (Patton, 2002).

Phenomenological Method

Based upon the foundational question regarding the "essence of lived experience" for African-American women who successfully completed doctoral physics programs, the current investigation utilized phenomenology (Moustakas, 1994; Patton, 2002). Patton (2002) related the method "focuses on descriptions of what people experience and how it is that they experience what they experience" (p. 107). Creswell (2009) explained that "understanding the lived experiences marks phenomenology as a philosophy as well as a method" (p. 13). Merriam (2009) contended that phenomenology can be used as a method or tool to "depict the essence or basic structure of experience" (p. 25).

Phenomenology involves a process of data collection and how data is analyzed. An overview of the Husserl's process was conveyed by Moustakas (1994). He showcased four processes researchers must use when conducting phenomenological research. First, researchers must use *Epoche*, or bracket their prejudgment, presupposition, or preconceptions to "discover the nature and meaning of things as they appear and in their essence" (Moustakas, 1994, p. 26). Second, during the analysis process, researchers must use *transcendental reduction*, which means "data are spread out for examination, with all elements and perspectives having equal weight" (Patton, 2002, p. 486). Third, *imaginative variation* provides a description of the "context or setting that influenced how participants

experienced the phenomenon" must be presented (Creswell, 2007, p. 61). Lastly, a composite is developed to form a *synthesis of meanings and essences.* Moustakas (1994) described this as the "intuitive integration of the fundamental textural and structural descriptions into a unified statement of the essences of the experience of the phenomenon as a whole" (p. 100). How the researcher utilized these methods is presented below.

Journaling

In accordance with process steps for phenomenology, the researcher engaged in Epoche, or bracketing her biases, through reflective journaling preceding each interview. Moustakas (1994) wrote that investigators must "set aside their experiences, as much as possible, to take a fresh perspective toward the phenomenon under examination" (p. 88). Here the researchers bracketed out her own experiences in order to depict the experiences of others as objectively as possible (Creswell, 2007). Hence, the researcher digitally recorded any biases or past experiences with African-American women who earned physics doctoral degrees before each interview.

Merriam (2009) related that Epoche is necessary for those researchers who have had "direct experience with the phenomenon" (p. 25). Moustakas stated that the "researcher must set aside any assumptions, feelings and previous experiences and allow only one's own perception, acts of consciousness to remain as pointers to knowledge, meaning and truth" (p. 88). Though the researcher did not have any direct experience in a doctoral physics program, she was acquainted with one African-American woman who was not successful in acquiring her doctoral degree in physics at a predominantly White research institution.

Journaling allowed her to continually be both self-reflective and receptive to the data gathered within the interviews because she entered each interview as "as a blank slate, ready to acquire information" (Moustakas, 1994, p. 88). Therefore, the researcher utilized Epoche as the crucial first step in undertaking this phenomenological study.

The researcher also engaged in digital journaling following the interviews and while in the analysis process. The researchers noted her feelings and reactions immediately following each interview. These notes described each participant and the setting in which the interview took place. Thus, this method addressed Creswell's (2009) suggestion that "field notes on the behavior and activities of individuals" (p. 181) should be taken.

During the analysis process, Moustakas (1994) asserted that any error in judgment is discovered through an intuitive-reflective process revealing the "naked presence" of a phenomenon (p. 32). Understanding a phenomenon involves nonjudgmental conscious reflections on our interactive communication with others. Thus, the researcher also utilized journaling as a way to ascertain errors in judgment when examining emergent themes.

Sample Selection

Participants in this study were acquired through a mixed (extreme and criterion) purposeful sampling method. In a phenomenological study individual perspectives become valuable variables to collective outcomes (Patton, 2002). Creswell (2007) acknowledged the "common or shared experiences of a phenomenon" for several individuals is appropriately suited for phenomenology (p. 60). Patton (2002) indicated that extreme sampling is utilized to learn from "unusual manifestations of the phenomenon of interest," while criterion

sampling simply involved "selecting cases that meet some criteria" (p. 238). Patton (1990) indicated that "the logic of criterion sampling is to review and study cases that meet some predetermined criterion of importance" (p. 238). The predetermined criteria for this study were:

1. Participants identified as African-American women;
2. Participants have earned a Ph.D. in physics; and
3. Participants have attended a doctoral research institution within the United States.

Accordingly, no specific year, time span, or institutional type were allocated for degree completion in this study. The rationale for these exclusions were: 1) The pool of available African-American women Ph.D.'s in physics was small; 2) To examine the spectrum of experience for African-American women Ph.D. recipients in physics since the 1970s; and 3) The researcher wanted to be able to determine whether any emergent information was common to a particular time period. However, the researcher relied on snowball sampling, which disproportionately secured African-American women who graduated within the 2000s. This was not a deterrent to the study as these graduates had a fresh perspective and vividly recalled their experiences within their respective doctoral physics programs. Also, rendering of the current landscape within doctoral physics programs was salient to forming contemporary recommendations that may impact policies and procedures.

Participants were recruited via e-mail addresses from an online list of Black Women Physicists. Additionally, the National Society of Black Physicists, a professional network catering to the needs of African American physicists, was contacted to solicit names of

African-American women meeting the study's criteria. These women were also contacted via e-mail and asked to participate. In line with Polkinghorne (1989, as cited in Creswell, 2007) recommendation of 5 to 25 study participants for an adequate phenomenological study, the researcher interviewed five study participants.

Data Collection

This study utilized three primary data sources of data collection: a nine question background survey, one open-ended in-depth interview, and documentation provided by each participant. Each data source is described in more detail below.

Brief Survey

According to Katz (1946), a survey renders the applicable background and personal data for a study. Prior to the start of the interview, each participant answered a brief nine question survey. The purpose of this survey was to ascertain demographic information that was not collected within the in-depth interview. These questions consisted of background information concerning each participants doctoral experiences, including initial date of enrollment, an estimate number of minority groups present in doctoral program, an estimate number of women in the program, an estimate number of African-American women in the program, etc. (See survey protocol in Appendix D). These questions enabled the researcher to describe the doctoral environment for the study participants while enrolled in their doctoral physics programs. These questions also enabled the researcher to portray the significance of their success upon graduating from their doctoral physics programs.

Interviews

The researcher utilized interviews as the primary data source. These interviews involved the "meeting of two persons to exchange information and ideas through questions and responses, resulting in communication and joint construction of meaning about a particular topic" (Janesick, 1998, p. 30). Moustakas (1994) related that “broad questions…may facilitate the obtaining of rich, vital, substantive descriptions” (p. 116). Kvale (1983) also contended that in phenomenological interviewing, short, descriptive questions are meant to produce lengthy, detailed descriptions of the lived experience under study. Thus, open-ended questions were utilized for data collection.

The primary method of data collection was one formal face-to-face interview, not lasting less than an hour and a half. All interviews were conducted during a one-month period during the spring 2012. All but two study participants were interviewed in-person at a quiet location chosen by the study participant. Two study participants were interviewed via Skype, computer video software allowing virtual face-to-face interactions with two or more people, to keep cost at a minimum. One of the Skype interviews were the shortest interview, lasting only a hour and a half, while the other Skype interview was the longest interview, last about four hours.

The researcher followed a semi-structured interview approach, utilizing an interview protocol guide (See Interview Protocol in Appendix D). This open format also provided the researcher with “quotations which reveal the respondents’ levels of emotion, the way in which they have organized the world, their thoughts about what [was] happening, their

experiences, and their basic perceptions" (Patton, 2002). The researcher found that that sometimes these prescribed questions were not used at all once the participants begin recounting their stories and a certain flow emerged. This was consistent 1with what Moustakas (1994) stated:

> Often the phenomenological interview begins with a social conversation or a brief meditative activity aimed at creating a relaxed and trusting atmosphere. Following this opening, the investigator suggests that the co-researcher [the study participant] take a few moments to focus on the experience, moments of particular awareness and impact, and then to describe the experience fully. The interviewer is responsible for creating a climate in which the research participant will feel comfortable and will respond honestly and comprehensively. (Moustakas, 1994, p. 114)

The researcher began each interview asking the study participant her definition of the term, "resiliency." Following this, questions related to the participant's doctoral physics experiences followed until a narrative flow was established (See protocol for interview in Appendix D). In this way, the open protocol for each interview acted as a guide for participants to elicit full disclosure of their lived experiences (Moustakas, 1994). Following each interview, the researcher obtained permission to seek follow-up information from the participants for clarification via telephone or e-mail within six months of the interview. A follow-up e-mail was sent to each participant once during the study. This e-mail was sent to

acquire member-check approval of the transcription within four months following the date of their interview.

All interviews were audio recorded and transcribed by the researcher. Each interview was stored in a directory located within a password-protected laptop. Participants were given the opportunity to read an electronic version of the transcriptions and each confirmed its accuracy as a member check within a two-week timespan in August 2012. Participants were able to revise their statements within the transcription. Only two participants made minor revisions their transcripts in effort to future secure their anonymity.

Document Analysis

Document analysis was also conducted as part of this study. Lindolf (1995) contended that documents are important items of information in explaining "past actions" of study participants (p. 208). Additionally, Creswell (2009) contended that documents are an unobtrusive source of information.

Upon confirming the interview, the researcher solicited a résumé from each study participant, which listed doctoral institution, date of graduation, awards, and publications. Also, participants were asked to submit any media press (such as news articles, announcements, web sites, etc.) concerning their achievements as an African-American woman in physics. These documents were used as a crediting source for each participant and filled in gaps concerning their profile histories. Any additional documentation relating to their doctoral experiences provided by study participants were accepted and analyzed by the researcher as well.

Data Analysis

Data analysis was arguably the most difficult and tedious aspect of conducting this qualitative research study. This period lasted about six months. The researcher began data analysis immediately following the first interview. As Patton (2002) described it:

> The data are … organized into meaningful clusters. Then the analyst undertakes a delimination process whereby irrelevant, repetitive, or overlapping data are eliminated. The researcher then identifies the invariant themes within the data…. (p. 486)

This study utilized Moutakas' (1994) modified version of Stevick-Colaizzi-Keen's phenomenological analysis process presented below (pp. 121-122):

1. Using a phenomenological approach, obtain a full description of your own experience of the phenomenon.
2. From the verbatim transcript of your experience complete the following steps:
    a. Consider each statement with respect to significance for description of the experience.
    b. Record all relevant statements.
    c. List each nonrepetitive, nonoverlapping statement. These are the invariant horizons or meaning units of the experience.
    d. Relate and cluster the invariant meaning units into themes.
    e. Synthesize the invariant meaning units and themes into a description of the textures of the experience. Include verbatim examples.

f. Reflect on your own textual description. Through imaginative variation, construct a description of the structures of your experience.

g. Construct a textual-structural description of the meanings and essences of your experience.

3. From the verbatim transcript of the experience of each of the other co-researchers, complete the above steps, a through g.

4. From the individual textural – structural descriptions of all co-researchers' experiences, construct a composite textural – structural description of the meanings and essences of the experience integrating all individual textural – structural description into a universal description of the experience representing the group as a whole. (p. 122)

Throughout the analysis process, the researcher engaged in a *horizontalizing* process, a process in which all of the pieces of data are treated as equal and each transcript is read over and over, parceling out statements of significance (Creswell, 2007; Merriam, 2009; Patton, 2002). The researcher used *transcendental reduction* to give all elements the same weight of perspective (Patton, 2002). This focused the researcher's attention on the data in order to reflect on singular parts that unify these statements into emergent themes (Moustakas, 1994). Thus, the researcher began a process of open-coding following the first interview.

Once each transcription was open-coded, the researcher began arranging them into numerous thematic clusters. The researcher also engaged in a process of *imaginative*

variation to present the "context or setting that influenced how participants experienced the phenomenon" (Creswell, 2007, p. 61). Moustakas (1994) contended that the aim of imaginative variation is to "arrive at structural descriptions of an experience, the underlying and precipitating factors that account for what is being experienced" (p. 98). Patton (2002) argued that this step allows the researcher to "see the same object from differing views," or different perspectives, in order to develop "enhanced or expanded versions of the invariant themes (p. 486).

Once this was completed, the researcher arrived at four emergent themes from which she developed a composite to form a *synthesis of meanings and essences,* which Moustakas (1994) described as the "intuitive integration of the fundamental textural and structural descriptions into a unified statement of the essences of the experience of the phenomenon as a whole" (p. 100). These descriptions included information from the transcriptions and documentation submitted by the participants. During this phase, the researcher relied on Henderson and Milstein's (2003) list of internal and external protective factors to provide structure to showcase the composite textural and structural descriptions of each theme. Moustakas (1994) additionally pointed out that an essence is a common quality or condition of a thing, and the "essences of any experience are never totally known" (p. 100). However, Creswell (2007) related that the readers should better understand the phenomenon after reading the study.

Thus in summary, during the analysis phase, the researcher developed numerous thematic clusters through a process of open-coding the significant statements from each

participant's interview. The researcher then continued to narrow down the numerous thematic clusters into themes. These themes were narrowed down based on link resiliency experiences among at least three of the five participants, and four emergent themes surfaced from which composite textural and structural descriptions were rendered.

Validity and Reliability

Many researchers, especially in the quantitative tradition, are concerned with validity and reliability. In quantitative inquiry reliability and validity influence the generalizability of a study. However, there is on-going debate regarding how reliability and validity in qualitative research is defined and tested. Usually, reliability is the "extent to which results are consistent over time" and the "results of a [reliable] study can be reproduced under a similar methodology" (Joppe, 2000, p. 1). Validity, however, is based on the truthfulness of the study's results and emphasizes "whether the study truly measures what it is intended to measure" (Joppe, 2000, p. 1). This is often based upon an administered instrument (Patton, 2002).

Patton (2002) stated that "in qualitative inquiry, the researcher is the instrument" and "the credibility…hinges to a great extent on the skill, competence, and rigor of the person doing fieldwork" (p. 14). Golafshani (2003) argued that reliability and validity must be redefined and "conceptualized as trustworthiness, rigor and quality in qualitative paradigm" (p. 604). This study utilized Golafshani's redefined conceptions of these terms in that phenomenology is a highly involved and rigorous process utilizing multiple perspectives that seek to arrive at a shared experience or truth (Patton, 2002).

According to Piantanida and Garman (2009), qualitative methods can take many forms throughout the research process. In many ways qualitative inquiry is fraught with ambiguity though "attention to procedures is important" (p. 55). As a result, qualitative researchers would do well to take Mason's (1996) suggestion and match the "logic of the method to the … research questions … and … social explanation" (p. 147). Creswell and Miller (2000) related that triangulation serve as "a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study" (, p. 126).

The use of these methods coincided with what the literature tells us about data collection in qualitative research (Bogdan & Biklen, 2007; Patton, 2002). Researchers use triangulation to add depth and rigor to their studies, especially when using multiple perspectives to provide thorough findings (Patton, 2002). Triangulation also confirmed the accuracy of the precise nature of the reality explored by verifying statements collected during the interview process (Lincoln & Guba, 1985).

Therefore, to ensure the reliability and validity of findings, the researcher corroborated participant interviews with two other primary data sources. Thus, the background survey, résumé, and other submitted documentation was used to cross-check the validity of the interview data. Study participants were also asked to member check their transcriptions as a validation procedure for their descriptive experience. Within the member checking process, an electronic copy of the interview transcripts was given to each recorded participant. They had approximately two weeks to verify or correct any misquoted

statements and were given an opportunity to edit statements from their interview transcripts. However, they were not given the opportunity to corroborate or disapprove any of the researcher's interpretation of those findings.

Also pertinent to reliability and validity were decisions on how the researcher constructed her themes. Each theme emerged from the experiences of at least three study participants. Though numerous themes were ascertained from the transcripts, only four were salient once the thematic composite took shape. Thus, the researcher adhered to the guideline that each theme must have more than half of the participants experience it.

Researcher's Bias and Assumption

Researchers in the qualitative tradition are susceptible to individual biased perspectives (Patton, 2002). Based on one's epistemological and ontological worldview, a researcher may question: "what do I know" and "how do I know it?" (Guba & Lincoln, 1994; Patton, 2002). Piantanida and Garman (2009) described qualitative research as an interpretive and reflective process where the researcher iteratively engages in critical reflection to examine internal biases and beliefs. However, Merriam (2009) stated that "the extent to which any person can bracket his or her biases and assumptions is open to debate" (p. 26)

As a researcher engaging in a phenomenological study of African-American women who graduated from doctoral physics programs, I faced only minimal biases. In full disclosure, I am an African-American woman who was born within the United States. This inducted me also into a double-bind based upon my race and gender. However, I have never

attended a minority-serving institution or majored in a science or science-related discipline, which is thought to compound the double-bind experience.

As an African-American woman, I was aware that race and sex discrimination existed. I have experienced discrimination, especially as an undergraduate when one White male professor blatantly told me that I "looked like a 'C' student." As an African American attending a predominantly White institution, I often contributed race as the rationale for my discrimination; however, upon entering the graduate field, I have witnessed White women also experiencing some of the same discrimination, such as invisibility in meetings, condescending conversational tones, and unfair grading practices. Thus, I was led to question if these inequities were based upon my gender as well. However, my doctoral experience in educational research hardly accounted for discrimination. However, there was discrimination solely based upon the critical mass of women faculty of any race within the department. In contrast to the faculty, the women students seemed to be at a critical mass within the doctoral program.

While there was a critical mass of women students in my doctoral program, there was not a mass of African-American or women faculty in my educational research program. In fact, I knew of no full professors on the faculty who were African American. While enrolling in courses, my adviser recommended that I take courses with potential committee members. Following his advice, I enrolled in courses with two African-American women, who were completely swamped with doctoral students and did not wish to take on any more. Though I desired to find an African-American female mentor within my field, I chose to

remain with my adviser, an African-American male, to mentor me through doctoral completion.

My committee selection also proved to be a bit difficult on account of not finding a critical mass of women faculty in my department for committee membership. While there were several non-tenure track women, there was only one tenure-track White female faculty member in the department. When I first visited her to solicit her participation on my committee, she used language to dissuade me from placing her on my committee by revealing that she had a negative reputation among students, using a swear word to describe what they called her. She opened a Microsoft Excel spreadsheet to reveal her commitment to an extreme load of students, but agreed to serve anyway. Though I was happy to have a female faculty member on my committee, I felt sad because, as a former chair of the Council on the Status of Women at NC State, I read about how female faculty members were often overworked and underpaid. It was clear that she was overloaded; and though I wanted a female mentor of some sort, I was determined to find another female mentor. Every female faculty member, regardless of race, I contacted was overwhelmed and reluctant to take on any additional doctoral students. Despite her reluctance, I was able to secure one African-American female faculty member once my department merged with another department.

These experiences were program challenges to me as an African-American woman. I desperately wanted an African-American female mentor. If this was not possible, then I would have settled for any female mentor. However, finding female faculty member who would have been happy to take on one more student proved challenging; and I was unwilling

to be mentored by anyone unwilling to accept me. Therefore, while engaging in this study, I bracketed, or epoched, my experiences of securing female committee membership in my doctoral department.

While my experiences with departmental peers were positive, my experience in securing female faculty members for committee membership and mentors was disappointing. Therefore, I was aware and I have acknowledged that aforementioned biases were crucial to interpreting the findings of this study. I was aware that other biases may emerge as I engaged in this study. Hence, I kept a journal of these and any emergent biases prior to and proceeding each interview in an effort to gain a fresh perspectives during the data collection and data analysis phases. Only by continual self-reflective journaling could my research be sound and truthful to the physics doctoral experiences of African-American women.

Ethical Issues (IRB)

Researchers who study human beings must treat those individuals ethically and respectfully. They must protect their rights, especially in serving as active participants of the study. To meet the ethical guidelines, the researcher secured the approval of the Institutional Review Board (IRB), an institutional watch group that protects the rights of study participants (See Appendix A). Study participants were protected through consent forms. Each study participant interviewed signed an agreement stating that they understood the purpose of the study and agreed to participate. The consent forms also provided a way of withdrawing from the study if they were no longer interested (See Appendix B). Thankfully, there was no attrition among the participants in this study.

The researcher guaranteed confidentiality to protect research participants. Pseudonyms were used for each participant and her doctoral institution. Because each participant in this study was the only African-American woman to graduate from her doctoral physics program, the year of graduation was replaced by the decade of graduation. Because so few of these African-American women have graduated within the United States, the field of research was not presented.

Electronic data, such as recorded digital interviews, digital and written journaling records, and all electronic documentation, was secured in a folder on a password-protected laptop. Paper materials were secured in locked in a storage compartment to ensure safe keeping. The researcher also created back-up files on a USB key for all electronic data. This back-up key was also placed in the locked storage compartment with the other paper files.

