DIFFERENCES WITHIN:

A COMPARATIVE ANALYSIS OF WOMEN IN THE PHYSICAL SCIENCES-

MOTIVATION AND BACKGROUND FACTORS

A Dissertation

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by

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ABSTRACT

Science, technology, engineering, and mathematics (STEM) education has become a critical focus in the United States due to economic concerns and public policy (National Academy of Sciences, 2007; U.S. Department of Education, 2006). Part of this focus has been an emphasis on encouraging and evaluating career choice and persistence factors among underrepresented groups such as females in the physical sciences (Hill et al., 2010; National Academy of Sciences, 2007). The majority of existing STEM research studies compare women to men, yet a paucity of research exists that examines what differentiates female career choice within the physical sciences. In light of these research trends and recommendations, this study examines the following questions:

1. On average, do females who select chemistry or physics doctoral programs differ in their reported personal motivations and background factors prior to entering the field?
2. Do such variables as racial and ethnic background, age, highest level of education completed by guardians/parents, citizenship status, family interest in science, first interest in general science, first interest in the physical sciences, average grades in high school and undergraduate studies in the physical sciences, and experiences in undergraduate physical science courses explain a significant amount of variance in female physical scientists' years to Ph.D. completion?

These questions are analyzed using variables from the Project Crossover Survey dataset through a subset of female physical science doctoral students and scientists. Logistic regression analyses are performed to uncover what differentiates women in the physical sciences based on their background, interest, academic achievement, and experiences ranging prior to elementary school through postsecondary education. Significant variables that positively predict a career choice in chemistry or physics include content specific high school and undergraduate academic achievement and positive undergraduate experiences. Two multiple regression models, one composed of female chemists and one of female physicists, examine significant predictors that positively associated with time to doctoral degree completion. The models account for little differentiation in the outcome of time to doctoral completion. In addition, significant predictors are based on demographic and achievement factors that were not paralleled in the two multiple regressions.

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APPROVAL OF THE DISSERTATION

This dissertation, "Differences Within: A Comparison of Women in the Physical Sciences- Motivation and Background Factors", has been approved by the Graduate Faculty of the Curry School of Education in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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3/12/2012 Date

DEDICATION

This work is dedicated to my past, present, and future teachers and students. You have taught me many invaluable lessons and continue to inspire me every day with a love of learning and teaching.

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CHAPTER 1

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) education has become a critical national focus in the United States due to economic and educational concerns. According to the National Academy of Sciences (2007) and U.S. Department of Education (2006), development of a STEM workforce is necessary to ensure that the U.S. remains competitive in the global economy. Current estimates show that the science, engineering, and technology workforce comprises 4% of workers in the U.S. Yet the U.S. Department of Labor estimates that by 2018, nine out of 10 of the fastest growing professions will be in fields that require at least a bachelor's degree in science or mathematics (National Science Board [NSB], 2010).

Despite the growing need for STEM employees in the U.S., recent policy reports have shown that in the past decade the number of bachelor's degrees in physical science, mathematics, and engineering has remained unchanged (NSB, 2010; National Academy of Sciences [NAS], 2010). Additional reports show that students in physical science and engineering are more likely to transfer into other degree programs, as opposed to transferring into these majors (NSB, 2008). The number of students who persist to doctorate degrees in mathematics and physical science has remained basically unchanged in the past decade as well (NSB, 2010). The resounding message from a majority of policymakers is that the current number of students trained in STEM fields will not be able to fill the gaps in the U.S. workforce in the future (NSB, 2010; NAS, 2010).

Beyond a shortage of students in STEM education, concerns have been raised as to whether the best and brightest students are being retained in STEM fields in the U.S. Recent reports have shown that the number of highest achieving students enrolling in and graduating from STEM majors has significantly decreased (Lowell, Salzman, Bernstein, & Henderson, 2009). Additionally, the number of high achieving students entering science and engineering graduate programs has declined (Zumeta & Raveling, 2002). Other concerns include an increased dependence on foreign students in STEM graduate programs, who may not remain in the U.S. For example, 33% of all doctoral students and 57% of all postdoctoral students in STEM hold temporary visas (NSB, 2010). While developing a global economy is important, building the STEM workforce in the U.S. is essential as well (NSB, 2010).

Based on these concerns, the NAS (2007) released a formal report, *Rising Above the Gathering Storm,* with recommendations for how to improve the U.S. STEM workforce. A primary emphasis has been a focus on achieving success in STEM education with such underrepresented groups as females (NAS, 2007). Interestingly, women currently hold less than one fourth of the jobs among these rapidly growing STEM occupations (NSB, 2010). Recommendations to change this status include enlarging the pool of female students pursuing degrees and careers in STEM fields. From the perspective of the field, women have the potential to make significant and critical contributions to work in STEM. From the perspective of individuals, entrance into the STEM workforce could help women obtain higher salaries and maintain a better standard of living, as STEM based careers are often better paid (National Association of Colleges and Employers, 2009).