No payment was made to ensure participation as specified on the consent form. Participation was completely voluntary. Though the researcher did not compensate the study participants, they were given a transcribed copy of their interview and the benefit of knowing that they were helping to potentially shape future policy for other African-American women pursuing doctoral studies in physics within the United States.

Chapter Summary and Conclusion

This chapter outlined the overall qualitative design of the study, which employed phenomenology. Also, the mixed purposeful sampling procedure involving both criterion and extreme sampling were addressed in the chapter along with three methods of data collection: brief background survey, one interview, and documentation. In addition, the

researcher also utilized Stevick-Colaizzi-Keen's phenomenological analysis process involving specific step-by-step procedures for analyzing collected data. This chapter also examined issues of validity and reliability. Lastly, to address current biases related to the study, the researcher stated her bias and assumptions in an attempt to limit them throughout the study.

CHAPTER 4: FINDINGS

Introduction

The purpose of this phenomenological study is to explore the resiliency of African-American women who graduated from doctoral programs in physics. In particular, the main objective of this chapter is to present the results which provide answers to the four overarching research questions, anchored broadly in the phenomenological ideology of understanding the lived experiences of these women while participating in physics doctoral programs. This chapter includes a composite analysis of the structural and textual experiences based upon the narratives of the study participants' lived experience and their interpretation of these experiences. The composites present the essences of meaning of their lived experiences (Moustakas, 1994) in adherence to phenomenological methods.

Therefore, this chapter will first provide profiles of the five study participants followed by how each of the participants defined resiliency. Next, major hindrances to these participants' success will be showcased. Following the hindrances, the study's four emergent themes will be presented showcasing what facilitated the resiliency of the study's participants. Each participant's "voice" will be brought to the forefront in the presentation of their experiences through the use of direct quotations. Grammatical errors were not corrected, except for repetitive wording. Brackets indicate researcher input while ellipses signify omissions.

Participant Profiles

As the researcher, I began the process of collecting the stories of my study participants during the springtime of 2012. At a location of their choosing, whether it was an office, a home, or via a Skype session, I recorded between 90 -180 minutes of data within a semi-structured interview format. The selection criteria of the study participants required that they had completed a doctoral degree in physics and that each self-identify as an African-American woman. Table 2 provides a quick summary of the participant profiles, which provides the attended graduate institution type, the decade of doctoral degree completion, information on whether or not these participants were the first African-American woman to complete a doctoral program in physics from their institution, and current employment position.

Below the summary table are the narrative profiles of the five participants, which present details on their lived experiences. Information was gathered from the interview transcripts, resumes, and media documentation from the Internet and books provided by each participant. The researcher used only first name pseudonyms to protect the identity of each participant. Many names, including participants, peers, faculty, institutions, and employment, also have been masked by fictitious pseudonyms to protect the participant's identity.

The profile of narratives below begins to relate the first overarching research question of this study: "What are the lived experiences of African-American women who completed doctoral programs in physics?" The following five profiles give background information into what sparked their love of science to circumstances surrounding their

enrollment and major obstacles throughout their doctoral pursuits. Later in this chapter, emergent themes will showcase additional information concerning their lived experiences in these doctoral programs.

Table 2

Participant Profiles

Participant	Undergraduate Institution Type	Master's Institution Type	Doctoral Institution Type	Decade	First to Complete
Donna	Large, prestigious, private research university		Large, prestigious, private research university	1980s	Yes
Jenni	Large, prestigious public HBCU	Large, private Ivy League research university	Large, prestigious, private research university	2000s	Yes
Mae	Small, prestigious, private liberal arts college		Large, prestigious, flagship, public Ivy League research university	2000s	Yes
Maria	Large, prestigious, Ivy League, private research university		Large, land grant, public research university	1990s	Yes
Sarah	Small, private, liberal arts college		Small, prestigious, public Ivy League research university	2000s	Yes

Donna

Donna, a self-proclaimed military brat born in Topeka, Kansas credited her love of science fiction as the primary impetus that sparked the curiosity that led her to science. She relayed that as a young girl, she wanted to write science-fiction novels, but first she needed to understand the science employed in creating these masterpieces.

After high school, Donna entered Matthews Institute, a large, prestigious, private research university in the northeast region of the United States, in the 1960s where she majored in physics. Though her family felt science was mysterious, they still cheered her on throughout her educational studies. Being the first in her family to major in science, Donna admitted it took her a few years to decide to major in physics because she was unsure if she was intellectually prepared to handle the difficulty of the major. However, though she initially felt intimidated, she entered the major mainly on account of her ability and being surrounded by an array of role models in her physics department, including a White female professor, an African-American male professor, and a handful of African-American graduate women who cheered her on through her undergraduate years. In the following excerpt, Donna related her undergraduate experience in her own words:

> There was one black professor that I ended up having in my junior year. I had to take a course from him. We were friends up until then; then it was really hard because he didn't want to show any favoritism, and I was afraid to ask. So, you know, that was like a tough period. But, I really had a lot of respect for him. He was very good. It was hard, but the hardest class for me was

> probably like electricity and magnetism because it was very alien. A lot of concepts I've never seen before. So, there were a few times when I was getting ready to quit and Janet Shelly [a famous female physicist] came around and consoled me. Somehow or another she heard, showed up at my doorstep in the dorm, "What's this I hear about you quitting, missy?" …I think I had a journal back then…and I was amazed at how many times I was apparently quitting.

She credited her African-American female graduate support system with sticking to the major: "I would hang out with them; and that, I'm sure, made a big difference."

Like her supportive peers while in undergraduate education, Donna began setting her sights on graduate school. She applied to four different schools, and finally settled on Saber University, a large, prestigious, private research university located in the Western region of the United States, due to its inclusive environment, including the critical mass of African-American students it enrolled. Donna referenced three major obstacles in her doctoral experience: 1) acquiring a supportive research adviser; 2) overcoming peer isolation; and 3) defending her dissertation. In the early 1980s, she became the first African-American woman to earn her doctoral degree in physics from Saber University.

After earning her degree, Donna worked at a number of prestigious corporations and laboratories. She has served on many national boards and committees. Donna served as a member of both professional and honorary societies; and she has also acquired two patents. At the time of the interview, Donna was employed, but considering consultant opportunities.

Jenni

Jenni, an only child of a single mother and born in Philadelphia, Pennsylvania, became interested in science while participating in a selective high school minority program focused on science and engineering. Being encouraged to pursue science in college, Jenni was attracted to the field of physics because it was an uncommon choice of her peers, the financial scholarships available in the major, and the future career opportunities. She applied and was accepted into Sunny Agricultural and Mechanical University (SAMU), a large, prominent historical black university in the southeastern region of the United States, in the 1990s.

While at SAMU, Jenni received a wakeup call after failing freshmen physics the first semester due to too much partying. She knew she had to keep her scholarship to stay in school and she was determined to do so. Jenni recounted how she overcame this setback: "I had a little more focus in my sophomore year." She also recalled that as early as her freshmen year at SAMU, she was encouraged by all the professors to get a PhD in physics:

> HBCU professors would say, "Other people don't think that you can go get a PhD in physics but we are preparing you. You're going to major in physics, you have to come into it with a mindset that you are going to go out and get a PhD, and it's not going to be as easy as you think it's going to be. There's going to be a lot of people who don't think that you're not going to be good enough to do it because you're black, because you are a woman, because you come from an HBCU." So ...it was an undercurrent throughout my entire time

> there. It was just kind of, "You have to be better. You have to try to work harder and make sure that you're learning this, because we are going to send you out there into the world and they expect you to fail."

By the end of her senior year, against the recommendation of her faculty advisers, Jenni applied and was accepted into Banner University, a large, private Ivy League research university in the northeastern region of the United States. However, upon arriving, she recalled culture shock and a high level of competition caused her to reconsider her decision. She explained:

> My high school was all black, my college was pretty much all black, and now here I am not just competing against some of the best people in America, but competing with the best in the world. So I did okay academically but I did not pass the qualifying exams. Half way through my third year I failed the qualifying exams for the third time and the final time and I had to decide did I want to continue on and try to go to a different school or did I want to get a job and start my life.

In the end, she earned only a master's degree from Banner University. However, Jenni was highly encouraged to continue by her young, but supportive, White male adviser at that institution.

Though Jenni ultimately took the advice of her faculty adviser, who encouraged her to apply to other schools to earn a doctoral degree, she wanted to be proactive in the process. She strategically sought out and applied to Joseph Smith University, a large, prestigious,

private research university in the mid-eastern region of the United States, but also an institution that she perceived friendly to African-American students, though it had never graduated an African-American female in physics. Within this environment, Jenni's obstacles at Joseph Smith University included 1) passing the qualifying exams; 2) meeting the expectations of a demanding research adviser; 3) rallying peer support; and 4) meeting bias at major physics conferences. Jenni overcame all of these obstacles and was the first African-American woman to graduate with a doctoral degree in physics from Joseph Smith University in the middle of the first decade of the 2000s.

At the time of the interview, Jenni was working in a science area she loved. She had earned a number of awards and honors, which include being selected for membership into American Mensa. Jenni had also published one book and written six journal articles. She had also presented at various national conferences.

Mae

Mae, a staunch Christian born in Columbia, Maryland, became interested in science as a child when she desired to become a paleontologist. However, after three summer internships in paleontology at the NASA Goddard Space Flight Center in high school, she decided instead to earn a double major in math and physics in college.

College was not an option, but an expectation for Mae. Her parents valued education and pursued higher education within their own lives. Mae's father earned a master's degree in photography, and for a brief time, served as a college professor, and her mother earned an associate's degree in fashion and design; however, both her parents did not remain in a career

related to their academic field. Though they were supportive of Mae throughout her educational pursuits, she contended that they could not relate to the struggles of pursuing a doctoral degree in physics.

After high school, Mae enrolled in Kaitlin College, a small, prestigious, private liberal arts college in the northeastern Midwest region of the United States, where she focused on physics and math because she described them as "the easiest classes" for her. She recounted:

> I ended up settling into physics because math just wasn't applied enough for my interests. Well I also had some bad experiences in my first math classes in college and just not getting along well with the faculty; and so I just decided to take physics. And as I progressed through the physics program, physics was definitely something I could do, but I wouldn't say that it was my passion or anything like that. And so, I did really well at it. I just wouldn't say it was my passion. It was something that I could do, and I did it well. And so my physics professors were really excited going into my senior year because they're like, "Look, we have this minority student; and she's really good; and she's going to go to grad school; and this is going to be great!"

However, during her senior year of college, she had a mental breakdown due to a crisis of belief related to integrating science and faith, which challenged her continuance in the field. She explains below just what led her to reconsider physics:

> So my senior year, at the beginning things were going pretty well and it looked like I was on track to go to graduate school; and then sort of my life fell apart for a bunch of different reasons. And that started to impact my grades and my performance in my physics classes. Basically I had a mental breakdown; and the end result of that is that in order to complete the number of credits that I needed to graduate, I didn't need any more extra physics courses. So I dropped all of my physics courses and took the minimum number of classes I needed to take to graduate to stay enrolled basically. And I also decided at that point that I was not going to go to graduate school, which was so upsetting to my senior exercise adviser that he basically stopped talking to me for the second half of the year and didn't advise me on my senior exercise, which sort of resulted in me not getting distinction, highest honors that sort of thing, because I simply had no feedback on what I wrote. So that was sort of disappointing, but I graduated; and I needed a job; and I wasn't going to graduate school, so I ended up taking a teaching position at a K-12 private school. And I taught seventh, eleventh, and twelfth grade physics and astronomy courses. And it wasn't until that time that I actually discovered that I liked physics. I enjoyed physics; and I wanted to pursue it further.

Mae eventually created a strategy to attend graduate school because she felt that she was being led there by God. She quit her teaching job and took a job with NASA, which would

allow her more time to focus on going to graduate school. At the same time, she enrolled in a local university to remediate herself on coursework in physics that she had neglected to take as an undergraduate.

Mae enrolled at the University of Bolardo, a large, prestigious, flagship, public Ivy League research university in the western south region of the United States. While at Bolardo, she had to perform rotations in three research groups. In one of these rotations, she experienced sexism by her male research colleagues, which made her leave that group for another more "wholesome" research group. Mae's obstacles included 1) securing a peer study group; 2) handling a strained relationship with her research adviser; 3) defending her dissertation; and 4) obtaining academic employment without research publications. Mae was also racially isolated at Bolardo; however, though she was the only African American within her program and the first African-American woman to receive a doctoral degree in physics from Bolardo in the middle of the first decade of the 2000s, she asserts that having the presence of African Americans within her program was not something she needed. However, she was also the only participant to not wholly feel resilient after completing her graduate program. She revealed that she lost something while participating in the process though what she has lost evades her recognition.

At the time of the interview, Mae was a faculty member at Carter College, a private master's university in the Midwest. She has won numerous honors and awards. She has also finally published an article in her field of research.

Maria

Maria, the third child of educationally progressive parents, was born in Wooster, Ohio. Both of Maria's parents earned their doctoral degrees, with one earning their degree in a scientific field. Her father earned his doctoral degree in chemistry while her mother earned her doctoral degree in political science and black studies. One of Maria's older sisters also earned her doctoral degree in chemistry. Maria knew early that she was going to college and thought that she wanted to major in math after high school. She credited her family for giving her realistic expectations in her pursuit of a math and science degree:

> That it was going to be hard was so much a given. Then there's the idea of 'twice as good for half the credit.' I honestly, honestly can say that I am definitely not twice as good, but I didn't have some expectation that anything would come easily. That sense of having to put in a lot of work for it was very much a part of what they gave me. They gave me that sense. It was really, really important that I had this family.

Once Maria began her studies at Silverspoon University, a large, prestigious, Ivy League, private research university in the northeastern region of the United States, she learned pretty quickly that math was not for her, based upon a combination of being poorly prepared within that competitive environment and feeling socially unwelcomed. She recalled:

> There were a lot of kids that had very advanced boarding school programs and were very highly educated. The bottom line was that I found that the math

> department was really… it was just kind of that bad social fit. I felt like I just didn't belong there. Mainly, [I] just disliked the classes very much. I only took a couple as a freshman. I got that message over and over and over again, "You're out of place. You've got no business being here."

Maria's interest in physics was sparked when she was exposed to one introductory physics class as a freshman. She remembered that she thought the physics teacher was gifted, but that physics was the "best thing since sliced bread." Though she did not enroll in the class during her freshmen year, she decided to major in physics during her sophomore year. Maria admits that physics was a tough major for her and that she did not graduate with a very good grade point average. She recalled that she felt isolated during the first year and a half, but she soon found her stride despite any encountered obstacles:

> Things like, I didn't really understand that everybody else was studying in groups, and so I was trying to do everything on my own. …Then I found some women to study with. I never ever did do group study with any of the men. …I had done so well in high school that I don't think I really appreciated the hard work that it would take. It's not like I was undisciplined, but I just don't think that I realized just how much I needed to put into things. For instance, I thought I could still do as wide a range of activities as I had done always; playing on my intramural basketball, and continue to play music and do some other things. …I did have for instance, a professor in one of the labs I took basically to tell me to get out of the program. His comment was "This class

> was made for a certain type of student, and you're not that type of student." Looking back on that, it's very hard for me to believe that that was anything but racist and sexist, because the guy didn't even really know me.

As her undergraduate years were coming to an end at Silverspoon University, Maria worked in a lab, which made her stop and think about how she would approach graduate school. She recounted this experience below:

> When I worked in a nuclear structure lab, between my junior and senior years, and a lot of the graduate students that I met weren't really happy with the research they were doing. They were talking a lot about, "Oh if I could do it again, I'd do this type of physics or that type of physics," and so I decided that number one, I really did struggle as an undergrad and number two I wanted to be sure that if I were going to continue on in physics, that I really knew what I wanted to do. So, I decided to try and get a lab job, and work in the field before I committed to going back to grad school. I worked in corporate research lab for about three years. Actually, I stayed in the college town that I graduated in for a year, and I worked for a biotech startup, of all things. Then, I started looking for jobs in labs so I could see if I wanted to go back to grad school. I ended up working in this lab for three years and decided to go back to grad school. The main driver for going back to school was feeling like I was having good ideas and having things that I was interested in, but not being able to have kind of a seat at the table, because I didn't have a PhD. So,

> starting to really recognize how important a PhD was to do the work that I wanted to do.

Thus, Maria gave herself time to evaluate her career options before applying to graduate school. Also during this evaluative time, she felt as if she "matured" and "demystified the graduate process."

Maria enrolled at Land-grant State University, a large, land grant, public research university in the southeast region of the United States. She recalled that overall her doctoral experience was satisfactory. Culturally, Maria described her doctoral environment as "much more positive" than her undergraduate environment; however, academically she still continued to struggle:

> There were black folks in other departments that were doing really well and doing really great research, and getting their PhD's. There were women in the program. One of the professors that I talked to before I came seemed interested in having me on campus. My first gut, you know, stepping on campus, was not bad. I think the coursework was hard, but coursework is always hard in physics. I think there were certain subjects that really worked well for me, and others that didn't. To this day I never understood why I hated classical mechanics so much. I just hated it and it was just always a big… I honestly think it was a psychological thing as much as it was real. Because how is it that I get through Jackson Electromagnetism and get through the quantum mechanics and really struggle the classical mechanics?

> It didn't make any sense. I think some of that may have been a little bit of the nature of the math. It was a slightly different math framework. I think that was always really hard for me. In terms of other obstacles, I went in pretty determined. So like I say, my undergrad experience was so negative that it was a relief. It wasn't nearly as bad as the undergrad. Again, I didn't set any GPA records.

Maria related that the faculty members she encountered in her doctoral program seemed happy to have her at the institution, especially her faculty adviser. Though she had a supportive faculty adviser, she faced obstacles while in graduate school. Maria's obstacles included 1) securing a peer study group; 2) passing the qualifying exams; and 3) facing isolation at major physics conferences. She was the first African-American woman, and only the second African American, to earn a doctoral degree in physics from Land-grant State University in the early 1990s.

Maria, at the time of the interview, was an independent consultant to several environmental organizations. She held six patents and authored numerous publications. Maria also earned a number of honors and awards. She also served as a member of the board of directors for her degree college at Land-grant State University.

Sarah

Sarah, a young and enthusiastic researcher born in Columbia, South Carolina, credits the 1980s television show, MacGyver for sparking an interest in science and an impressive

high school science teacher for feeding her curiosity in the discipline. In her own words, she explained how her love of science began:

> MacGyver was one of these guys where he sort of, because it was a TV show, broke down what he was doing, how, when, and I always wanted to know, and I was like, "Okay that works." And I had a good physics teacher in high school, who caught our attention by tearing a soda can in half using pressure points on the can. And he wouldn't teach us how he would do it and so it became another one of those "I wanted to know how that works."

Sarah admitted that she narrowed the fields she wanted to major in down to chemistry, engineering and physics. But upon enrolling in Fortain University, a small, private, liberal arts college, she first opted for the engineering program. Then she finally narrowed it down to physics. Below, she recounted how she finally chose physics as her major:

> When I started I was actually going to do engineering. I decided that I actually didn't like that pretty much from day one. Then I was going to try physics and chemistry. I actually took chemistry classes the first year and I was going to start my physics later. And I hated chemistry, so I dropped that. So then it was straight physics. And because of the way I did my schedule, I spent three years with essentially no fun classes because I had to work everything in if I was going to go to graduate within four years. So, I was physics major. I took no break.

In Sarah's family, graduate school was expected and a love of science was nurtured. Her parents, both of whom earned doctoral degrees outside of math and science, were big believers in education and intentionally sought to instill in their children a thirst for knowledge. In fact, Sarah's mother had long possessed an interest in science, but grew up in a time and place where this access was closed to her. As a result, she frequently exposed her children, Sarah and her older brother, to science activities whenever possible. Both Sarah and her brother consequently ended up majoring in a science field and earning their doctoral degrees in these fields.

The selection of a graduate school was not easy, but Sarah and her mother visited various universities, until she found one, English College, a small, prestigious, public Ivy League research university, that had a familiar family feel. Sarah remembered being recruited by a woman into the program and the embarrassment she felt for not knowing that her recruiter was on the physics faculty:

> I knew at the time it was a good school…and she [her future research adviser] called me, and I'm sorry to say that I thought she was the secretary, and so when I called her back, I said, "Miss" instead of "Doctor" and she never said a word. And then I didn't realize she was a doctor until I got there and saw her name on the board, and said, "OH, my God!" which shows you what kind of person she was. She had no ego, but she was a hard worker and she was patient. So, she actually did recruit me and my mother and I went up to visit. We happened to be there over their Christmas party; and …we did the regular

> visit where you meet a few of the professors; and they send you to lunch with some of the current grad students and you can talk to them privately without anybody else around about their feelings of the program and what they like, what they don't like. Then we went to the Christmas party later that evening and we met more professors and … what struck me was how down to Earth they all were. Keep in mind, I visited a few other places where it seemed *HUGE*. I should say part of choosing this school for me was the comfort level. I came from this city, but not a huge city and so I never really looked for a large university with 40,000 people. This school wasn't. I mean, it was bigger than my undergrad, but the department felt like family, and that was key. I felt like I could learn here and not be lost by the wayside.

While at English College, Sarah became connected with supportive faculty and peers, though at first she struggled to meet people and ask for help. She identified three major obstacles, while enrolled: 1) remedying her lack of academic preparation for the coursework; 2) learning to ask peers and faculty for help; and 3) passing her qualifying exams. She related that she became a sponge during her doctoral lab experience and it was here that she developed into a scientist. Sarah joked, "I always felt like if MacGyver could do it out in the woods, then I could do it in a lab." She successfully met her own expectations and became the first African-American woman to earn a doctoral degree in physics from English College in the mid-2000s.

At the time of the interview, Sarah was employed as a research physicist for the federal government. She has authored numerous publications, performed numerous presentations, and received a number of honors and awards. Sarah has also become a member of a national physics organization within her area of focus.

Resiliency Defined

This section presents the results to the study's second overarching research question - relating how resiliency is defined by each of the African-American woman who completed a doctoral program in physics. In particular, prior to each interview, each participant received a questionnaire via e-mail that asked her to define resiliency. The researcher rounded out each interview by asking each participant if she felt that she was indeed resilient. The researcher asked these two questions pre- and post-interview to ascertain whether the participants would connect their definition of resiliency to their experiences as African-American women who completed doctoral programs in physics.

The results of how each participant defined resiliency varied. Prior to the interview, four out of five participants defined resiliency in their own terms, while one of the participants was utilized a literal dictionary definition. Four of the five participants indicated that though they were familiar with the term "resiliency," they had never applied this term to themselves prior to being contacted for the interview. Instead, they related that they defined resiliency indifferently to their own struggles and success. The study participants submitted the following definitions on the questionnaire:

- Donna: The ability to adapt to changing conditions.

- Jenni: (1) The power or ability to return to the original form, position, etc., after being bent, compressed, or stretched; elasticity. (2) The ability to recover readily from illness, depression, adversity, or the like; buoyancy. (Dictionary)
- Mae: Staying with something to completion even though it is oppressive or difficult while still maintaining a sense of internal identity. Both terms "oppressive" and "difficult" are defined very broadly (i.e. emotionally, intellectually, physically, etc.)
- Maria: The ability to just keep trying and to trust that you've got it in you to somehow get where you want to be.
- Sarah: Persistence and the will to overcome.

Sarah was the only participant to apply resiliency to herself prior to the interview. She revealed that only once, upon completing her qualifying exams in graduate school, did she think of this term as personably applicable.

Following the interview, all five participants had developed a sense of their own resiliency. Three of the five participants, Donna, Mae, and Sarah, expanded their pre-interview definitions to cover the breadth of their experiences within their doctoral programs (See Table 3 below for pre- and post-interview definitions). Donna expanded her definition to include stability and ability to function after reminiscing on the number of doctoral students who did not make it through her physics doctoral program due to mental breakdowns or mental instability. Mae expanded her definition to exclude loss. Sarah expanded on her definition of resiliency to include alternatives and options if the first plan

did not work out. She did not see resiliency as sticking to the original major or area of research, but as acquiring a doctoral degree:

> To me resiliency is having a problem in front of you and continuing to work at it until you figure out how to solve it. I mean, it's not quitting. And I know that in the real world sometimes you don't win; but to me, if you're resilient, sometimes you don't win, but you don't stop. You know, you find another alternative, or you find a work around, or you take it as it comes and you just suck it up. You deal with it; and you keep going. I mean, we all have, I guess, things that try to hold us back, problems. It could be family. It could be work-related. It could just be not knowing the answer. And to me, I've always felt like as long as I felt like I had an option, there was no reason for me to quit. And for me, there's never not an option.

Jenni and Maria never changed their definitions of resiliency, but instead acknowledged that they fit their chosen definitions after completing the interview. However, one participant experienced dissonance regarding what made her resilient. Mae expressed feelings of losing something valuable while pursuing her doctoral degree in physics. Consequently, she revised her definition to exclude loss. When the researcher asked her if she felt resilient near the end of the interview, she responded:

> In some ways, yes; and in some ways, no. I'm definitely here. I'm teaching. I'm a professor. It seems, at least on campus, that I'm well respected. I'm still waiting to get my first publication, and that sort of adds to some of the

> anxieties that I have. But the part where I sort of wonder about the resiliency is that I definitely feel like there's some ways in which I a fundamentally different person than I was when I started grad school. In ways that I wish could return, I feel like I lost something and I can't find what it was. And so there's the part of, you know, maintaining your identity that affects resiliency that I feel like I made it through, but I lost something in the process; and I don't know what it was. But I'm definitely here; and it's not that I'm unhappy, but there's something that's fundamentally different about me and I long for whatever that was to not be gone. I just don't know what it is, maybe it's innocence, or trust, or I don't know, but something along those lines.

Mae revealed that she questioned an array of motives that may have influenced her finally obtaining her degree. She questioned whether politics were at play in her successful completion of her dissertation defense; she wondered if her success was due to her being the first African-American woman or simply limited departmental funding, pointing to an article which mentioned her graduating from her institution at least two months prior to her defense. She also wondered if her graduating was due to her adviser running out of money in her area of research. However Mae was not the only participant to question the events that led to her finally graduating. Jenni also questioned this because her adviser kept his graduate students so long. She related she felt that her adviser's department was pressuring him to up his graduating stats, which may have helped her graduate from his program within seven years. Jenni, however, she did not question her resiliency.

Below, Table 3 displays the findings of how each participant defined resiliency before and any additions they felt were needed immediately following the interview. How each participant applied the term resiliency to themselves pre- and post-interview is also summarized.

Table 3

Resiliency Defined by Participants

Participant	Pre-Interview Definition	Post-Interview Definition	Pre-Interview Resiliency Application	Post-Interview Resiliency Application
Donna	The ability to adapt to changing conditions.	Must be stable and have the ability to function.	No	Yes
Jenni	The power or ability to return to the original form, position, etc., after being bent, compressed, or stretched; elasticity. Ability to recover readily from illness, depression, adversity, or the like; buoyancy. (Dictionary)	The power or ability to return to the original form, position, etc., after being bent, compressed, or stretched; elasticity. Ability to recover readily from illness, depression, adversity, or the like; buoyancy. (Dictionary)	No	Yes
Mae	Staying with something to completion even though it is oppressive or difficult while still maintaining a sense of internal identity. Both terms "oppressive" and "difficult" are defined very broadly (i.e. emotionally, intellectually, physically, etc.)	Without experiencing loss.	No	Yes/No

Table 3 continued

Maria	The ability to just keep trying and to trust that you've got it in you to somehow get where you want to be.	The ability to just keep trying and to trust that you've got it in you to somehow get where you want to be.	No	Yes
Sarah	Persistence and the will to overcome.	Continuing to work at [a problem] until you figure out how to solve it; not quitting; finding an alternative option.	Yes	Yes

In conclusion, each of the five participants defined resiliency in a manner consistent with their experiences within their doctoral programs in physics. The results indicated that four of the participants, Donna, Jenni, Maria, and Sarah, perceived that they were resilient upon looking back at their experience. Only Sarah was able to perceive herself as resilient prior to the interview, but all participants were able to see themselves as resilient post interview. Consequently, this was only a present-day acknowledgement as most of these women previously felt that a term of resiliency was reserved for uber-successful people who came through turbulent situations to be successful. While in their doctoral programs, it seemed as they were just trying to get to the next phase the best they could. Most indicated that leaving the pursuit of the doctoral degree was not an option for them because they did not know what to do if they left their physics programs. However, Mae, who felt a sense of loss, experienced some doubt as to her resiliency.

Doctoral Obstacles

What hindered resiliency?

The first step in the Resiliency Cycle is for the participants to realistically and effectively identify or recognize their major risk factors. Consequently, this step answers the study's overarching research question of what hindered the resiliency of the study's participants. The participants identified various risk factors within their programs connected to six main obstacles, such as:

1. Gender (sexism in class-isolation, laboratory, and at major physics conferences);
2. Race (isolation and critical mass);
3. Autonomy (program selection, coursework, research adviser selection);
4. Assertiveness (research adviser compatibility);
5. Study-group formation; and
6. Passing qualifying and defense exams.

A detailed presentation of these risk factors, which hindered the resiliency of the study's participants throughout their doctoral programs in physics, is described below.

Gender Obstacles

Throughout the interviews, participants did not mention race or gender frequently. In particular, racial bias was almost entirely absent from all of the interviews. Only three participants, Donna, Jenni and Maria, mentioned race at all. Their mention of race was in view of a social need, not due to obstacles stemming from their doctoral programs. However, participants sited gender, stemming from sexism, as an obstacle while pursuing their doctoral studies.

Their gender presented obstacles for the study's participants through their course, laboratory, and major conference experiences. These experiences were closely tied to the external protective factor of promoting close bonds. Four participants, Donna, Jenni, Mae, and Maria, experienced gender-related obstacles.

Donna experienced "isolation within isolation," a term defined by Jordan (2006), on account of her African-American peers with whom she sought to study. Mae experienced gender-based discrimination in the laboratory on account of sexually explicit computer screensavers; two other participants, Jenni and Maria, expressed how unwelcoming major physics conferences were for them while pursuing a doctoral degree in physics. However, though these major conferences are vital in being successful in the field of physics, they seemed to be haunting reminders of bias and isolation.

Donna recalled that her doctoral program had reached a critical mass of African-American students, but the African-American males in her classes were both not helpful and even manipulative. She was the only African-American female in her doctoral program for a time. Donna did not describe academic difficulty with her doctoral coursework, she focused on the isolation she encountered from males of her same racial category, which she described when asked about any sexist experiences in her program:

> So this one guy was really insecure; the guy that was in the same class with me. ...I mean, the guy had serious problems! …But this other guy, I think, he was the type of person that was manipulative and would purposely do stuff, not out of reaction, but to be cruel. There were some others that were very

> supportive. The guy that was manipulative, I think particularly when he was feeling really insecure where, you know, well he's really never been that helpful, in fact. …He's just one of these manipulative people. So, you know, I was always excluded. In fact, he did because it gave him a sense of power. …I joined the study group with some of the White boys. Stephen [An African-American male peer in her class] wasn't going to work with me; so I was like, "Okay. I'll just leave him alone."

While on a laboratory rotation, Mae also encountered sexism from her laboratory male peers. Though she was the only African American in her program, she did not describe the incident as racist, but sexist:

> And so I worked in that group; and it was extremely sexist, uncomfortably sexist. …The men were sexist. The men were just awful! It was actually a husband and wife team, but they were so busy. They were never around. So I don't think they really knew about the day to day interactions with students with each other. And so like the desktop on all the computers was "Britney Spears Guide to Electronics," where Brittany spears was wearing basically nothing. And when I went to talk to one of the guys because the laser I was working with wasn't working properly, he was like, "Oh well, let me help the laser," and proceeded to make motions to that effect; and so it just was not a comfortable environment for me to work in. …Well, I changed the desktop on the computer, but the next time I came back, it was changed; so that how I got

> with that one because there was nobody around. …I told him I was uncomfortable with that and I left. But I could never find like the faculty advisers for the group to actually talk with them because they were just always traveling around. So I basically decided I didn't want to be a part of this group. …Apparently, the woman in my study group, who ended up working there, had similar experiences; was able to actually communicate that to the advisers; and they put a halt to that sort of thing.

Mae failed to report the incident, unsuccessfully trying to halt the behavior herself. She admitted that this negative incident propelled her to leave the group and return to her wholesome environment of her original thesis adviser.

Two participants also encountered sexism at major physics conferences. Both Jenni and Maria cited the overwhelming bias owing to the relative absence of women at their major research conferences. Jenni addressed the bias behavior prevalent within the discipline, which also involves race, but she mentions gender seven more times than race in her following rant:

> At my graduate institution, I didn't really feel as much bias about …being a woman, but this was a very happy-go-lucky place. …But when I went to conferences, then you really see the 10 percent women. You're one of the few women there. I'm sure you've heard anecdotes about people, "Oh, I thought you were handing out drinks, I thought you were the secretary" -- that kind of thing. It does happen. …Because the expectation is that there's so few

> women, most places don't have any women professors. There's absolute bias. …"Honey, would you go and get me some coffee?" These are anecdotes I've heard from other women. For me I think it was just kind of more of strange looks, or looks of surprise, like, "Oh, you're a graduate student?" You know that kind of thing. But what I took from it was that when I left this cozy, little nest and went out into the world, I will be constantly questioned. "Are you good enough? Are you only here because they needed a woman professor? Did you get the grant because you're a woman? Oh, you probably just got it because you're African American and a woman."

Additionally, Jenni continued to question her place in the field of physics, and to wonder about her future in the real world of physics:

> It's a constant battle to prove that not just that you do good research, which is what everyone has to prove, but that you aren't here on some quota, that you aren't just here because you're a woman; that your research won't be looked at with bias because you're a woman. You know, the same with peer-reviewed journals and everything, if they know that you're a woman, then will you be getting the same type of evaluation? I mean, this constant question of 'are you really good enough?' I chose not to face that because I know that I'm good enough.

Sexism surrounding the critical mass of women in the field of physics concerned Maria. Though she was aware of the limited concentration of women in the field, the relative

absence of women at major research conferences presented an obstacle while she was pursuing her doctoral degree. Though she made connections with women at conferences, she also expressed feelings of isolation:

> I will say the one place where I felt the most uncomfortable was the conferences. It was absolutely torturous for me. I hated them. …That's when the numbers were so high, and you really did feel like it was all White men, some Asian men and the occasional woman. I was just very uncomfortable. Also, there were times when I was bored at conferences and would think, "Is there something wrong with me that I'm bored?" …. I did not like conferences. …I remember one or two foreign students that I met, and made a connection to, and maybe one or two women, but no, I felt very isolated at the conferences.

Hence, both Jenni and Maria referred to sexism and bias as a result of critical mass as deterrents to meaningful participation in the field of physics.

Therefore, gender presented a hindrance to participants while in their doctoral programs in physics. Though they may have been the only African-American female within their courses, laboratories, or at major physics conferences, participants cited sexism, more than racism, as obstacles to their success.

Race Obstacles

As mentioned previously, race was not a huge obstacle for many of the women in the study. Only one participant, Donna, mentioned race as a barrier. Donna graduated in the

1980s and attended graduate school during the initial inclusion period of the 1970s. She is the only participant to relate that she experienced isolation as a result of both her gender and race. Donna related the isolation she faced by many of her female counterparts in her physics program. She expressed that this isolation was hurtful because most of her White female counterparts did not consider her on equal footing:

> There were some [who were not friendly] and the way I got aware of it was … a women's college of the peninsula …was having a think panel, and they wanted some scientists on the panel to speak as role models to the students. So somebody asked me, and the other women in the physics department got wind of it. So they showed up and protested against me being on the panel. They were offended that Apex Women's College was using me as a role model for female scientists. That was when I realized how prejudice they were, and that did hurt my feelings.

Another race related obstacle encountered was the lack of African Americans within the doctoral programs. Three of the participants, Donna, Jenni, and Maria, felt the need to find and associate with students who looked like them. They were on a mission to fill a cultural void.

In addition to the racism present in her program, Donna also encountered an obstacle of racial critical mass due to the attrition of many of the enrolled African-American students within her doctoral program. Though her doctoral institution enrolled a fair number of African-American students, once there, these students lacked what it took to complete the

program. They would either fail out or have mental breakdowns. She recounted the problems faced in their matriculation:

> Blacks weren't the only ones to flip out; but they tended to pick people that weren't stable. So maybe they didn't have a lot of self-confidence. I don't know how to describe it; but basically they would admit people, but the attrition rate was really high. So when we got that committee, then the attrition rate dropped significantly. I think it's, you know, maybe some of what was going on. Sometimes people set you up for failure. I mean, I've had many times when people have just set me up for failure. They put you in these situations.

Jenni shared that she felt isolated due to not having any contact with African Americans. She longed to connect with other students who shared her racial identity and were pursuing doctoral degrees of any major. Jenni presented her experience regarding this void:

> Because even though we were in the middle of one of the blackest cities in America, I could go a week and not see another black face on campus or like walking from my apartment to campus is only one block so it would be a challenge just to see other black people.

Like Jenni, Maria also shared that there was a cultural void while pursuing her doctoral degree, but unlike Jenni, she did not look outside of her major. She longed to see African-American students succeeding in her major regardless of classification. Maria's

need for a racial presence was fulfilled in her acquiring peers under her doctoral classification:

> I would say that, an odd peer -- there were a couple African-American undergrads, who have gone on to do really well. They also were just a presence, they were doing really well and they were pushing each other. It was one of those situations where I think they ended up being better off because they were there together and pushed each other and were a little bit competitive. Just having some African-American folks around was very good.

She related that she filled this void through volunteering for an undergraduate tutoring program in her major catering to African-American undergraduate students.

Autonomy Obstacles

Autonomy (independence), which is an internal protective factor, is defined by the researcher as the ability to govern one's own actions, without regard to any outside influence. Any risk associated with autonomy in this study pertains to a participant's decision to be independent without regard to available outside assistance. Two participants, Sarah and Jenni, experienced this risk due to improper use of autonomy during coursework, program selection, and research adviser selection while pursuing their doctoral degree in physics.

Fearing slight to her intelligence or intellectual ability, Sarah struggled with being autonomous in regards to her coursework. Initially, she recoiled from reaching out for help from her course mentor or peers. An excerpt from this experience follows:

> I'm slow to make friends, and as I mentioned, I'm stubborn. So what this usually translates into as I get to a homework problem and get stuck, I feel that I got to work it out myself. If I don't make a friend right away, I don't really have somebody I feel comfortable going to and ask for help or talk to. And that's something that I still, you know, I wouldn't say struggle with, but it's something I'm aware of even unto this day. I like being able to figure it out myself. And I had to teach myself through grad school that, "Okay, it's okay to ask for help. It doesn't make me stupid. It doesn't make me slow."

Therefore at some point, Sarah gained awareness that the protective factor of autonomy, which may have served her positively in the past in coursework, was failing her in graduate school.

Jenni's risk was not in failing to ask for help, but making autonomous decisions in the selection of a graduate school and research adviser. First was the selection of an Ivy-League doctoral physics program against the advice of seasoned faculty at her large, prestigious, undergraduate historically black college and university (HBCU). She became aware of her mistake after being released from her program earning only a master's degree since she did not pass her qualifying exams three sequential times. Being a self-described pragmatic thinker, Jenni realized that her undergraduate faculty warned her against attending this institution because of its un-established record in graduating African Americans and that there were departmental politics at play. An excerpt from this experience follows:

> I applied for a bunch of grad schools and I got into an Ivy League school. I went there, against the recommendations of my professors at my undergrad because I was like, "It's Ivy League. I want to go to Ivy League." So I went to this Ivy League school and it was such a culture shock because it was just very different than anything that I had known. …So I did okay academically but I did not pass the qualifying exams. …So this school, I think they expected about half the people to fail every time they gave the exam. …It was just kind of the word on the street, the expectation, and it was also known that if your adviser had a lot of grant money you would probably pass if you did, if you were in the gray area, that they might move the line down a few points, the passing line down a few points, for you. …Academics is very political. …That school had never had any black people go through, women or men. And they [her HBCU faculty] were advising me to go to a different school in the South … friendly towards African Americans. They felt that I would have been, I guess, protected more at that school in the South. So those words came back to me.