Historically, women have been underrepresented in STEM fields due to a preliminary lag behind men in STEM related degrees. Data show that women now almost match men when it comes to attainment of bachelor's degrees in biological and agricultural sciences, chemistry, mathematics, and earth sciences (NSF, 2008a; see Figure 1-1). Yet women still receive bachelor's degrees at a significantly lower level than men in physics, engineering, and computer science. Furthermore, females remain underrepresented in all doctorates except for biological and agricultural sciences (NSF, 2008a; see Figure 1-2). Specific to these findings, recent educational policy has focused on the difference between female and male representation in doctoral programs such as the physical sciences (Hill, Corbett, & St. Rose, 2010).

Figure 1-1. Bachelor's Degrees Earned by Women in Selected STEM Fields, 1966-2006 (NSF, 2008a).

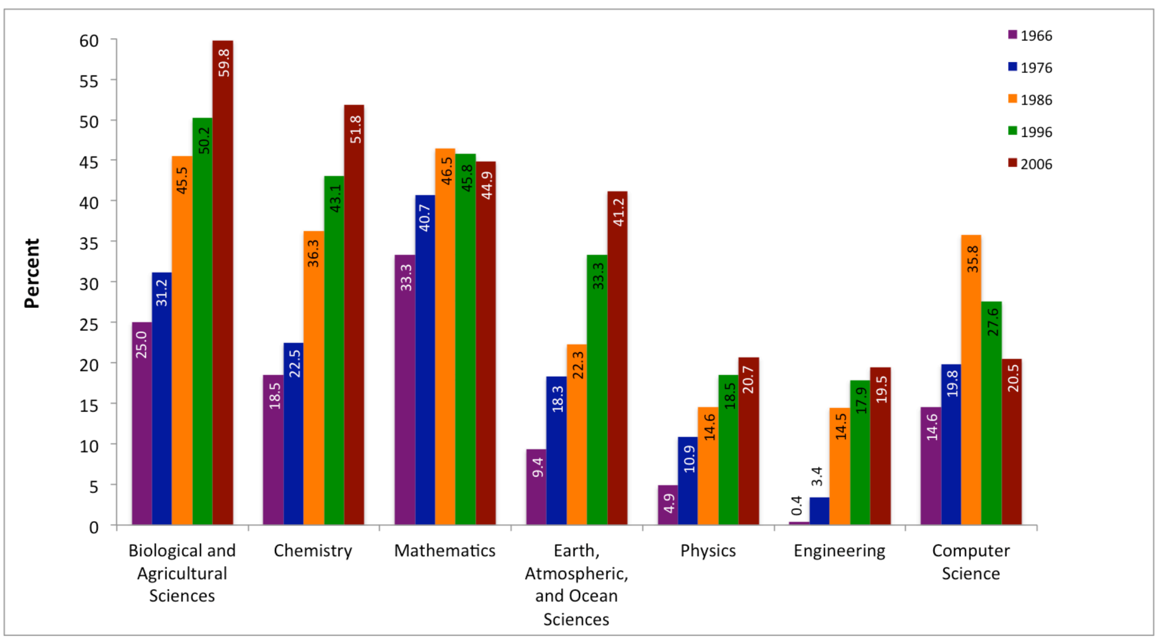
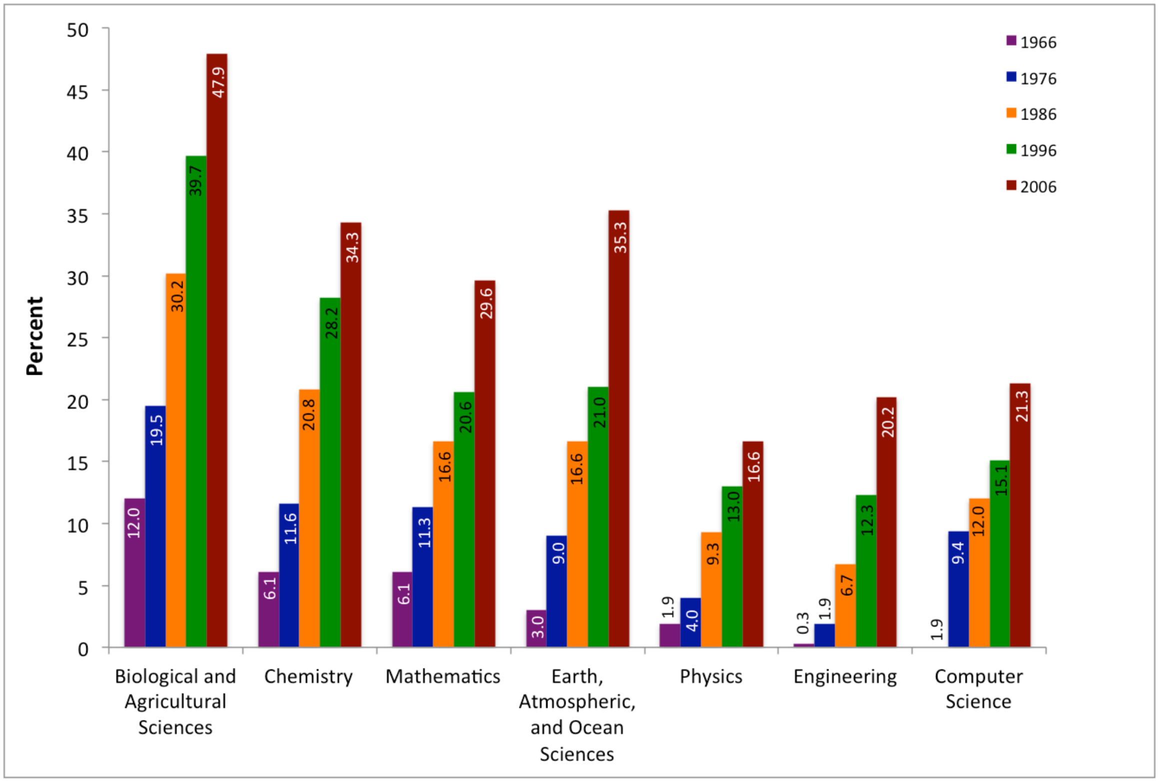