Jenni's second autonomous decision surrounding the selection of a research adviser occurred at her doctoral institution. She selected a demanding research adviser due to his prominent reputation in the field of physics. Though Jenni was thoroughly warned by a graduate student who worked in his lab of how tough this research adviser was on his

students, she took it as a personal slight to her abilities. This decision ultimately caused her a great deal of stress while in her program. An excerpt from this experience follows:

> My research adviser was Chinese male. I picked him because he brought in the most grant money. He did the most cutting-edge research. He was considered to be one of the toughest people. If you finish with him, you knew your stuff. Nobody doubted or questioned you if you worked for this professor. …I would have finished two to three years earlier. …I picked the tough one because I wanted, I thought I wanted, a challenge, I don't know. It was too much of a challenge. I could have an easier life but I was like everybody said, "This guy, he's so smart. He knows his stuff. They file lots of patents; they travel all over giving talks." That day we sat in his office and there were cues that it would be tough and I ignored them all. I believed that he would accept me as a grad student if I came in for the trial summer and worked hard. …We sat and we talked and he pulled out dissertations from former students and he showed me that "See this is two, three, four dissertations worth of work in this one dissertation because my students work hard. Each of these chapters was a different research topic, a different science article in the most established journal." … He showed where they had patent applications. I talked to some of his current students, one who was not Chinese, he was Dutch, and he said, "Don't join this lab! It will ruin your life," and I did not listen to him because I was like, "Oh, he doesn't think I can

> handle it. He doesn't know me I'm tough." …So I was like I'm going to work with this guy. It will be tough, I can handle it. I'm up for the challenge, but I didn't know what I was getting into.

She later gained awareness that her decision increased her time to graduation when she witnessed a former summer laboratory peer, who decided to choose another research group, graduate three years ahead of her. Jenni also came to understand that she must heavily weigh the advice of seasoned faculty and students when making key graduate school selections. Therefore, Jenni's experience showcased that autonomy is not always the best route to success.

Assertiveness Obstacles

Assertiveness, which is also an internal protective factor, likewise served as a major risk factor to successful completion of doctoral programs in physics for two participants. The researcher defines assertiveness as the inclination to forceful or aggressive actions or statements of self-will or government. As showcased within Jenni's story, within the graduate school environment, research advisers often hold reputations that attract graduate students to work for them. The pay-off for the graduate student is usually the ability to gain successful employment based on the reputation of the former research adviser. Therefore, within this sphere, the research adviser is the most powerful determiner of success for his students. For two participants, Donna and Mae, the improper use of assertiveness affected their compatibility with their research advisers and threatened their ability to be successful in their doctoral programs.

The experience surrounding Donna's use of assertiveness culminated in her having to find another research adviser and leave an area of research which she loved. She discloses her main reason for selecting the first research adviser was his ground-breaking area of research and the funding associated with it. Donna seemed to be excited about collecting data with her first research adviser, Andrew, and his group until she discovered that he had neglected to include her name on a research article. This incident led her to assert her right to be included and publish a paper with another faculty member. A lengthy excerpt from this experience follows:

> My first thesis adviser was a total disaster. … The first one …I like to describe him as one of the finest assholes I've ever met. …He was White. He was a jerk, He was a real jerk. He worked at Gale Labs and he was a department head and everybody in his department hated him. He had a lot of enemies and it took me about six or seven months to get to the point where I realized that, well, he had more than his share. …However, he earned every single one of them, okay. …So, he screwed over me about a year into it. …He was an adjunct faculty at Saber University but he was a department head at Gale Labs. He got me a fellowship. So that was a small problem because I had to get rid of him. It was clear after about a year, I knew, okay, this is not going to work. I called him up and told him off and I had talked to someone else and gotten them to agree to take me. Then this was just before Christmas because I had to go home and cool off. …I had already cursed the first one

out. …Well what was bad was that …we had been doing some work. … I was out there local and there was this post-doc that was out there local. So once we got some data and stuff like that -- the first couple of nights we got really nice data --- he told John [his post-doc], "Okay, write up this paper," and he told him whose names to put on it and he left my name off. It was like very humiliating because they even acknowledged the technicians that strung the cables for the experiment. …So I saw a copy of the paper and I was like, "Where is my name?" I went to John, "What's this? Where's my name?" He says "Well, Andrew [her first research adviser] told me, you know, to write this up and whose name to put on it. I mean, I'm just following orders." …Okay, so, I called him up on the third of January and said, "That's it! I'm done!!!" During the conversation, I had reversed the charges by the way. I began to realize that he was trying to get me to tell him what it was that he had done that I had just found out about so that he could apologize. …That means that wasn't the only thing he had done to screw me; and he had to know which one I had just found out about so that he could apologize! Then I kept him on the phone for three hours without telling him, and then when this other guy backed out, I had to … allow him to talk me back into his group until I could find, you know, another position. …He had pushed me out of my element. That was not comfortable for me at all, and I did not like myself during that period at all. … …At first, I was going after things that I thought were sexy;

> and then, after the experience with the first thesis adviser, I decided ….having a relationship with your adviser was important; so after that, I was looking for somebody that I was going to be compatible with and wasn't going to be fighting with all the time cause …I don't like confrontation. I did get a paper out with somebody else. That he didn't know about until the conference. I remember I was there when he realized; and he was really pissed. …I knew that I couldn't stay in that field because he was dominant in that field. So there was no way I could continue working in that field.

Therefore, Donna discloses that this experience gave her awareness of the importance of a compatible relationship with her next research adviser.

Mae's assertiveness also hurt her compatibility with her research adviser, though she remained with him through graduation. Their relationship was strained and she had a few disagreements with him concerning her research project, which ultimately led him to hold up the progression of her data collection very close to her doctoral defense date. This incident led her to assert her right over her research even more, but caused her a tremendous deal of stress in the process. A lengthy excerpt from this experience follows:

> Basically because of his desire to get more money, however he was doing it, he relied on us graduate students. That put more pressure on us and …he was starting to work those longer hours. I remember having an email battle with him at two in the morning, and finally I said, "I'm going home. I'm done!" …He actually sabotaged my experiment. We were having a disagreement

about what I needed to do to finish up my PhD; and I wanted to do more things than he wanted me to do, but they were things that I felt were necessary. He wanted me to show that my system worked. I wanted to show that, not only did the system work when I knew it should work but that it didn't work when I knew it shouldn't work, just to fully prove the theory. And so, I had just gotten the system working where I could just start taking data. And he wasn't happy with how quickly the system was working, but it was still good enough for me to take data. And he has always said, "Always take the data before you start fluxing with the system because you never know if you'll be able to get it back again." So take the data with the system you have, then improve it, and take more data because you don't know whether or not: 1) you actually can improve it; or 2) how long it's going to take you to do that, or whatever. …So he had talked about a crystal in the system that he had wanted me to try; and I said, "No, I want to take this data first, and then I'll put in the new crystal." He came and took my crystal out the lab and hid it for two weeks. …He just, he just, he took it. He took it! … And so, he emailed me and said, "I'll just put the new crystal in for you when I get a chance." And I was like, "What? Okay fine. You can do that because I need to work on writing my thesis." My thesis hadn't been finished yet. But, after the second week I wrote him an extremely nasty email basically saying to him, "You can't do this!" …I was like, "What the hell? I literally can't do anything. I

> can't take data, any data!" … I was working on my thesis, but I didn't have any data. I had no data and I was defending in eight weeks, seven weeks, and I had zero data. …So I sent that e-mail about four o'clock in the morning. I wandered in to work because I was exhausted at 10. Ten is late for me. And the crystal was in the stove when I got there. …Somewhere between 4 a.m.-10 a.m., he had gone in there and put a new crystal in there. Not the crystal that I had originally worked with, but the crystal that he wanted me to try. …I didn't care. I just wanted to be done and I wanted to be out of there. I wanted to get my data. …It ended up that the crystal worked better. I was able to take data faster, but he took a component from my system without my explicit permission.

Mae acknowledged that the backlash to her assertive actions may have been subtle following the incident. She mentioned that after this incident her research adviser made no effort to moderate her defense, which left Mae having to create a strategy for survival. Therefore, Mae's assertiveness also produced negative, not positive, consequences for completing her degree.

Forming Study Groups

The formation of study groups was also a source of angst that two of the study's participants, Mae and Sarah, faced. Both participants referenced being stifled in regard to study groups. Mae mentioned that she thought the process of study group formation was a

formal process. Sarah, on the other hand, admitted that initially she felt a bit of intellectual doubt about studying in a group.

Upon enrolling in her doctoral program, Mae was concerned about forming a study group. Her hiatus from higher education left her doubtful of her ability to fit in so that she could be successful. Not understanding the prevailing culture of study group formation, she related:

> I think I had sort of expected that people would say make a big announcement, "Oh we're going to get together to study here. Why don't you join us?" … or some open invitation; and that never happened. So that meant that I needed to sort of figure out where they were meeting; and how they were deciding to meet; and figure out whether or not I could be a part of that. …I had been out of undergrad for four years; and I was taking classes with most students who were just out of school. So how am I going to do in classes when I had been out of school for four years? How am I going to do on exams? This stuff is not as fresh for me. I remember at some point during the first couple of weeks crying because I couldn't figure out how. I didn't hang out with them. I'm four years older; and in general, my mom says I was born thirty… and basically, that's true. I don't go out and drink. I don't go out and do those sort of things that kids that age did; so how am I going to form a study group? And it seems like once I cry things out, I think better.

Sarah, who previously cited her need for autonomy, did not realize that study groups were the life-blood of her graduate program. Always one to figure things out for herself, Sarah did not quickly join a study group. She had to figure out that relying solely on herself for all of the homework problems was not the answer to being successful in graduate school. She recalled her initial experience:

> I'm slow to make friends, and as I mentioned, I'm stubborn. So what this usually translates into as I get to a homework problem and get stuck, I feel that I got to work it out myself. If I don't make a friend right away, I don't really have somebody I feel comfortable going to and ask for help or talk to. And that's something that I still, you know, I wouldn't say struggle with, but it's something I'm aware of even unto this day. I like being able to figure it out myself. And I had to teach myself through grad school that, "Okay, it's okay to ask for help. It doesn't make me stupid. It doesn't make me slow.

Passing the Qualifiers and Defense Exams

Passing the qualifying exams was an obstacle cited by three study participants, Jenni, Maria, and Sarah. Their ability to pass the qualifying exams produced a source of stress that either left them confounded, devastated, or doubting intellectual ability. All participants mentioned their qualifying exams, but Donna and Mae did not list their exams as an obstacle. However, the ability to pass these exams directly correlated with the ability to succeed through doctoral completion in physics.

At her doctoral institution, Jenni's qualifying exams were more spread out than at her master's institution. Though Jenni had all of the preparation she needed to pass one exam, she still did not pass the exam:

> As I mentioned, we had six exams to get through for our qualifying process and of the initial first set of four there was one that I just could not pass and this was electromagnetics. Now mind you, I have taken electromagnetics two semesters as an undergrad. I took it one semester at my master's school. I took two semesters graduate level at my doctoral school, failed the exam. I then took the undergraduate electromagnetics at my doctoral school again thinking then that I had missing blocks in my foundation. I passed the course, failed the exam.

Thus, Jenni seemed to be a bit confused as to why she failed this one exam. She had taken all the necessary courses to pass this exam numerous times, and yet she was unsuccessful initially.

Maria also failed a portion of her qualifying exams. For her, test taking was hard and stressful. Maria recounted that though she was devastated at the time, she did not check out of the doctoral process:

> First of all, test taking in general was hard for me, and nerve wracking. I took my qualifiers, and I didn't pass classical mechanics. I did have to go back and grade for the senior classical mechanics class for, I think, just one semester. Actually, the guy that I worked with … he was a really positive

> experience here. I didn't feel too stigmatized by it. Of course I was really upset that I had failed that part of the qualifiers. …I do remember at the time being really pretty devastated by it, but it's a vague memory in the overall experience. I don't think that I failed it and thought, "Oh, I have no business being here" or "I need to get out." I still felt like it was what I wanted to do, and I still felt …that I wanted to continue. I didn't have the, "I'm going to go home and quit."

Sarah recalled that for a brief period of time, the stress of failing part of her qualifying exams caused her to doubt her intellectual ability. Failing the qualifying exam made her face failure and look inside for strength and commitment to continue through her doctoral program:

> Well two years in, you can take a test that says you have mastered the bookwork enough to move on to your research. … That was the last obstacle was getting through that test. Because the first time, my mentor came down and said, "Well, you didn't pass it, but you take it again. You got close, and, you know, we felt like you'd be fine," and I was like, "Okay that's fine." For 24 hours though, you feel really despondent and stupid. And you're like, "Oh, God! I don't know if I can do it again!" Then you just suck it up and like, "Alright I'm not a total failure. I didn't completely fail the test. Let me just pick up what I didn't get and refresh in places that I did get and just focus more." So the second time around, I went into that test and I was just like,

> "Damn it, I'm passing this thing because I'm not doing it a third time!" And actually doing it a third time, you have to request anyway because if you don't usually pass it a second time, you get a masters and they let you go. And failure at the point just wasn't an option. In the end, all five participants faced obstacles that put them at risk for failure. These obstacles caused them stress, which at times made them question their doctoral paths. To combat any risk, these five participants developed ways to mitigate their obstacles. The next section presents how these participants facilitated their resiliency to move to doctoral completion.

Passing the qualifiers was just one exam obstacles. Two of the participants, Donna and Mae, who did not mention any hardships with the qualifiers, faced obstacles passing their doctoral defense. Donna discovered that one of her committee members were known to intentionally "knick pick" students during their doctoral defenses so that he could impress her committee chair. While Mae faced obstacles during her defense from a strained relationship she had with her chair and his wife.

Donna became aware that one of her committee members, Lamvir, was extra demanding on the graduate students during their final defense. She recounted that she learned about this too late in the process. Donna noted below that she would have changed her committee membership had she known about this earlier in the process:

> I think if there had been close peers, I would of known about Lamvir before asking him. … He wanted to impress my thesis adviser; so he would basically

> give my thesis adviser students a run for their money in order to make an impression. …I mean, I was talking to somebody, "Who's on your committee?" And I was like, "Oh! I got such and such, and Lamvir." And then, "Lamvir, you know, has gotten it in for Henry's [her thesis adviser] students." I was like, "Oh, okay!" It was too late for me to tell him, "No, I don't want you on my committee," that would look kind of tacky.

Mae's assertiveness left a strained relationship with her adviser. However, a larger obstacle was that her research adviser and his wife reduced their graduate students to instruments of war to fight one another. May recounts that she did not her adviser did not help her during her defense and his wife was not the most dissenting member of her committee:

> Obviously, he was on my committee; and his wife, even though I didn't want her on my committee, was on my committee. …During the defense, my adviser let me run the entire thing, which was sort of fine except I was getting questions from her where she was never satisfied with my answer.

Emergent Themes of Pluralism

What facilitated their resiliency?

This section contains the emergent themes of this study based upon the overarching research question of what facilitated the resiliency of the study's participants. Previously, the participants identified six risk factors, or obstacles, which served as impediments within their doctoral programs. These obstacles were connected to gender, race, autonomy, assertiveness,

forming study-groups, and passing qualifying and defense exams. The second and third steps in the Resiliency Cycle, discussed in Chapter 2, answers the study's overarching research question of what facilitated the resiliency of the participants. Beginning with the second step in the cycle, which is to have the ability to manifest and/or seek out protective factors that will offset or mitigate potentially negative effects of risk factors, the researcher presents findings significant to these participants. In this section, thematic structural composites are rendered from three of the five common experiences. Under each structural theme, textual descriptions of the lived experience are presented. The most significant discovery of how these study participants facilitated their resiliency was the use of pluralism, which the researcher defines both socially and literally. The researcher uses the term "social pluralism" to refer to the diversity of ethnic and cultural groups within a society that interact in a constructive and positive manner, possibly to achieve a desirable goal, while the term "pluralistic" is used more literally to refer to having, using, or acquiring multiple experiences, techniques, or skills. These themes showcase how participants offset or mitigated their risks by utilizing both internal and external protective factors. Risk factors were mitigated by the participants seeking out pluralistic connections, experiences, or strategies in both a cultural (social pluralism) and literal sense. This pluralism was manifested in four ways encapsulating four significant emergent themes: 1) Forming pluralistic peer connections (social); 2) Acquiring pluralistic laboratory skills (literal); 3) Utilizing pluralistic problem-solving (literal); and 4) Forming pluralistic support connections

(social and literal). These skills were constantly refined and implemented in order to be successful. Table 4 showcases a summary of this section.

Table 4

Emergent Themes on Facilitating Resiliency in Doctoral Physics Programs

Theme	Type of Pluralism	Protective Factors	Obstacle Overcome
1) Forming pluralistic peer connections	Social	Is sociable; has the ability to be a friend and form positive relationships; Gives of self in service to others and/or a cause	Gender, race, autonomy, assertiveness, forming study-groups, passing qualifying and defense exams
2) Acquiring pluralistic laboratory skills	Literal	Has the capacity for and the connection to learning; Is self-motivated; Is flexible	Gender, race, autonomy
3) Utilizing pluralistic problem-solving	Literal	Uses life skills, including good decision making, assertiveness, impulse control and problem-solving	Assertiveness, passing qualifying and defense exams
4) Forming pluralistic support connections	Social / Literal	Uses high-warmth, low-criticism style of interaction; Encourages supportive relationships with many caring others; Provides leadership, decision making, and other opportunities for meaningful participation; Appreciates the unique talents of each individual	Gender, race, autonomy, assertiveness, passing qualifying and defense exams

Note: All protective factors used within this section are taken from Table 1.1 (p. 9) of Henderson and Milstein's (2003) book, *Resiliency in Schools*. This list of internal and external (or environmental) protective factors is also found within this document in Chapter 2 (p. 50).

Theme 1: Forming Pluralistic Peer Connections

A number of participants displayed their pluralistic abilities while using the internal protective factor of sociability. Social pluralism was needed in graduate school environments where these women were both a gender and racial minority. At least two participants, Maria and Sarah, mentioned that they grew up in predominantly White environments and may have developed these skills early on. However in college, each participant was sure to utilize this protective factor to unite with various peer groups in order to gain support, not only within the discipline for study groups, but also to connect with graduate students within other majors around their doctoral institution. This fostered their success because they gained an awareness of the struggles that other graduate students faced as well as valuable access to information needed that enabled them to persevere.

Donna could not rely on social or academic interactions with her African American male peer because of his own insecurities. Being the only African-American woman for a time while she was enrolled at her doctoral institution, she had to branch out and form study groups with others outside of her race and gender. In the following brief excerpt, Donna describes her experience:

> I joined the study group with some of the White boys. Rick [her African-American male class peer] wasn't going to work with me; so I was like, "Okay. I'll just leave him alone."

Later, she mentions that even after she graduated from her doctoral institution, she had to continue to be pluralistic in forming collaborations. Though the "White boys" accepted her

within their study group during her doctoral coursework, she had a difficult time transferring that into life outside of the doctoral institution. In the following excerpt, she relates how she had to connect with international, or foreign, researchers in her field in order to establish a name for herself:

> For research in general, yeah well not as a student, but when you get out and start working you're supposed to get your own funding; and do stuff and establish a name for yourself. So when I first got out, I collaborated strongly with the foreigners because it was difficult for me to get into the cliques with the White boys. So I would be working with the foreigners. It could be anybody, Indian, German, French, wherever. But then once they got to a critical mass, they didn't need me anymore. Then I got shut out by those cliques. But it was like something that happened gradually. It was like I just woke up one day and discovered that was the case. So I had form a certain pattern for how I would work and survive and stay afloat.

Though the social pluralism so critical in the field of physics did not persist even in the working world, Donna had utilized a vital mitigating protective factor while in graduate school.

Jenni also revealed that social pluralism was important to her survival in graduate school. Since she was the only African-American woman in program, she figured out that she would have to work with others to succeed in tackling demanding coursework and being successful in the laboratory. Because Jenni also understood that pluralism doesn't negate

interactions with same-race peers, she was also instrumental in forming an organization that enabled African-American graduate students to come together socially to support one another. Excerpts of her experience follows:

> I don't think that one was more supportive than the other. I think that my support came from, as far as peers, came from three places – the students in my department and my lab, the black graduate students at the university, and the student who I met and stayed in contact with at the annual black physics conference.

Pertaining to the doctoral physics coursework, Jenni points to women as her main support system. The following excerpt is her recollection of this experience:

> My first year at my doctoral institution, we had five women out of the fifteen and that was like huge. …So the five of us came in together and we are all pretty friendly. …People were more willing to work together. It wasn't as much like, "You're my competitor." It was more like, "You're my classmate and we can work together." So that made a huge difference in how much I learned and how I was able to do in the classes.

In addition to her need for sociability, Jenni's department fostered interaction with graduate students by hosting a daily afternoon social event, which was helpful for disseminating information on research advisers and laboratories. The following excerpt is her recollection of this experience:

> Every day at three o'clock we had cookies and tea …At three o'clock we all come down and socialize and sit and talk about whatever is going on, water cooler talk, or you could talk to people who were much further along than you about graduate school or picking advisers. So when I said I think I want to work with professor so and so and they were like, "Oh, you should talk to Mike." So I talked to the Dutch guy and …then they tell me stories about people who've left, the people who have graduated or didn't graduate, you know what it's like to work in the other labs. So you could get this informal mentoring every day at three with some free cookies. So that was very helpful.