Figure 1-2. Doctorates Earned by Women in Selected STEM Fields, 1966-2006 (NSF, 2008a).



Women in the Physical Sciences

The underrepresentation of women in physical sciences doctorate programs indicates a need to evaluate what may influence their career choices and persistence (Hill et al., 2010). Women have made gains in the past 40 years with regard to attainment of bachelor's and doctoral degrees within the physical sciences. Specifically, in 1966, women received 18.5% and 4.9% of bachelor's degrees within chemistry and physics, respectively (NSF, 2008a; Figure 1-1). Most recently, in 2006, women received 51.8% and 20.7% of bachelor's degrees in chemistry and physics, respectively (NSF, 2008a; Figure 1-1). While women have made gains with regard to doctoral degree attainment in the physical sciences, these increases are nowhere near the growth seen with bachelor's degrees. In 1966, women earned 6.1% of doctorates in chemistry and 1.9% of doctorates in physics (NSF, 2008a; Figure 1-2). As of 2006, women earned 34.3% of doctorates in chemistry and 16.6% of doctorates in physics, respectively (NSF, 2008a; Figure 1-2). Research shows that female gains in the physical sciences are still slight in comparison to men, especially with regard to physics and the attainment of doctoral degrees. Furthermore, striking differences exist among women in the physical sciences. Female chemists are closing the gender gap at a significantly faster rate than female physicists in regard to both bachelor's and doctoral degrees. Yet there is no comparative research examining why there are differences in representation among females in physical science.

One method of promoting advanced science education of women has been the use of outreach programs to provide guidance and support to special interest groups both academically and professionally (NAS, 2007). Unfortunately, without a better understanding of what motivates these female students and STEM graduates in specific fields of science, support cannot be adequately provided in order to encourage individuals to enter and persist in these fields (Fox & Stephan, 2001). Despite longstanding educational efforts, females are still underrepresented at the doctoral level in the physical sciences. Research that looks at factors that contribute to this underrepresentation will become necessary (Hill et al., 2010). Research must target certain subpopulations in specific fields of study, such as females in chemistry and physics, to truly understand the factors that are associated with entrance into graduate school and persistence of students (Gardner, 2008).

What we do know is that women, in comparison to men, are less likely to receive doctorates in the physical sciences, and, when they do, they are also less likely to achieve tenure positions and tend to make lower salaries (Hill et al., 2010; National Center for Science and Engineering Statistics, 2010; NORC, 2011). Theories and studies abound including lack of interest (Lubinski & Benbow, 2006), chilly climate (Acker & Feuerrverger, 1996; Barres, 2006; Ferreira, 2002; Gunter & Stambach, 2005; Menges & Exum, 1983; Prentice, 2000; Settles, Cortina, Malley, & Stewart, 2006), lack of critical mass of women (Girves & Wemmerus, 1988; Kleinman, 2003), and conflicts between family and work life (Wyss & Tai, 2010) as to why women in comparison to men do not persist in STEM fields. The majority of this work examines factors that influence female persistence in their doctoral fields of study. Therefore, many questions still remain unanswered as to why existing background and motivation supports prior to entrance into doctorate fields of physical science are not sufficient (Hill et al., 2010).