Upon entering the laboratory, Jenni mentions that she was able to connect with at least one international student, a Chinese male, who was able to help her in the lab. The following excerpt is her recollection of this experience:

> In my lab I was the only non-Chinese person in the lab. Everybody, all the grad students, the post docs, my adviser, and even the visiting scientists, were all Chinese. …My good friend …the Chinese kid, he was very helpful and friendly. So he did all of his work and he did really novel stuff. He's got two patents I think. He had a wife who was in material science but did her research in our lab. I would think he probably did like a good quarter to half of her work. She's a very nice girl, but she never struck me as super bright but he definitely helped her a lot. He helped me a lot. I would say he gave

> me like a ten percent boost on things that I would have to go back and do from first principals, reinventing the wheel. He's like, "No, no, no. You do it this way. You do it this way" -- that kind of stuff.

In addition to connecting academically to other races academically, Jenni felt the need to also connect with other African Americans. The following excerpt is her recollection of this experience:

> I was also active in getting a section of a black graduate students' association formed and off the ground and getting other students to come out of their labs and come out and socialize. … And initially, the point of the black graduate students' association was to get people to come out of their labs, see another black face and eat some pizza, and that is what we did. And that was tremendously helpful …to come out and see other black graduate students who could relate to your struggles because, "Oh, tell me about physics, I'll tell you about chemistry. This is the crazy thing we do over here. This is the crazy thing." It was very de-isolating. You didn't feel like you're the only one going through this. You knew that there was somebody who understood.

Jenni's last support structure was same-race peers at the National Society of Black Physicists meeting. The following excerpt is her recollection of this experience:

> Just when you feel like everything is horrible and it's terrible and I'm never going to get out of here and keep me forever, you go to this conference and you meet old friends who you know from this conference for ten years or so

> and you hear about their problems and struggles and you get reinvigorated about going back and kicking some butt. So it was the combination of all of those that was really helpful.

Thus, Jenni recognized that social pluralism was a valuable protective factor against isolation and attrition while in her doctoral program.

Mae acknowledged that besides being the only African-American woman in her doctoral program, she was also the only African American. Consequently social pluralism was a necessary condition for her success within her program. Mae was able to form study groups with White male and female peers, which developed into long-lasting friendships. Though inclusive interactions were part of her personality, she desired to discover what support structures were in place from the National Society of Black Physicists (NSBP). Excerpts of her experience follows:

> One of the things that I realized was that a lot of the first-year graduate students didn't work in research labs. I had a special fellowship; so that I was already working in a lab, like as soon as I started off. But most of them, I'd say 90 percent of them, actually were TAs. And so in the TA room, there is a big center table. They all had offices….but when they were ready to do their homework, they would gather around this sort of central table. And so the lab I was working in was actually right down the hall; so I would sort of peek down there and see when people were gathered around the table; and wander in and say, "Hey, can I join you?" …I managed to form that group and we've

> been friends ever since. …There was sort of a smaller group that I ended up hanging out with more. … They were all White. …We would meet at each other's houses over pizza or whatever. We would do problems.

In addition to forming lasting friendships with her White doctoral peers, Mae also utilized a national society to gain access to employment because she knew it might be resourceful to her. Nearing the completion of her doctoral program, she realized that not having any publications would be detrimental in gaining employment as a faculty member. Mae's sociability at the NSBP conference enabled her to secure employment despite this shortfall. The following excerpt is her recollection of this experience:

> I went to the NSBP meeting multiple times. At one of those meetings, I was scouted by a faculty member at small liberal arts school who was watching me give my poster presentation; was impressed with how I taught as I presented that information; and invited me out for an interview for a visiting position. Actually he offered it to me on the spot and then said he wanted to convince me to take it. And so, he invited [me] to his school; I gave a presentation in the department; we negotiated salary. …So, they hired me sort of knowing the back story. ..On top of that, the guy that originally recruited me for that visiting position, one of the students in my study group was his advisee when he was a student at that institution; so he know everything about what happened with my adviser. So, he knew that I wasn't making up anything I said. He had independent verification of how much a jerk this guy was. …But

> there's also the part of, "Well, could I have gotten this position if I had applied to a school who didn't know that backstory? Maybe it was just a fluke that everything happened to converge for me to get this position.

Just like all of the above participants, Maria realized that pluralism would enable her success due to being the only African-American woman at her doctoral institution. She was able to connect with both White male and female peers within her program, though she felt more comfortable with the women. In her laboratory experiences, Maria recalled that "Over time even within that group, I'd say there was actually a warmth that developed with a lot of the Chinese students in particular." However, her need for a fully pluralistic social experience led her to be a volunteer tutor for an office at her doctoral institution, which catered largely to African-American undergraduate students. Thus, she utilized another internal protective factor of giving herself in service to others. Excerpts of her experience follows:

> I fell in with a group of three or four folks almost immediately. We were pretty tight. There were two other guys and another woman, and we did a lot of our studying together. Even beyond that real core group, there were another three or four folks that we did a lot of studying together. There was one African-American guy in that group. I did have that sense that I belonged. I didn't have that sense that I didn't have a right to be there. …Yeah …as soon as I got to grad school there were one or two women that I really bonded with and studied a lot with, although at that point then I started

> to study with more men, also. I think I naturally just gravitated toward the women because I had a pretty positive experience with them.

Sociability in forming positive relationships was also revealed in her work with undergraduates at her doctoral institution. Tutoring also seemed to give her a sense of purpose. She shared that tutoring provided her with a presence of other African Americans and a connection to an office that felt like a "home base." The following excerpt is her recollection of this experience:

> I did tutoring for the Physical Science Tutoring Program and that tutoring helped me so much. It helped me because, I had this sense that I was helping people and I always say, whenever you have to achieve something you have to understand it to another level of depth than you do when you're just studying it on your own. I think that helped me feel like my knowledge was a little bit deeper, so it built up my confidence. Then, there were people who were like "oh my god, you're doing your PhD in Physics and you're a black woman" so when I was teaching these black undergrads I meant something to them. And it meant something to me that I meant something to them. Dr. Hale, who ran the Physical Science Tutoring Program, ran that office. Just that office was a place …where you just walk in and it's a little home base so if you just needed to go be around some colored folks. That office was largely about the undergrads. It meant a tremendous amount to me, tremendous. Then, along with that Dr. Russ was part of that same thing too. He was again, somebody

> who just treated me with respect. Based on my undergrad that wasn't my expectation. Those folks treating me so well meant so much. It was big deal.

Thus, Maria was aware of the importance of connecting pluralistically with her White and Chinese graduate peers, but also the value of connecting with her same-race undergraduate peers and administrators.

Sarah knew that social pluralism was beneficial to her success. Her doctoral program held many activities to connect the graduate students socially, such as cookouts and keg nights, but Sarah had to form a social bond with her peers on her own as well. Though Sarah vaguely remembered seeing a picture of an African-American male student hanging in her department, she never actually met him. As a self-described tomboy, she had no trouble connecting to White male peers who were also required to take undergraduate courses during their first year of graduate school, but she eventually connected with females of other races and formed both a study group and a lasting friendship. An excerpt of her experience follows:

> The other two people I made friends with were, [and] there were two other people, …one was a chemistry major who decided to switch to physics; the other one was a guy who went to a small school. They were also in the undergrad classes with me. So we would work together. They were both White males. They were northerners, both from Pennsylvania. The girl, she was actually from Thailand. She was one of the two foreign women in the class. …Our particular class was actually pretty close. We did a lot of things

> together as time went on. The department had its cookouts, but the students, we would have our own cookouts too separately. We would grill; we did movies; we played hockey.

Thus, Sarah connected both academically and socially with peers within her department.

Therefore, participants honed in on the benefits of social pluralism as a significant protective factor while in graduate school. They recognized that they were one of the only African Americans in their programs and utilized the protective factor of sociability to connect with their peers. Though some participants had a need to make a same-race connection, they were also aware that a holistic pluralistic experience was a must have to be successful within their doctoral programs.

Theme 2: Acquiring (and Maintaining) Pluralistic Laboratory Skills

Participants also utilized pluralistic skills in the laboratory. Within the laboratory environment, the participants utilized the protective factors of life skills, involving decision-making, problem-solving, assertiveness, and sociability. These pluralistic protective factors are all situated in the presentation of how the participants acquired and maintained their laboratory skills. In fact, three of the participants, Jenni, Maria, and Sarah, sought out research advisers who sought to develop these pluralistic skills within their graduate students. In general, acquiring multiple skills within a laboratory produces a more competent, and according to Sarah, a more efficient research scientist.

Jenni chose a research adviser that wanted to build well-rounded physicists. Though she grew to question her adviser selection, she mainly wanted to join his group because of

the available funding, research group activities, and the stellar reputation of her adviser. She respected her research adviser's pluralistic approach in educating his graduate students. Excerpts of her experience follow:

> So in some labs one person makes the samples and one person analyzes them and one person writes the paper. He says, "That's no way to live." Then, when you graduate you can't do everything. In our lab you must build your device, build your experiment, analyze it, and write the paper. You do everything. So you need to know how to do everything and how to use everything. So he had these videos starting with how to use a screwdriver, "How to Use a Screwdriver," "This is a Phillips head, this is a flat head;" and so …. we inventoried the lab. We counted how many O rings are in each drawer, how many screwdrivers, how many wrenches, and how many bolts, everything in the lab. He was like, "This is great because now you will know where everything is and what it does. If you pick up something and you don't know what it does then you go and you ask somebody." It is a good way to learn but it was annoying a little bit and that was in between doing our regular research, but I was like, "He's right. This way I will know what everything in the lab is and what it does." So I stuck with it. In his mind, letting you out with a B.S. PhD, a bullshit PhD, is a disservice to you because you're not going to be able to be successful, but other professors go with the mindset of, "Okay, you're here. You're in second year. I'm going to get you out in five

> years. Just pick a project that you can do it two years, give it a year to write and look for jobs and then you're done." He was making a whole scientist, someone who can build a lab, ask the questions, analyze, be part-theorist, part-experimentalist, mentor students, give great talks. He's an outstanding public speaker but, I mean, he taught us all his methods and everything. And then he has definitely helped me in my career subsequent.

Maria also bought into the notion of pluralism in the laboratory. She selected her research adviser so that she would be able to learn a gamut of laboratory skills. Maria wanted to leave her dissertation program with a variety of skills. An excerpt of her experience follows:

> I liked a couple professors, but the one thing I liked about the professor I chose, was that everybody did everything. In some research groups this person did this type of measurement and this person made the materials and this person did this other thing and in this group everybody did everything. I liked that a lot. That's why I chose that group.

Sarah pointed to her research skills as a strength. She wanted to be in the laboratory. She wanted to be a sponge and soak up all there was to know. Pluralistic skills in the laboratory meant more than learning the equipment, it meant being able to exist without help from anyone else. Consequently, she also learned to purchase items, a task often left for administrative assistants. An excerpt of her experience follows:

Getting through that initial period was the toughest. And learning the equipment and learning what the results meant when I made something. And I quickly learned to make my space my own. I learned to organize my section the way I wanted; I learned to optimize my equipment the way I wanted, make my own upgrades. I learned to work at night; come in on the weekends on my own. And after a while, I noticed that my mentor was over there once a week to once a month, which I thought was nice because it meant that there was a trust factor. …Well, I learned one of the most valuable things a scientist can learn in my opinion and that's purchasing-- How to purchase what you want; how to find what you need; and how to buy it -- which is no small feat because I didn't think it was that difficult. And eventually, I became the purchaser for the lab. I kept it stocked. And that's not trivial because you need to make sure you got what you need when you need it but you don't want to overbuy and learn to look for pricing and not everything is easy to find; so you have to find the company. I learned some programming that I didn't know before. …I learned the adage that time is money. Sometimes it's better to buy what you want rather than to make it because of the time it takes you make it and optimize it is the time that you could've bought it and be using it. I learned the importance of having the proper tool when you need it as opposed to kluge something together as we would say. Duct tape doesn't fix all evils. So, I learned to check behind myself. …I also learned to share

> my space a little bit because there were other people in the lab. It's not a huge lab it's about the size of this room, a little smaller and we all had our own equipment and there might be something that somebody would need to use that I have or that I need to use that they have. I learned the value of returning other people's equipment and having my equipment returned. I learned the value of research; looking up papers; trying to think outside of the box. And I learned to be a sponge.

What Sarah meant when she related that she learned to be a sponge was clearly crystallized by a speech given at a colloquium by a former doctoral physics graduate, who had since started his own business. She recalled that one of her graduate peers asked him what was the most valuable thing he learned in graduate school; and he said, "To be a sponge." This experience deeply impacted the way she operated as displayed within the next excerpt:

> And I remember that to this day because of the way he said it and how he went to explaining about, "Learn from your secretaries. Learn from the people who work under you; learn from the people above you because there's always something more you can learn and there's always something they can teach you." So I learned it just by listening to him, but then I had to go back and practice it. If somebody has something that they can do that I can't do, I usually ask, "Well, how did you do that? Can you teach me?" or "I am willing to learn that! Can you show me how to do that?" One of the guys who worked in the lab, he was actually an older gentlemen, a former president of a

> small company, and he is a vacuum science expert, he gave a little seminar for us, all of the students. I have all of his notes to this day. So I think as a scientist I just learned so many things; I'm sure I cannot voice them all. I learned working with others, and I've always known how to do that, but sometimes you get a lot of egos in the room, and you learn to let someone else do it and not feel the need to just reach in and grab it. And I learned -- I think the biggest thing was learning to trust myself. Learning that, I've been turned loose in the lab. It's okay, even if I break something --even if I set something on fire -- it's okay. As long as I have a plan, it's okay.

Therefore, the use of pluralistic skills within the laboratory environment enabled these participants to take on other protective skills, such as self-confidence, competence, and even a degree of independence. Each felt that these skills would translate well into the work world. These laboratory experiences, though fraught with the challenge of having to learn so many things, enabled these participants to grow as physicists.

Theme 3: Utilizing Pluralistic Problem-solving

Three participants also used pluralistic internal protective strategies to mitigate potentially negative outcomes. Specifically the protective factor of life skills, encompassing assertiveness, decision-making, and problem-solving capabilities, was utilized by Donna, Jenni, and Mae either before entering or nearing the completion of their doctoral programs.

Sometime before her dissertation defense, Donna learned that one of her committee members was extra demanding on the graduate students of faculty researchers he tried to

impress. Her only option was to use a pluralistic strategy to off-set any negative input from him during her defense. Not only did she make sure she was prepared for questions concerning her research, but she also developed a pluralistic strategy using the "Six Phases of a Research Project," which are 1) Enthusiasm, 2) Disillusionment, 3) Panic, 4) Search for the Guilty, 5) Punishment of the Innocent, and 6) Praise and Honors for the Non-Participants, to distract this committee member enough so that she could successfully defend her dissertation. An excerpt of her experience follows:

> So I just decided, instead of just being on the defensive, to attack. Put him on the defensive. … I was worried about Lamvir, so I set it up so that I distracted him during the defense. What happen was…you know they have these six phases. …So that was the way I structured my defense. I started off with enthusiasm. This is the problem, I'm excited, then, you know, here's the disillusionment; here is the problem; and then here you are trying to solve the problem. Perseverance was the, let's see, panic, perseverance, and the fifth one is something. Then the last one is praise and honor for the non-participants. So that was the way I structured the telling of my thesis. When I'm going through, you know, everybody knew the six phases, right. So they're expecting me to say something about like praise and honor for my thesis adviser. I get to that point; and I go, "Praise and honor for Lamvir for …" – Inadvertently, I had borrowed equipment out of his lab from his student, right? I said, "I want to …take this opportunity to thank Lamvir for

> inadvertently supplying half of the equipment I needed to complete the experiment!" So during the defense portion all he could do is ask, "What did you borrow from my lab?" So he was incapacitated. Then this other guy started questioning me and …the other thesis adviser jumped into it eventually, told the guy, "You're wrong." You know, like I was getting ready to answer; Stephen jumps in and starts arguing, "You're wrong! You're off-base! Blah, blah." Lamvir tells me, Donna just shut up. You got the experts arguing with each other. So he was really in my corner at the end of the day; and it worked out okay. ... He ended up being in my corner so that was good, maybe because he wanted to get his equipment back, I don't know. But, yeah, I just thought about it like, "Okay if I can't get him off the committee, then go on the offensive." So that's what I did, and it worked.

Therefore, Donna successfully utilized a pluralistic approach to mitigate any negative behavior from one of her committee members during her defense.

Mae also utilized pluralistic problem-solving strategies during her defense. After witnessing how her research adviser and his wife reduced their graduate students to instruments of war to battle one another, she paid close attention to how her laboratory partner made it through his defense. Because she had a strained relationship with both her research adviser and his wife, who was also on her committee, she called on her problem-solving capabilities to move her dissertation discussion along, utilizing a successful strategy from her lab partner's defense. However, when that failed, she quickly developed a strategy

to make it through her defense. Therefore, she utilized three distinct problem-solving strategies: 1) ensuring that one committee cared about her success; 2) utilizing a previously successful doctoral defense strategy of going into closed door session; and 3) maintaining a strategy of silence during arguments between committee faculty. An excerpt of her experience follows:

> Obviously, he was on my committee; and his wife, even though I didn't want her on my committee, was on my committee. Actually, the guy that ended up being my postdoc adviser was a person in electrical engineering; he was the person I actually wanted. The outside department person, he was the person I wanted. He came to my defense, and he actually asked good insightful questions. But, anyway, so him and his wife and then there are a couple people who were sort of general specialist signal processing in the physics department; and so one of those people was a member of the committee. And then, there was a guy who was on my comps II committee so proposal, he was selected there. …So, during the defense, my adviser let me run the entire thing, which was sort of fine except I was getting questions from her where she was never satisfied with my answer. … It was dragging on the length of my presentation and it wasn't going anywhere, so I said, "Umm, we should probably discuss this further during the close door portion of my defense so that I can continue this." But, she just kept coming back on this one issue, which is interesting because it's the same issue that when my labmate was

defending, my adviser had asked him the exact same question and badgered him on that question. And, I gave the exact same response plus some. …It was very strange, and, she actually stepped in during my lab partner's defense and said, "You know, we should discuss this later. So, she actually stepped in and went behind closed doors." I talked to my labmate later and he said that it was rough. It was really rough. Basically, my adviser was going after him and everybody else was like, "Back off!" So I'm not sure what was going on there. So in my defense, she was doing the exact same thing to me. He didn't say anything. I was the one that cut her off. And in the closed door part of the meeting, she started up again and basically she and one of probably the most senior members of my committee were actually having an argument for about 20 minutes. I sat back and watched them because it was lunch time and I knew that they would probably get hungry. And I knew that they probably had to go to other things, so I just let them eat up time. So they went back and forth and the issue was why should people use the technique that I'm using to solve problem as oppose to some other method of solving this problem, which is a very good and important question; and I had answered that question, but I don't know what she was looking for, but I wasn't giving it. And she was going back and forth with this other physics faculty member. And, basically what he said at the end was, "We're physicist. We don't have to justify

anything that we do." And therefore I didn't have to add a chapter to my thesis explaining why our method was better than others.

Jenni also utilized a pluralistic problem-solving strategy to ensure that she selected a graduate institution that catered to African-American students. She learned her lesson regarding attending a prestigious institution that had no established record with African Americans. She utilized the National Society of Black Physicists to locate a new doctoral institution once she obtained her master's degree. Jenni expressed that she wore an ivy-league sweatshirt as an additional strategy in order to be favorably recruited by the doctoral institution of her choice. An excerpt of her experience follows:

> Here's what I did. This was January. I found out I didn't pass. I signed up to go to the National Society of Black Physics Conference. …I knew if I went to that conference, I would find graduate schools that were looking for black students and that is what I wanted. So I went and printed out all my resumes, I put on my Ivy League sweatshirt and I went to see every table that was there. And I happened upon a table of my doctoral institution and they had not one but two black students, two black students! … They had not just two black students, they had two black students, a White girl, and an Asian American guy; and they had a young professor. All of them had come to promote this institution and they were happy. Because at my master's school the graduate students were not happy and the undergrads were just like giggly and playing in the sunshine. They were just so happy, they had a great time. At my

> doctoral institution the graduate students were pretty happy and the undergrads were sad and mopey. It was ranked like the second least happy undergrad. You know, they do the party school listings. It was almost the lowest in the country. Undergraduates are miserable there but the graduate students are reasonably happy. So I meet these four happy physics graduate students and this young professor and even though it was past the deadline he said, "Prepare your application; send it to me directly; I will get the committee to look at it," and he did exactly that and I got in. In the beginning I think they were always happy to have me because it was a novelty and they are very liberal in that way, but it wasn't in any means easy to finish the degree, but had it not been for that conference, I would have just been applying blind yet again.

Thus, Jenni was successful in finding a doctoral institution that would be invested in her success through her use of pluralistic problem-solving.

Therefore, these participants were able to utilize pluralism in a literal sense to mitigate negative or un-established barriers. Using protective life skills, inclusive of problem-solving, they were able to both examine a potentially negative situation and find multiple ways to extinguish the negative consequence. Their use of pluralistic problem-solving propelled them to successful doctoral completion.

Theme 4: Forming Pluralistic Support Connections

The third step in the Resiliency Cycle is to have protective factors work in concert to propel the student toward high academic achievement. This theme also reveals how all five of the study's participants facilitated their resiliency through the literal formation of pluralistic support connections. The most significant protective factor utilized for this step is not internally protective, but externally desired. This means that each participant looks outside of herself for support or validation. Various external protective factors come into play for these participants, such as connecting with faculty who:

- Utilize high-warmth, low-criticism style of interaction;
- Encourage supportive relationships with many caring others;
- Provide leadership, decision making, and other opportunities for meaningful participation; and
- Appreciate the unique talents of each individual

These protective factors were often manifested in the form of encouragement.

For African-American women in physics doctoral programs, encouragement seems to be important, whether or not a faculty member was formally assigned to the participant. Each participant identified a time when the support, validation, or simply encouraging words of faculty course mentors, research advisers, course or laboratory peers, or even deity were just the thing to press them onward to successful completion of their degree.

Donna described her second research adviser as extremely supportive. Due to having a poor relationship with her first adviser, she had come to esteem compatibility over her

research area. Before she graduated, she was considering leaving the field because she wanted to work in photonics, an area that physicists at her doctoral institution frowned upon for not being fundamentally pure. Despite the prevalent mindset within the department, her adviser encouraged her. An excerpt of her experience follows:

> I asked him if I should stay in physics; and what he did, he pointed out that I wasn't like the other guys, right? He said, "Well, you know you have some skills that they don't have." So he thought I should stay in because… [I was] trying to do something that was practical in that environment that's crass. So I'm thinking, "I want to do photonics. Take this stuff and use it." I was asking him about that, and he says, "Well, yeah!" He was encouraging there, and I said, "Well, do you think I should stay in physics? He says, "You know, you bring a different set of skills that's very unusual, and yes, you should stay." I felt I was very encouraged by that. He was encouraging despite the snobbish environment [of looking down on any area that is not pure physics]. He was encouraging me to stay and continue trying to find my way in this field!

Donna also remembered that when she initially began her program, she received encouragement through some of the peers in her co-op, including one older male, African-American doctoral physics student:

> So I was in the co-op because there was another black physicist there and his wife, stuff like that. Then I had that support structure the first few years. That I was there I was in that co-op. …We socialized. So those were the good

> years; and then eventually the house broke up; and Ridgland graduated and took another job somewhere. So after that was when I moved into my own apartment or I moved into another house with some other folks. By then we had a bunch of these guys that came along. Then there was a few of them playing that game of they are insecure; so they're going to try and make you feel worse. I sort of went through a period where some of the follow-on classes were playing that game with me.

However, Donna does mention that she was instrumental in bringing in many other African-American students by chairing the graduate admissions committee at her institution. She also revealed that 100 percent of her recommendations for admission were accepted into graduate school.

Jenni had the encouragement of her research adviser at her Master's institution and other departmental faculty members were supportive mentors at her doctoral institution. Her research adviser at her Master's institution was a young man who believed in her abilities as a physicist. After she did not pass the qualifying exams for the third time, he encouraged her to keep going. Excerpts of her experience follow:

> My research adviser at my Master's institution still believed that I would be a good scientist. He knew what I could do in the lab. He knew that that exam was somewhat political. The passing mark was set based on which professors needed certain students to pass. Professors have seniority or tenure; he was a

> young professor. So he encouraged me to apply to other schools. … He definitely encouraged me. He wrote strong letters for me.

At her doctoral institution, Jenni found that she could not rely on her doctoral research adviser for encouragement, but she found encouragement in other faculty. Jenni found helpful words of advice and support from an international faculty couple within her department who were husband and wife, and a White male professor at another institution. An excerpt of this experience follows:

> There was one couple, and they were married -- I guess that goes without saying-- they were both supportive. They were supportive towards all the female students probably because she was one of the two female professors there. So when we had difficulties we would go talk to them and they would give us advice and they were very helpful. The professor that I met at the conference, he was very helpful and supportive. He ended up being chair and the dean and now he is president at some other school. …The couple was international. I think they were…Greek. And the professor who I met at the conference was a White professor from Middle America somewhere.

Jenni was also instrumental in bringing to campus an Association for the Concerns of African-American Graduate Students, to bring together African-American students from various departments to serve as support systems for one another.

Maria proclaimed that she received encouragement and validation though her father and her research adviser while in graduate school. Maria and Sarah were the only two

participants whose parents, both father and mother, had earned PhDs, though not in the field of physics. Maria's father, a chemist, propelled her forward by giving her rational advice regarding the dissertation process, especially after she failed her qualifying exams. An excerpt of her experience follows:

> That was one of those times where my Dad said, "That happens." That people don't always pass all their qualifiers. He just said, "That's the way it goes." I think there was an acceptance, which I probably didn't even appreciate then, and I appreciate a lot more now. I think they knew the insanity of what I had decided to do, which is "Who in their right mind gets a PhD in physics?" It's ridiculous. … I still say this over and over and over again, which is something my Dad said to me, which is "There's no such thing as a super PhD." His feeling about a PhD is either you finish it or you don't. If I stumbled, I think he did encourage me that it didn't matter so much, as long as I was making progress. That was tremendous.

While the words of Maria's father were helpful in making it through the doctoral process, the approach by her research adviser validated her identity as a physicist. An excerpt of her experience follows:

> It was really just the fact the he challenged. He was explicit about positive feedback, in some really critical moments. When he was pleased with something, he would say it, he would acknowledge. Like that talk that I mentioned about, he was so proud of me, and he said it. He didn't just walk

away and smile. He told me, "Wow, you did a great job." So yeah, that was a big deal.

Lastly, both Sarah's course and research advisers gave her words of encouragement during the most challenging times of her doctoral process. Her course adviser encouraged her when she most needed it after failing the qualifying exams. He made sure that she understood that the faculty committee reviewing the exams were not out to get her, but interested in her success. An excerpt of her experience follows:

> Well two years in, you can take a test that says you have mastered the bookwork enough to move on to your research. … That was the last obstacle was getting through that test. Because the first time, my mentor came down and said, "Well, you didn't pass it, but you take it again. You got close, and, you know, we felt like you'd be fine," and I was like, "Okay that's fine." For 24 hours though, you feel really despondent and stupid. And you're like, "Oh, God! I don't know if I can do it again!" Then you just suck it up and like, "Alright I'm not a total failure. I didn't completely fail the test. Let me just pick up what I didn't get and refresh in places that I did get and just focus more." So the second time around, I went into that test and I was just like, "Damn it, I'm passing this thing because I'm not doing it a third time!" And actually doing it a third time, you have to request anyway because if you don't usually pass it a second time, you get a masters and they let you go. And failure at the point just wasn't an option. … My male mentor even said after

> the second time I passed that the committee who was reviewing the test was happy that I'd passed. To me this isn't as big a deal because to me it's not necessarily about being liked, but they did say that they were happy to see me pass because apparently I was well liked in the department; and I guess they wanted to see me succeed.

Adding to the culture of care that was prevalent in Sarah's doctoral department, her research adviser also provided her encouragement while she was acclimating to the laboratory environment and when it was finally time for her to defend. An excerpt of her experience follows:

> Right around the time that my research adviser told me that I was going to defend… that it was time for me to go. I started feel self-conscious like, "I'm not ready. I'm not ready. You can't turn me lose on the world!" And I don't know if it showed on my face or if someone told her that I was acting nervous, but the next day she came in and we talked about some stuff. And she said, "You know, I just want you to know that you're ready for this. I wouldn't turn you loose if you weren't ready. You'll be fine." And then my male adviser, the first couple of years, he said, "You can do this. You were close the first time. You'll get this!" When we were going over stuff, he was very supportive and very helpful. I would say that in those instances, it was the little, subtle things that I probably didn't think much of that made me feel the best because they were a boost when I needed it.

Mae was the only participant who did not mention receiving encouragement from her research adviser or any departmental faculty. She did mention a postdoc adviser in the electrical engineering department favorably, but she related that her core support system came from her laboratory peers. She acknowledged that they were extremely supportive through her doctoral program. In an excerpt of her experience, she relates that they were:

> Very, very supportive! You know we'd just hang out and chat. And you know, we worked hard in the lab together, but we would also go and do things outside of the lab together. And, it was a nice group. …I just felt like one of the guys. …It's not like they made me feel like a guy or that I needed to be a guy, but I was just of the one of group.

Mae also mentioned that God was a key source of support. She believed that God called her to enroll in graduate school and he would provide her a way to succeed there. An excerpt of her experience follows:

> I would say the biggest thing that helped me get through was my belief that God told me to go to grad school. I can't explain it more than that. I felt like told me to go to graduate school; and since I really didn't have any like long-term goal that really required a Ph.D., I was planning to go back and teach in middle school and high school. I didn't need a Ph.D. And, therefore, if God wanted me to get a Ph.D., then He must have some reason for it; and therefore, He would figure out a way for me to finish. So in some sense that's

what I relied on. My faith that God had a reason for this and that He would get me through it, however that happened.

Therefore, having pluralistic support structures, which provide encouragement, including invisible support structures, such as deity, were significant for the study's participants while in their doctoral programs in physics. Having external protective factors help mitigate the obstacles within the environment and provide on-going support was important to their meeting their completion goal. Finding anyone with both formal and informal ties to believe and validate their ability made a difference for these women.

Chapter Summary

The results of this chapter are presented within a composite rendering of the lived experiences of African-American women who completed doctoral programs in physics. The lived experiences of these participants were introduced within the participant profiles which were presented before the results of how each participant defined resiliency. The six main obstacles for these study participants were next showcased before a presentation of four emergent themes connected to social and literal pluralism. These themes revealed how these participants utilized pluralism to facilitate their resiliency while in these doctoral programs. Each theme was presented within three steps of Morales' (2000) Resiliency Cycle and utilized both internal and external factors. The next chapter connects the results presented in this chapter to the literature and as well as significant implications for future African-American women pursuing a doctoral degree in physics in the future.

CHAPTER 5: DISCUSSION AND IMPLICATIONS

The purpose of this phenomenological study is to explore the resiliency of five African-American women who graduated from doctoral programs in physics. This study is grounded in the paradigm of educational resiliency, which Morales and Trotman (2004) propose uncovers the process and results of an individual's story of success through obstacles that had impeded others. The findings of these five interviews indicated that African-American women who completed doctoral programs in physics are challenged by obstacles while in graduate school. This is consistent with research literature on African-American women in doctoral programs (Fries-Britt & Holmes, 2012; Johnson, 2011). In this study specifically, obstacles are connected with gender, race, autonomy, assertiveness, forming study-groups, and passing qualifying and defense exams. Though more internal protective factors were utilized by these women than external protective factors, both types of protective factors were invoked to overcome challenges.

The participants facilitated their resiliency utilizing pluralism. Four emerging themes, both social and literal, were identified regarding the use of pluralism: 1) Forming pluralistic peer connections (social); 2) Acquiring pluralistic laboratory skills (literal); 3) Utilizing pluralistic problem-solving (literal); and 4) Forming pluralistic support connections (social and literal). Consequently, the next section of this chapter presents a discussion of both the obstacles and themes in light of the prevalent research. Within this discussion, these obstacles and themes are presented in smaller sections headed by characteristics and protective factors of resiliency. Preceding this section, the researcher presents salient

conclusions based upon this discussion as well as a process paradigm, which became evident from the discussion of this study. Following this section, implications are provided for future African-American women pursuing a doctoral degree in physics as well as doctoral program faculty and administrators seeking to retain these women in physics. Lastly, recommended future research topics round out this chapter.

Discussion

The framework of educational resiliency was applied to African-American women who completed a terminal degree program in science, specifically physics, which is often described as a White, androcentric discipline fraught with bias for women and minorities (Bug, 2003; Chubin, 2007; Fries-Britt & Holmes, 2012; Malcom, Hall, & Brown, 1976; Morales & Trotman, 2004; Ong, 2005; Ong, Wright, Espinosa, & Orfield, 2011). Within this study, one premise for challenges within the graduate environment is the notion of the double-bind (Malcolm, Hall, & Brown, 1976; Ong, et al., 2011).

Educational resiliency deals with both internal and external (or environmental) protective factors. Generally, protective factors positively permeate any successful experience, which involved overcoming stress and risks, thought of as obstacles caused by the double-bind. The findings of this study reiterated Morales and Trotman's (2004) statement that resiliency is a "very personal journey and process" and that "no two resilience experiences are exactly the same" (p. 153). Still, these researchers realize that there are commonalities among the experiences of students who have been successful, and these

commonalities are portrayed throughout this study, both in the challenges, or obstacles, faced and in the ways the study's participants surmounted these challenges.

Resiliency literature on education relates the dispositional, family, and community characteristics leading to resiliency (Benard, 2004; Henderson & Milstein, 2003; Morales & Trotman, 2004; Thomson, 2002). Dispositional characteristics are enhanced by internal protective factors, which lead to personal strengths encompassing social competence, problem-solving, autonomy, and sense of purpose (Benard, 2004). However, depending on how some protective factors are utilized, these may be injurious when utilized in inappropriate settings, examples of which are autonomy and assertiveness. Other resiliency characteristics, such as family and community are discussed in relation to support systems, which involve external protective factors. The literal and/or social meaning of pluralism is also discussed in relation to these characteristics. Therefore, the discussion within this section focuses on resiliency characteristics regarding the obstacles, themes of pluralism, and how the participant experiences tie to extant literature.

Disposition: Social Competence

The ability to form meaningful relationships is an outcome of possessing social competence. Social competence includes dispositional characteristics of caring, communication, positive temperament, and altruism (Benard, 2004). Social competence was utilized by study participants in a number of ways. In fact, sociability, as Henderson and Milstein (2003) termed it, is a dominant protective factor in this study. It surfaced as a means for the participants to form valuable peer relationships, such as study groups and

friendships, which enabled them to overcome the challenges of coursework and the stress of exams, such as the qualifiers. Congruent with the literature on African-American students in doctoral physics programs, study participants often connect with peers to form study groups for coursework and to pass the qualifiers (Chubin, 2007; Fries-Britt & Holmes, 2012).

Sociability was also instrumental in obtaining a pluralistic experience that also connected these participants to peers and faculty members to propel them through the program. All participants related that connecting with peers was instrumental in assisting them with matriculating through their program. Connecting with peers was also helpful in securing information on potential research advisers. Four study participants, particularly Donna, Jenni, Mae, and Maria, highlighted the importance of tapping into especially seasoned peer connections, whether or not they actually heeded the advice themselves while in their doctoral programs. This finding is in concert with the research that affirms supportive peers enable women and minorities to navigate the graduate school policies and culture (Dean & Fleckenstein, 2007; MacLachlan, 2006; Mwenda, 2010). However, MacLachlan's (2006) study emphasized that often minority women find it hard to connect with their graduate peers. Though this was true for some of the participants initially, eventually they became proactive in forming these connections.

Social competence was also revealed in their social pluralism ability, or their ability to positively interact with an array of cultures, including their own. All participants mentioned interacting with peers different from themselves, whether the dominant culture in America or foreign nationals. Morales and Trotman's (2004) work presented

multiculturalism as "…a variety of thoughts and ideas intended to expand opportunity and content" (p. 31). Three participants, Jenni, Maria, and Sarah, mentioned an array of cultures from which they were able to select peers, but two participants, Donna and Mae, specifically mentioned that their study group consisted of only White peers.

In Donna's case, her study group consisted of only White males due to being ostracized because of her gender from the African-American male peers in her doctoral program. Donna related that only one African-American male student, a few years ahead of her, within her co-op was helpful during her coursework. This affirms Jordan's (2006) finding and coined term of "isolation within isolation," where mainstream (male) scientists, which in Donna's case included many of her same-race male counterparts, intentionally isolate female scientists (p. 24).

However, gender was the most cited obstacle. In addition to Donna, three other participants, Jenni, Mae, and Maria, cited gender bias or sexist practices within the laboratory or at major physics conferences. Jenni and Maria especially mentioned, as Fries-Britt, Younger, and Hall (2010) pointed out, that they had entered into a "never ending proving process" based upon their gender. Though these women were socially competent, gender may continue to threaten their resilience in this science field in the future.

Mae is the only participant to specifically rely on her course and laboratory peers as her main support system while in her doctoral program. Research has already substantiated that when departmental mentors do not rise to a student's mentor expectation, then the student will enlist the aid of an external female mentor from family, sorority, community, or

church for psychosocial support and encouragement (Patton, 2009). However, most of the participants used a combination strategy in connecting with both faculty and peers to obtain information.

Therefore, all participants relied on their social competence to form socially plural relationships to succeed. Their sociability provided the backdrop to their success as it enabled them to continue to utilize other pluralistic abilities. Without their social competence, these women would have been entirely alone, which is detrimental in a doctoral program in physics.

Disposition: Problem-solving

Related to an individual's disposition, problem-solving is another protective factor of personal strengths. Henderson and Milstein (2003) describe problem-solving, under the protective factor of life skills. The ability to plan and execute a plan was a familiar tale for three of the participants, Donna, Jenni, and Mae. These women used pluralistic strategies to succeed. Donna and Mae both utilized strategies in relation to defending their dissertations. Jenni utilized two strategies to secure admission into a student-and –minority friendly doctoral institution. Thus, they utilized multiple strategies to secure their intended outcome. Strategic problem-solving was not a cited theme in any of the literature on African-American women in doctoral science programs, however, Johnson-Bailey's (2004) article relates instances where African-American women in graduate science programs may strategically band together to succeed amidst challenges. Ong (2005) also related that women of color at the undergraduate and graduate levels may utilize fragmentation or multiplicity strategies,

which allow them to fit in or stand out, to problem-solve the obstacles of being, or seeming, a female minority in the White, male-dominated environment of physics.

Disposition: Autonomy and Assertiveness

Autonomy (independence) was a protective factor for three participants, Jenni, Maria, and Sarah, especially in relation to skill plurality. These women wanted to have multiple skill sets when leaving their doctoral programs so that they could be as autonomous in the real world as possible. Consequently, these participants sought multiple skill sets within their laboratory training. For these three participants, being in a lab that allowed the acquisition of just one skill was not agreeable to them. Instead, they intentionally hunted for research advisers who developed their research groups holistically. This plurality of skills was considered important for their transference into the real world, where it was likely that the environment would be more hostile than the environment they faced while in graduate school. This plurality of skills is an un-established finding within the prevalent research. The researcher could find no other study that discussed the value of acquiring multiple laboratory skills within a doctoral program in science; however, this embracing of independence and self-reliance does coincide with a finding within MacLachlan's (2006) study.

According to Dean and Fleckenstein (2007), all women must be assertive in order to succeed in a science environment. Being assertive often leads to positive outcomes for women in any science environment. For example, Mae is the only participant to witness sexist behavior in a laboratory environment while on rotation. Mae demonstrated a high

degree of assertiveness by removing the sexist material from the lab computers, but interestingly, she never reported the behavior. Perhaps this was due to not wanting to cause a problem because she was the only African-American woman in the group. Johnson (2011) explained that women of color in science environments want to feel a sense of belonging and to be on equal footing with peers. However, despite her assertiveness, due to not reporting the behavior, it continued in that laboratory causing Mae to select another more "wholesome" lab group.

Though it is not entirely clear within this study, it is likely that all of the study's participants developed some level of autonomy and assertiveness throughout their previous educational experiences, which they may have believed would translate well into situations within the graduate environment. These personal strengths, highlighted in regard to dispositional characteristics, challenged the doctoral success of four study participants, Donna, Jenni, Mae, and Sarah. Autonomy and assertiveness arose as two damaging, or unprotecting factors when incorrectly utilized in a graduate setting. The researcher termed "unprotecting factors" as factors that appear as a protective, but in the end may have caused negative consequences to the participants during the doctoral process. Therefore, protective factors must be continuously refined throughout life. This validates Thomsen's (2002) finding that resiliency is a "lifelong process" and the participants continue to develop and hone skills throughout their educational process that have worked in the past (p.171). Throughout this process, resilient individuals must learn to identify which environments these acquired factors may be unprotecting.

Autonomy was utilized by two study participants, Jenni and Sarah, in ways that would seemingly protect them from naysayers; however, utilizing this factor in the wrong situations in during their doctoral pursuits put them in a stressful or challenging position. First, Jenni's lack of adherence to her HBCU faculty members advice on initially selecting an "unknown" Ivy League institution in combination with her refusal to heed a veteran student's warning on her research adviser, increased the time to graduation. Increasing the time to doctoral degree posed a completion risk as she also faced numerous hurdles during her time in graduate school. Morales and Trotman (2004) admit that minorities will face challenges moving from "…racial/ethnic environments where they are the racial majority into environments where they are minorities" (p. 35). MacLachlan (2006) also posits that women of color previously enrolled in HBCUs face difficulties once enrolled in predominantly White institutions.

In a similar manner, Sarah's utilization of autonomy in her refusal to get help with her doctoral coursework also caused her temporary hardship and stress. While Benard (2004) associates autonomy with mastery and positive identity, Sarah's reason for not asking for help was predicated on her intellectual image. Jordan (2006) stated that "image is everything" (p. 22); and Sarah seemed to feel that she had an image to maintain. Consequently, she was forced to uncover and reframe her emotional response to receiving help that made her negatively self-conscious (Benard, 2004). Had she not sought help with the challenging coursework, she may have been an attrition statistic despite the overwhelming support available in her doctoral program.

Assertiveness, defined as the inclination to forceful or aggressive actions or statements of self-will or government, is also utilized as a second unprotecting factor within this study. Two participants, Donna and Mae, may have been overly assertive once they were angered by their research advisers. Though Donna's first adviser was what she described as "a total disaster," "the finest asshole," and "a real jerk," her decision to become perceptively irate with him caused her to have to leave an emerging and exciting area of interest, which challenged her to seek another area of interest. Though Mae ultimately stayed in her preferred area of interest, her decision to combat her research adviser and his wife, both committee members, left an irrecoverable strain on her relationship with them. This strain caused her great challenges, which placed a great deal of burden on completing her research and defending it.

Therefore, from the above an understanding is gained that utilizing certain protective factors, such as autonomy and assertiveness, may not be useful in all settings or situations. Instead, a disposition to heed seasoned advice and maintain an amiable relationship with a research adviser may have been more useful in diminishing the stress and obstacles for these four participants.

Disposition: Sense of Purpose

This study supports Fries-Britt and Holmes' (2012) finding that African-American women in graduate physics programs feel a need to give back to their communities. These researchers also posit that African-American women in physics are keenly aware of the importance of being an African-American woman in the field of physics (Fries-Britt &

Holmes, 2012). This is connected to the theme of forming pluralistic support connections to overcome challenges of race. Three participants, Donna, Jenni, and Maria revealed that a sense of purpose allowed them to succeed in their programs, which highlights their need for service. Donna chaired her graduate admissions committee; Jenni was instrumental in bringing an association for the concerns for African American graduate students to her institution; and Maria enjoyed tutoring undergraduate students. "Women who are able to persist and connect with a larger purpose enhance their success and reach a level of perseverance to meet the challenges of the discipline and field to become physicists" (Fries-Britt & Holmes, 2012, p. 214). Henderson and Milstein (2003) also describe an internal protective factor of resilient students as willing to give "self in service to others and/or a cause" (p. 18). All of these things lend credence to anecdotal reports on African-American women in physics (Corley, 2009; Horton, 2010; Nealy, 2008).

Family

Family also served as an externally protective resiliency characteristic within this study. Family support fits into the protective factor of valuing and encouraging education (Henderson & Milstein, 2003). Though it was not a significant part of their story, all participants cited family as a means of encouragement while in their doctoral programs. All participants related that their families were unaware of what it took to gain a doctoral degree in physics, but they were still extremely supportive. This finding coincides with various studies on African-American women in science having supportive families (Fries-Britt & Holmes, 2012; Hanson, 2004; Hanson; 2007; Ong, et al., 2011).

Only two participants indicated their family as instrumental in their pursuit of a science doctoral degree. Dean and Fleckenstein (2007) argued that most women would have never "entered science without the support and encouragement of their families" (p. 43). Two participants, Maria and Sarah, mentioned that both of their parents had earned doctoral degrees, which gave them special insight into the process. Mae's parents also were college graduates. This finding relates to Fries-Britt and Holmes (2012) finding that "at least one parent … attended college and some parents completed a graduate degree" (p. 208). Also, that at least one parent earned a science degree or influenced exposure to science (Fries-Britt, Younger, & Hall, 2010). Additionally, receiving guidance from family members while in the process also coincides with Grant and Simmons' (2008) suggestion that having college educated parents who exercise professional leadership roles in their homes might give their children "a sense of familiarity with formal educational institutions, and a level of expectations … for these institutions" (p. 510).

Community: Faculty and Departmental Support

Faculty members are part of the external protective factors for this study. They are part of the community, which expresses high and realistic expectations for success and appreciates the unique talents of each individual (Henderson & Milstein, 2003). In line with previous literature (Fries-Britt & Holmes, 2012; Patton, 2009), faculty connections proved to be important for the study's participants, though connections with only one faculty mentor were not especially useful for two of the participants, Jenni and Mae. Donna was the only participant to completely part ways with a faculty mentor due to what she describes as

behavior that "was not right." Therefore, this study did not entirely confirm the findings in extant literature that women of color receive poor levels of support from faculty in doctoral departments (MacLachlan, 2006; Ong, et al., 2011).

Though all of the participants felt as if their resiliency was mostly based on completing the coursework and the qualifiers, three participants, Donna, Jenni, and Mae, had to traverse the graduate waters without having a devoted faculty mentor at one time. Success in a doctoral program and lacking dedicated mentor support are not substantiated in the extant literature. Instead, a number of researchers relate that a close connection to a faculty mentor is important in succeeding through a doctoral program (Chubin, 2007; Fries-Britt & Holmes, 2012; Ong, et al., 2011; Patton, 2009). However, the results of this study indicated that a close connection is not necessary as long as these African-American women connect to caring faculty who will give them advice, which in most cases was not their dedicated research adviser. Grant and Simmons' (2008) work also supports the importance of informal mentors for African-American women. Therefore, a close faculty mentor connection, though desirable, was not necessary to make it through the program.

Two participants, Jenni and Mae, often made inquiries on the advice their research advisers gave them. This seems to coincide with Johnson-Bailey's (2004) finding of the "mis-advisement" that African-American women attending graduate school could receive from assigned, but unsupportive, advisers. This type of mis-advisement could be detrimental to African-American women pursuing doctoral programs in physics if they did not take informal precautions to seek alternative advice from peers inside and outside of the

institution as well as other faculty members. Consequently, this study reveals that African-American women would look elsewhere to acquire programmatic and research advice, especially if encountering difficulty with their research mentor. This is especially true for Donna, who published a research paper with another faculty member similar to the publication from which she was excluded by her first research adviser.

An encouraging faculty member, though not particularly the adviser, was significant for resiliency in a physics doctoral program for African-American women. As stated above, though they did not need to be particularly close to a mentor, these women seemed to be dependent upon various, amiable faculty members who would give them advice and point them in a positive direction. This was especially true if they were prone to doubt the advice of their faculty adviser. An encouraging word was also helpful in quenching any doubts of their abilities to succeed in the program. Therefore, more than anything else, encouraging words, in the form of advice and a pep talk, made a significant difference for these women.

This study also validated other research findings that women faculty are important to African-American women pursuing graduate level physics degrees (Fries-Britt & Holmes, 2012; Grant & Simmons, 2008; Patton, 2009). Though Donna, who graduated within the 1980s, did not have a woman faculty member within her department, other participants, graduating in the 1990s and beyond, had the fortune of having at least one woman on their committee. The only participant not to positively engage with a woman faculty member was Mae, whose female committee member was married to her research adviser, with whom she had a strained relationship.

Turner, Gonzales, and Wood (2008) assert that the poor representation of minority faculty may be a hindrance to the success of minority students. The findings of this study did not validate this assertion. As Czujko, Ivie, and Stith (2008) pointed out, these women did not expect to see other African-American male or female faculty on the rosters at their institutions. At best, they were very interested in how the doctoral programs catered to the success of African-American students. For instance, Jenni relates that her HBCU undergraduate faculty only advised their students to attend graduate institutions that were friendly to African-Americans. Though all of these women were the first African-American women to graduate from their respective institutions in physics, at least three of these women, Jenni, Mae, and Sarah, knew they were pioneers, as each were highlighted in news articles prior to graduation.

Interestingly, interview data from this study did not validate any double-bind assertions that intentional bias existed within the classroom or laboratory experiences from faculty for all minority women (Malcolm, 2006; Malcom, Hall, & Brown, 1976; Ong, 2005; Ong et al., 2011). Unlike Fries-Britt and Holmes (2012) findings of faculty babying and overcompensation, often these women expressed that they were treated like everyone else by their research advisers and course faculty. All but one participant, Mae, was able to generate publications while in their doctoral program, though she relates that her lack of publications was not on account of the double-bind, which the researcher inferred to be the reason Donna had difficulty in securing her initial publication. Two participants, Jenni and Maria, even recounted being encouraged to give talks at conferences by their research advisers.

The findings of this study revealed that two participants had a high level of departmental support. Henderson and Milstein (2003) describe this as an external protective factor, which encourages supportive relationships with many caring others. For Jenni and Sarah, the department fostered events that connected them with valuable peer relationships. For Jenni, daily departmental meetings with cookies were very helpful, while Sarah found the array of cookouts and socials beneficial. Unlike the findings in Joseph's (2007) dissertation study regarding African-American women in predominantly White environments, these women felt comfortable in their graduate environment. The other participants did not mention any departmental events that connected them, but it is important to note that no participant mentioned departmental hindrances once enrolled. For instance, Chubin (2007) posits science departments play a negative role in increasing competition for resources among their African American students, but no participant of this study mentioned that competition as a hindrance.

Community: Conferences

Conferences emerged as both an aid and an impediment to the participants' resiliency. However, conference participation is generally seen as a positive exercise. It enables the external protective factor of forming close bonds (Henderson & Milstein, 2003). Closely tied to the internal factor of sociability, participants engaged in organizations and societies that enabled their success.

Aiding resiliency, the National Society of Black Physicists (NSBP) conference was a positive and prominent influence for three of the participants, Jenni, Mae, and Maria.

Racially, the connection to same-race peers going through the same struggle proved to be valuable at the NSBP conference. This finding was highlighted by other researchers (Fries-Britt & Holmes, 2012; Fries-Britt, Younger, & Hall, 2010). Though Donna did not mention attending the NSBP conference, she hailed it as a resourceful environment. The only participant not to mention the attending the NSBP conference at all was Sarah.

However, major research conferences served as a deterrent for two of the participants, Jenni and Maria, on account of critical mass in relation to gender. Lott, Gardner, and Powers (2009) realized that women and students of color desire a critical mass to be retained. Jenni mentioned that race was also a factor at major physics research conferences, which would be an effect of the double-bind. Presently, extant literature does not validate the negative effects of African-American women attending major research conferences in physics. Therefore this is a unique finding.

From the discussion above, this chapter presents a rich examination of the findings. However, a few major conclusions may be drawn from this discussion. The next section presents three salient conclusions from this study and the evident process for resiliency for study participants.

Salient Conclusions and the Process of Resiliency

From the analysis of the findings, three salient conclusions cut across the discussions of this study. These conclusions are helpful to African-American women seeking to enter in doctoral programs in physics and also faculty advisers wishing to help these students succeed while in these programs. Also, from the analysis of the interviews and transcripts, the

researcher has developed a model within the context of Morales' (2000) Resiliency Cycle, which frames the process of resiliency as it relates to the study's participants, detailing what fosters resiliency in African-American women who complete doctoral programs in physics.

First, based upon the discussion, a salient conclusion pertains to necessitated interactions among a diversity of peers and multiple mentors within doctoral physics programs. Interaction provides the antidote to isolation within physics programs, which has been commonly cited in research literature (Chubin, 2007; Fries-Britt & Holmes, 2012; Jordan, 2006; Patton, 2009). Therefore, if African-American women -- who may find that they are the only African American or woman within their program -- desire success, they must choose diverse peer associations and seek support from unlikely sources, including approachable faculty members besides their dedicated mentors. At the same time, departmental faculty who are supportive of diversity must openly showcase their support for these women. The National Society of Black Physicists conferences also emerged as a place for these women to receive support and rejuvenation.

Second, African-American women entering doctoral physic programs must understand when it is appropriate to utilize strategic problem-solving, and at times a multi-layered problem-solving approach, to be successful in navigating their programs. Nowhere in the extant literature was there evidence that African-American women actually utilized strategies to succeed in doctoral physics programs; however, this study showcased strategic ways that participants utilized premeditated and strategic problem-solving to ascertain

doctoral fit, overcome possible doctoral defense setbacks, and to mitigate job market threats after graduation, especially when it came acquiring multiple skill sets.

The third salient conclusion is that protective factors may have limitations based upon setting and situations. This finding also was not established in extant literature. Autonomy and assertiveness, which are generally positive protective factors to aid resiliency in science fields, were utilized improperly in certain situations within the doctoral setting to produce negative consequences or obstacles for almost all of the participants. Therefore, the process of resiliency dictates that women learn to what these limitations are and when to utilize various protective factors.

Lastly, a resiliency model relating to doctoral acquisition for African-American women in physics was established based upon the findings. This model is represented in Figure 2 below on page 172. Behavior and actions depicted by the model flow from left to right. The model begins with the possible creation of a double-bind, influenced by gender and race as well as the culture of physics, which has the ability to affect the process of resiliency for African-American women pursuing doctoral physics programs. The model depicts that other possible forces acting upon these women are obstacles, or risk factors, as highlighted in the "Obstacles / Risks" section in hierarchical order, with the weightiest obstacles featured first. These risks could present an opportunity for the creation of obstacles which impede progress, as well as deleterious stress. In physics, like in all science disciplines, the data seems to suggest that the effects of gender outweighed the effects of race for these participants. In this study, only one participant, Donna, specified that she had any

racist doctoral experiences while in her doctoral physics program. There are an array of other risks that may confront these students, which may include protective factors, such as autonomy and assertiveness.

In contrast, the model reviews that the women were also influenced by pluralistic factors, which provided the major themes of this study that could enable them to mitigate obstacles so that they could be successful in the program. Pluralistic protective factors help off-set/mitigate these major risks factors for African-American women by providing an array of support, skills, and strategies to help them complete their doctoral degrees in the male-dominated field of physics.

Therefore, this model and the three salient conclusions arising out of this study reveal a fresh perspective on women who complete their doctoral degrees in physics. These conclusions shed light on aspects of their experiences that may have been either overlooked or taken for granted by other researchers. These conclusions provide a base for future research within this area for other researchers to explore. Consequently, immediately following the next section, which is on the implications of this study for African-American women considering pursuing a doctoral degree in physics as well as program administrators and faculty seeking to discover what interventions to put in place to enhance the chances of their resiliency, a section on future research is provided to shed light on other aspects of resiliency for African-American women in physics doctoral programs as well as their resiliency once they make it into the competitive and presumably biased job market.

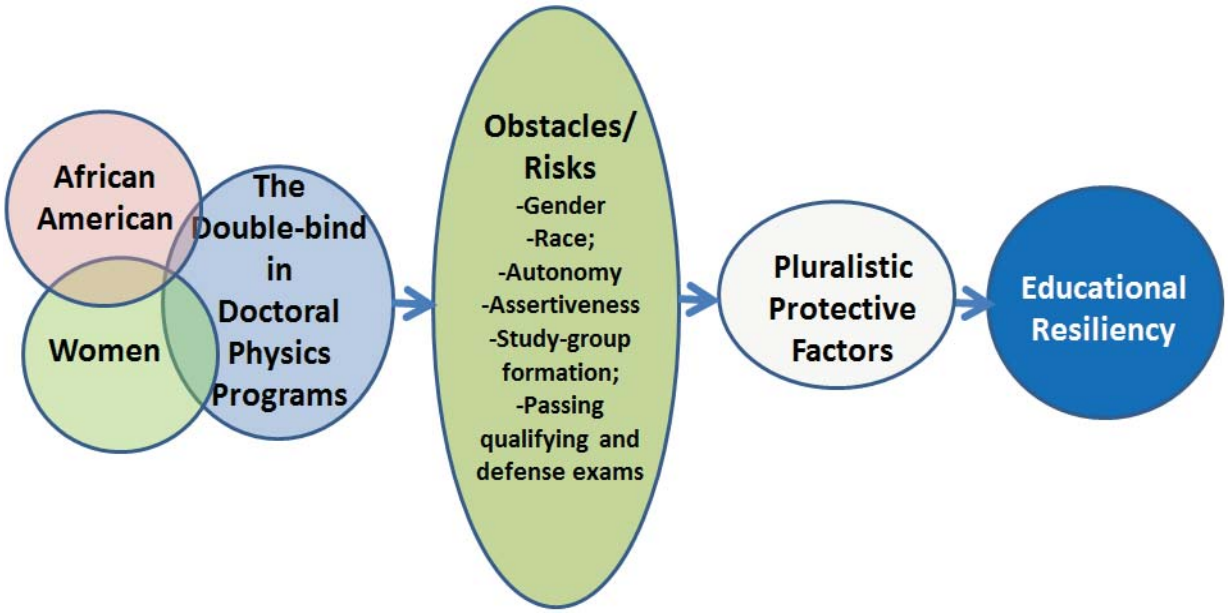

Figure 2: Process of Resiliency for African-American Women Who Completed Doctoral Physics Programs

Implications

As discussed in the previous section of this chapter, the findings of this study opened new discussions of how African-American women overcome obstacles within doctoral programs in physics. Based upon these findings, there are several implications for African-American women pursuing a doctoral degree in physics, doctoral program administrators seeking to retain these women in physics, and future researchers interested in this topic. These implications are highlighted below in reference to how these women utilized the most significant protective factors within this study.

Though most research relates the importance of mentorship, the first significant implication from this study is that connection to faculty is more important than having a close faculty mentoring relationship at the doctoral level, meaning that having faculty available to answer questions and give advice is very important. At this stage of educational experience, mentorship could be given in a number of ways. Departments could hold a Q&A session to foster interactions between faculty and graduate students or simply have various events to allow faculty members to meet with program graduate students. In so doing, students not having access to the one female faculty member in her doctoral physics program may have the opportunity of asking her questions without bombarding her with hopeful advisees. Therefore, the findings of this study seem to suggest that role models may matter more while pursuing an undergraduate or a masters-level degree.

Another important implication for African-American women is how they utilize protective factors developed throughout their educational journey. Though some may have had to project dominant traits of autonomy (independence) to meet the demands of their previous programs, independence has a less dominant place in doctoral programs where peer interaction and faculty help are crucial. Asserting too much independence may lead to isolation and attrition within these programs. Protective factors can only be protecting to these women if utilized in situations and settings where they would produce positive outcomes.

Another implication for African-American women pursuing a doctoral program in physics is that they must do their research on the program they wish to enter. They must also

heavily consider the advice of their undergraduate faculty advisers when it comes to selecting a graduate institution. The results of this study made clear that African-American women will do well to understand whether a program is a great fit in terms of research interest, to acquire previous statistics on African American success within the program, and to place importance on the critical mass of women in a program, if such things are needed for success. These factors are a significant aid in persistence. It also may be a good idea for future African-American doctoral applicants to visit the campus and to speak with faculty in their area of interest and current enrolled graduate students to understand what the daily lab routine is like before they enroll.

African-American women pursuing a doctoral program in physics should learn to value plurality in terms of social interactions and skills. Due to having a limited racial and gender presence in the field, these students will have to learn to work with a variety of people from other cultures. The concentration of Chinese international students and faculty was often cited as a mainstay in the area of physics. Forming pluralistic relationships with Chinese international doctoral students was a significant successful interaction, especially once in the laboratory. All, but one of these students related some interaction with other nationalities, such as Indians, Germans, Greeks, and South Africans. Therefore, having the ability to form study groups and friendships with other cultural populations should provide positive outcomes for other African-American women in physics.

Acquiring a plurality of skills is also important to success for African-American women. Due to the double-bind, once an African-American woman graduates from her

doctoral program, she may undergo a proving process (Fries-Britt & Holmes, 2012; Fries-Britt, Younger, & Hall, 2010; Johnson, 2011). Most of the women within this study certainly seemed to feel the need to hone multiple skills before facing the outside physics world. Having an array of skills within the laboratory environment would allow them a degree of independence and was one proactive way to counteract any negative push back due to the double-bind.

Lastly, program administrators and faculty should encourage their African-American female graduate students to attend race-based physics society meetings, such as the NSBP, as a retention strategy when enrolled within their doctoral programs. These types of organizations help form pockets of encouragement and rejuvenation for African-American women in doctoral programs. They also provide a link to resources for employment and other opportunities.

Future Research

The findings of this study echo both participants' voices and Joseph's (2007) study that no person's experience in doctoral physics, or any in STEM discipline, is the exact same. By conducting a phenomenological study, the researcher hoped to shed light on significant factors that may aid those pursuing a doctoral degree in physics with enough information to be successful. Though this study attempted to be as thorough as possible in investigating these phenomena, there were several gaps in information that will allow other researchers to explore this topic in more depth.

First, studying the resiliency of a larger pool of participants may yield more concrete findings. This would also allow greater validity of the study's findings. Within this study, the findings contradicted extant findings in other studies in terms of the importance of a dedicated faculty adviser to successful completion of a doctoral program, but a larger study may indicate that prevalent research on this topic is valid. Also, more obstacles may emerge in a broader study on the resiliency of this population. Thus, a more in-depth study of a larger pool of participants may expand the findings of this study.

Second, this study related the importance of the NSBP conferences for at least three of this study's recipients. Understanding the role of the NSBP conferences in the retention of African-American women in physics would be an interesting topic to explore. Due to the relative exclusivity of the field regarding race and gender, understanding the degree to which African-American women in doctoral programs in physics utilize this society for support, employment, and other resources would be meaningful.

Third, a number of participants explained that the discipline of physics is losing White males but gaining a number of Chinese internationals. Therefore, exploring how African-American women partner with Chinese international students while in doctoral programs in physics is an interesting topic. Understanding how this connection leads to future opportunities globally may be of value to increasing the success of multi-cultural populations within this field.

Lastly, further studies examining gender in relation to African-American women in the field of physics is worthy of examination, both during and after acquiring a doctoral

degree. Affecting four of the five participants in this study, gender seemed to be the most prevalent obstacle for the African-American women in their doctoral physics programs. Consequently, understanding the importance of gender over race in the double-bind for African-American women in doctoral physics programs is worthy of investigation. Also, many participants in the study cited a lack of competition within their programs; however, it would be interesting to explore how these African-American women cope with the androcentric and highly competitive job market when they enter the working world. Furthermore, what type of occupation they are most likely to attain once they acquire a position would be of interest. Included in this exploration is how likely African-American women are to be employed and retained in industry and government careers.

Limitations

A major limitation of this study is that it only offers insight into what may be the factors of resiliency for African-American women completing doctoral degrees in physics. As the study was limited to only five participants, true generalizations cannot be made. Further qualitative studies, such as the ones presented in the section on future research above, will need to be implemented in order to corroborate the results of this investigation. The limited amount of knowledge currently surrounding African-American women in doctoral physics programs also serves as a limitation of this study. This population is an important human resource and their absence in extant literature must be remedied.

Chapter Summary

This study offered a composite of the lived experiences of African-American women who completed doctoral programs in physics. Participants identified six major obstacles: gender, race, autonomy, assertiveness, forming study-groups, and passing qualifying and defense exams. Within this study, gender was cited as the prevalent obstacle over race. However, race was cited in connection with gender referencing bias in the field, especially conferences. These obstacles were all overcome by the use of pluralism, which was emergent in the following four protective ways: 1) Forming diverse peer connections with other racial ethnicities; 2) Gaining an array of training within the laboratory; 3) Utilizing multiple strategies to solve foreseen problems; and 4) Seeking multiple support connections from faculty, family, and other helpful physics community entities.

Conclusions revealed these five participants utilized an array of internal and external protective factors involving disposition, family, and community; however, situation and setting greatly influences positive consequences. If protective factors are not used at the appropriate time or in the appropriate setting, they may become unprotecting, or lead to negative consequences. Other significant conclusions arising out of this study revealed that African-American women seeking to pursue a doctoral degree in physics should form relationships with a diverse group of peers and faculty for support. Also, these women should not expect to merely sail through their doctoral programs, but utilize strategic problem-solving to overcome foreseen challenges, which includes acquiring multiple skill sets to succeed upon entering a potentially biased and highly competitive market. A process

paradigm regarding resiliency was also rendered for African-American women who enter doctoral physics programs.

I wish I Could Have …

For this study, there are a few things I would do differently if given the chance to do it again. First, I would have selected all of the participants from the same decade, if possible. My rationale for doing this is because at the end of the study, I am not sure that race really played a true role for women graduating in the first decade of the 2000s. Race did play a role for Donna, however, who graduated in the 1980s. Maria, who graduated in the 1990s, also seemed to feel a bit racially isolated. Jenni, who graduated in the first decade of the 2000s was the only one who mentioned not seeing any people of her race on a daily basis. Mae and Sarah, who also graduated within the first decade of the 2000s, seemed not affected by race. Therefore, I wonder how significant race would have been if I only selected study participants who completed their doctoral degrees in physics within the last 10 years.

Lastly, I would also focus my questions solely on gender obstacles instead of trying to organically glean if this was a factor in their resiliency. Recently I attended a seminar on the women in science, technology, engineering, and mathematics and was shocked at how many women in male-dominated programs seemed frustrated at the biased departmental culture. I wish I could have gleaned this more directly from my study participants. Though four out of five of the participants indicated gender as an obstacle, they did not delve deeper into why this may be so. Gender was only mentioned by them during times of blatant bias or sexist behavior. I am left to wonder when my participants began seeing clues that gender

was a factor within science. Was it since their undergraduate years? Did it ever become apparent that women, especially African-American women, were not the norm in physics? Why was it easy to accept that they had no faculty members who mirrored their race and gender? Did they internalize any gender-related clues that physics would be difficult or was the difficulty of the major solely based upon perceived intellectual ability? These questions I considered as I began developing themes from my data; and I wish I would have had the foresight to include these in my protocol. Alas, I sigh and resolve to the overwhelming fact that I am hopelessly flawed, but should I continue this research, I would simply have to ask next time.

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APPENDICES

Appendix A: International Review Board Letter

North Carolina State University is a land-grant university and a constituent institution of the University of North Carolina

Office of Research and Innovation
Division of Research Administration

NC STATE UNIVERSITY

Campus Box 7514
Raleigh, North Carolina 27695-7514

919.515.2444 (phone)
919.515.7721 (fax)

From: Deb Paxton, IRB Administrator
North Carolina State University
Institutional Review Board

Date: May 4, 2012

Project Title: Resiliency in physics: The lived experiences of African-American women who completed doctoral physics programs

IRB#: 2646

Dear Ms. Burnette,

The project listed above has been reviewed by the NC State Institutional Review Board for the Use of Human Subjects in Research, and is approved for one year. **This protocol will expire on April 26, 2013 and will need continuing review before that date.**

NOTE:

1. You must use the attached consent forms which have the approval and expiration dates of your study.
2. This board complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU the Assurance Number is: FWA00003429.
3. Any changes to the protocol and supporting documents must be submitted and approved by the IRB prior to implementation.
4. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days by completing and submitting the unanticipated problem form on the IRB website.
5. Your approval for this study lasts for one year from the review date. If your study extends beyond that time, including data analysis, you must obtain continuing review from the IRB.

Sincerely,

Deb Paxton
NC State IRB

Appendix B: Informed Consent

Revised 04/2009

North Carolina State University

Institutional Review Board For The Use of Human Subjects in Research

GUIDELINES FOR PREPARATION OF INFORMED CONSENT FORM

PLEASE READ ALL OF THIS INFORMATION CAREFULLY

PRIOR TO COMPLETING THE CONSENT FORM

An **Informed Consent Statement** has two purposes: (1) to provide adequate information to potential research subjects to make an informed choice as to their participation in a study, and (2) to document their decision to participate. In order to make an informed choice, potential subjects must understand the study, how they are involved in the study, what sort of risks it poses to them and who they can contact if a problem arises (see informed consent checklist for a full listing of required elements of consent). Please note that **the language used to describe these factors must be understandable to all potential subjects, which typically means an eighth grade reading level.** The informed consent form is to be read and signed by each subject who participates in the study **before** they begin participation in the study. A duplicate copy is to be provided to each subject.

If subjects are **minors (i.e. any subject under the age of 18)** use the following guidelines for obtaining consent:

0-5 years old – requires signature of parent(s)/guardian/legal representative

6 – 10 years old - requires signature of parent(s)/guardian/legal representative and verbal assent from the minor. In this case a minor assent script should be prepared and submitted along with a parental consent form.

11 - 17 years old - requires signature of both minor and parent/guardian/legal representative

If the subject or legal representative is *unable to read and/or understand the written consent form*, it must be verbally presented in an understandable manner and witnessed (with signature of witness). If there is a good chance that your intended subjects will not be able to read and/or understand a written consent form, please contact the IRB office 919-515-4514 for further instructions.

***For your convenience, attached find a sample consent form template that contains necessary information. In generating a form for a specific project, the principal investigator should complete the underlined areas of the form and replicate all of the text that is not underlined, except for the compensation section where you should select the appropriate text to be used out of several different scenarios.**

***This consent form template can also be adapted and used as an information sheet for subjects when signed informed consent is waived by the IRB. An information sheet is usually required even when signed informed consent is waived. The information sheet should typically include all of the elements included below minus the subject signature line; however it may be modified in consultation with the IRB.**

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

Title of Study: Resiliency in physics: The lived experiences of African-American women who completed doctoral physics programs

Principal Investigator: Samara Fleming Burnette Faculty Sponsor (if applicable): Paul Bitting

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

This study will investigate the past experiences of African-American women who have graduated from doctoral physics programs.

What will happen if you take part in the study?

If you participate in this study, you will be asked to complete a brief nine question survey prior to the interview. Each participant will also take part in an in-depth interview, which will last approximately two hours. The interview will be audio-recorded. The survey will be sent via e-mail and completed prior to the interview. The interview will take place at a location of your choosing. During this interview you will be asked about your experiences during your doctoral physics program. The researcher requests that the location you choose be quiet to insure the supreme quality of the recording and the trustworthiness of the data collected. The audio-recording will be transcribed by the researcher and sent to you for approval and/or revisions.

You will also be asked to provide a recent résumé and any media press (news articles, announcements, or web sites) about your achievement as an African-American woman in physics. These documents could be submitted via paper copy or e-mail. Links to this information (if available) will also be accepted in lieu of paper copies.

Risks

There are risks. Because of the small number of African-American women who graduated with a doctoral degree in physics, there may be ways to identify each study participant via name, graduate institution, or year of graduation. To alleviate any potential risk, pseudonyms will be used for you and your doctoral institution. In the event that you were the only African-American woman to graduate from your doctoral physics program, your year of graduation will be replaced by the decade in which you graduated. In the

event that the meeting site may be a source of identification, generic identifiers, such as science facility, science funding facility, University, or home, will be used.

Benefits

The information gained from this study may help us to better understand the experiences of African-American women while in doctoral physics programs and identify factors that are necessary for successful completion of these programs. The researcher seeks to inform policy and practices regarding how to retain and graduate African-American women who pursue doctoral physics programs.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely in a directory located within a password-protected computer or locked in a compartment. Due to your submission of study materials, such as résumé and any media press, full confidentiality cannot be guaranteed; however, diligent efforts will be made to prevent you from being identified. Your name and institution name will never be used in any reports. Pseudonyms will be used for each participant and her doctoral institution. To further protect your identity, your year of graduation will be replaced with the decade in which you graduated. The researcher will assign broad categories to information pulled from any study materials (résumés and/or any media press) you provide. For example, if you have received a national or regional award, it will not be named, but the number of national or regional awards received will be specified.

Compensation

You will not receive any type of compensation for participating in this study. Participation in this study is strictly voluntary.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Samara Fleming Burnette, by telephone (919-656-7079) or E-mail (sdflemin@ncsu.edu).

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature_____ **Date** _____

Investigator's signature_____ **Date** _____

Samara Fleming Burnette, MPA
Department of Leadership, Policy, and Adult and Higher Education
Poe Hall, Box 7801 North Carolina State University
Raleigh, NC 27695-7801
(919) 515-3127

Appendix C: Survey Protocol

Background Survey

Date_____

Name Pseudonym_____

Demographic Information Questions

1. What doctoral institution did you attend?
2. What was the initial date or semester/year of your enrollment into this program?
3. Describe the racial composition of your department.
4. How many African-American faculty members were in your department?
5. How many women faculty members were in your department? Were any of these African-American women?
6. How many African-American students were in your department?
7. How many women were present in your in the program? Guesstimate. _____
   - African-American women: _____
   - Other minority women: _____
   - Foreign women: _____
   - White women: _____
8. Were you the first African-American women to graduate with a Ph.D. in physics from your institution?

Concluding Question

9. How do you define resiliency?

Appendix D: Interview Protocol

In-depth Interview: Face-to-face Protocol Guide

Date_____
Time_____
Name Pseudonym_____
Institution Pseudonym_____
Generic Meeting Location: _____

Introduction

- ☐ Provide informed consent for participant's review and signature.
- ☐ Provide structure of the interview (audio recording, taking notes, and use of pseudonym)
- ☐ Ask if they have any questions
- ☐ Test audio recording equipment

Questions about the doctoral physics experience (obstacles, stress, conflict)

1. Before I get started with the interview questions, I want to know if you have ever heard or thought of the term "resiliency" before this interview. How did you define the term "resiliency?"

2. Beginning with your undergraduate major and school, what was your path to physics doctoral degree?

3. Think back to a time in your doctoral program when you felt there were obstacles. What was going on?

4. How were you able to overcome these obstacles? What strategies or actions did you take to allow you to solve these challenges?

5. Tell me about your departmental peers. What challenges come to mind? How did you overcome them?

6. Tell me about writing your dissertation. Were there circumstances surrounding this experience that posed challenges? What were they? How did you overcome them?

7. How did you form your committee? Where there any challenges in this process? How did your committee help you?
8. Did your adviser believe in your abilities? Describe why you think this.
9. Tell me about the experiences you have surrounding your defense.

Concluding Questions and Statements

10. Is there anything else you would like to add or share about this topic that you feel is important for me to know?

Concluding Statement

- Thank them for their participation
- Record any observations, feelings, thoughts and/or reactions about the interview

Appendix E: National Science Foundation E-Mail Data

E-mail from Mark Fiegener, NSF

On Thu, May 26, 2011 at 11:13 AM, Fiegener, Mark K <mfiegene@nsf.gov> wrote:
Samara,

The data on numbers of black female grad students enrolled in physics fields appears below, for 1999-2008. Please note, the totals (male plus female) do not match what appears in table 56 – the data in that table are limited to grad students enrolled in particular categories of institutions (the research intensive universities), whereas the data below are derived from all institutions.

	1999	2000	2001	2002	2003	2004	2005	2006
Female	70	67	53	52	57	57	67	58
Male	164	168	158	168	179	191	205	171
Total	234	235	211	220	236	248	272	229

	2007	2008
Female	46	45
Male	164	170
Total	210	215

Please let me know if you have questions about these data.

Best,

Mark

Mark Fiegener, Ph.D.
Project Officer, Survey of Earned Doctorates
National Science Foundation
Division of Science Resources Statistics
703-292-4622
703-292-9092 (Fax)

mfiegene@nsf.gov

We are now the National Center for Science and Engineering Statistics
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From: Samara Burnette [mailto:sdflemin@ncsu.edu]
Sent: Monday, May 23, 2011 10:25 PM
To: Fiegener, Mark K

Subject: Re: Disaggregated Statistics on African-American women in physics

Thank you so much, Mark!!!! I can update the numbers from 2006 doctoral awardees and 2007 enrolled in graduate physics programs. This makes my night!!!! :) -Samara

On Mon, May 23, 2011 at 4:14 PM, Fiegener, Mark K <mfiegene@nsf.gov> wrote:
Samara,

I've attached a spreadsheet of the 1998-2008 trend data you requested (it also includes the counts of black female doctorate recipients in physics fields that I included in the previous email).

I've forwarded your request for counts of black female grad students enrolled in physics programs to the survey manager of the Graduate Students & Postdocs in S&E survey – I'll let you know what she finds.

Best,

Mark

Mark Fiegener, Ph.D.
Project Officer, Survey of Earned Doctorates
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703-292-4622
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mfiegene@nsf.gov

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From: Samara Burnette [mailto:sdflemin@ncsu.edu]
Sent: Tuesday, May 17, 2011 11:11 AM
To: Fiegener, Mark K
Subject: Re: Disaggregated Statistics on African-American women in physics

Mark:

I have just a few more questions that I am hoping you can help me answer. In Table 56 (http://www.nsf.gov/statistics/nsf10307/pdf/tab56.pdf), I see that in 2007, 195 African Americans were enrolled in graduate physics programs. How many of the 195 were African-American women?

Can I get the same 1998-2008 trend table for Black men, White men, and White women in doctoral

physics that you have already provided for Black women? I need something to do some comparisons by.

I hope this will be no problem. I REALLY do APPRECIATE the help you've given me so far. I'm almost certain that I will not need anything else after this. I hope I don't. Thank you.

Best,

Samara

On Tue, May 10, 2011 at 7:00 PM, Samara Burnette <sdflemin@ncsu.edu> wrote:
Wow! Thank you VERY MUCH, Mark!!!! While I am disappointed that the enrollment doctoral numbers are not available, I'll figure a way around it. What you did provide is VERY helpful. Thank you again!!!

Best,

Samara

On Tue, May 10, 2011 at 5:03 PM, Fiegener, Mark K <mfiegene@nsf.gov> wrote:
Hello Samara,

Included below are counts of black women (U.S. citizens and permanent residents only) who were awarded doctorates in physics between 1998 and 2008, by subfield and year. I'm afraid I can't help you with the enrollment data – the surveys that collect data on graduate enrollments do not distinguish masters-level from doctoral-level.

I hope this helps. Please let me know if you have questions about these data.

Best,

Mark

Mark Fiegener, Ph.D.
Project Officer, Survey of Earned Doctorates
National Science Foundation
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703-292-4622
703-292-9092 (Fax)
mfiegene@nsf.gov

We are now the National Center for Science and Engineering Statistics
A new name. A broader mission.
www.nsf.gov/statistics/

TABLE A

Black doctorate recipients, women: 1998–2008

Field	1998	1999	2000	2001	2002	2003	2004
All fields	993	1,064	1,107	1,055	1,080	1,146	1,269
Physics	3	4	1	1	5	5	5
Applied physics	na	na	na	na	na	na	1
Biophysics (Physics)	na	na	na	na	na	na	1
Condensed matter/low temperature physics	1	0	0	0	1	0	0
Fluids physics	0	0	0	0	0	0	na
Nuclear physics	1	0	0	0	2	1	0
Particle (elementary) physics	0	0	0	0	0	0	1
Plasma/fusion physics	0	0	0	0	0	0	1
Acoustics, optics/phototonics	0	2	1	0	0	3	0
Atomic physics, polymer physics	0	0	0	0	1	1	0
Physics, general	1	1	0	0	0	0	0
Physics, other	0	1	0	1	1	0	1

TABLE A (con't)

Black doctorate recipients, women: 1998–2008

Field	2005	2006	2007	2008
All fields	1,137	1,131	1,251	1,298
Physics	2	2	2	3
Applied physics	0	0	0	1
Biophysics (Physics)	0	0	0	0
Condensed matter/low temperature physics	2	1	1	0
Fluids physics	na	na	na	na
Nuclear physics	0	0	0	0
Particle (elementary) physics	0	1	0	0
Plasma/fusion physics	0	0	0	0
Acoustics, optics/phototonics	0	0	0	1
Atomic physics, polymer physics	0	0	1	0
Physics, general	0	0	0	1
Physics, other	0	0	0	0

From: Samara Burnette [mailto:sdflemin@ncsu.edu]
Sent: Tuesday, May 10, 2011 2:34 PM
To: Fiegener, Mark K
Subject: Disaggregated Statistics on African-American women in physics

Mr. Fiegener:

I am writing concerning the latest disaggregated data by race and gender for African-American women in physics. Information on the enrollment and graduation statistics for African-American women in physics

at the doctoral level is what is pertinent for me. The latest disaggregated data I found is from 2006, but I questioned whether indeed this is the last I can obtain. I was then determined to contact you to see whether or not you would provide me with disaggregated data for African-American women in physics at the doctoral level.

I am also confused as how to separate the enrollment from masters level from the enrollment of doctoral level in physics and most of the current data aggregates physics into an umbrella of physical sciences.

Any help you can provide in these areas would be greatly appreciated. Thank you so much!

Best,

Samara