A review of existing STEM research indicates that a wide variety of background and motivational factors may influence student persistence and career choice. These motivational and background factors include such variables as interest (Maltese & Tai, 2010; Tai, Liu, Maltese, & Fan, 2006), family influence (Small, 2005; Turner, Steward, & Lapan, 2004), academic achievement and self-efficacy (Hyde, Lindbergh, Linn, Ellis, & Williams, 2008; Pajares, 1996, 2005), postsecondary experiences (Tai & Sadler, 2001; Carlone & Johson, 2007), and demographic factors (Denecke, 2004; Hill et al., 2010; Lewis, Menzies, Najera, & Page, 2009). However, these studies focus on generalized STEM outcomes or gender comparisons and are inadequate when it comes to a thorough analysis that differentiates between women in different fields of study, such as doctorates in chemistry or physics.

In the end, women are leveling the playing field faster when it comes to bachelor's degrees in physical science. The shift in attrition, however, occurs when they later enter doctoral programs (NSF, 2008a). Specifically, women are closing the gender gap in the field of chemistry at a faster rate than in physics (NSF, 2008a; Figure 1-2). The majority of theories and studies examine variables in doctoral programs that influence persistence, success, and satisfaction while eschewing early educational supports prior to entrance into doctorate fields. Existing research on female physical scientists compares women to men or examines women as a single entity. Therefore, there is a paucity of work regarding the differences that exist prior to entrance into doctoral programs among females in the field of science. Perhaps in the end the question is not how women differ from men, but what differentiates women who choose one field of science instead of another? More specific to these findings, what prior motivation and background factors are associated with and differentiate women that enter and persist in chemistry or physics doctoral programs?

Purpose of this Study

The purpose of this study is to examine early career choice factors among women in the physical sciences. First, this study will investigate whether women who choose either chemistry or physics differ based on their early motivation and background factors. Motivation and background factors in this study will include: family influence, individual interest, academic achievement, undergraduate experience, and demographics. This will provide a better understanding of what factors may differentiate female career choice in the fields of chemistry and physics. Second, this study will examine whether these motivation and background factors not only differentiate females in the physical sciences, but also influence their persistence or time to doctoral degree completion. The research questions addressed in this study are:

1. On average, do females who select chemistry or physics doctoral programs differ in their reported personal motivations and background factors prior to entering the field?
2. Do such variables as racial and ethnic background, highest level of education completed by guardians/parents, citizenship status, family interest in science, first interest in general science, first interest in the physical sciences, average grades in high school and undergraduate studies in the physical sciences, and experiences in undergraduate physical science courses explain a significant amount of variance in female physical scientists' years to Ph.D. completion?

These research questions will be examined through a series of descriptive analyses, variable correlations, logistic regressions, and multiple regressions. All statistical analysis will include controls for demographic factors of participants.

Significance of this Study

The significance of this study is its ability to provide a clearer picture of what factors may influence female entrance and persistence in the physical sciences. It will provide motivation and background variables that are associated with a career choice in either of the physical sciences. To date, the majority of literature examines career choice across gender, male to female, as opposed to within gender, female to female. One strength of this research is its ability to compare women's career choice of chemistry or physics based on these early motivational and background experiences. Additionally, a further examination of persistence or time to doctoral degree completion can provide a larger picture of the possible influence of these early experiences. This study includes research based on factors such as family influence, individual interest, achievement, undergraduate experience, and demographic influences on science career choice in the United States. Variables will range from early interest, potentially prior to school, and academic experiences through elementary, middle school, high school, and college. A clearer knowledge of female career choice based on these factors and seminal experiences in the physical sciences can provide educational policy makers with research to better influence science education decisions in the United States.

CHAPTER 2

REVIEW OF LITERATURE

Media and educational policymakers have recently given attention to women in STEM fields (Hill et al., 2010; NAS, 2007; NSF, 2008a). In particular, these reports focus on the lack of women in such degree programs and areas of STEM expertise as doctorates in the physical sciences. Specific studies have examined certain factors that may lead to female doctoral degree persistence, or remaining in the STEM workforce (Acker & Feuerrverger, 1996; Barres, 2006; Ferreira, 2002; Girves & Wemmerus, 1988; Gunter & Stambach, 2005; Kleinman, 2003; Menges & Exum, 1983; Prentice, 2000; Settles et al., 2006; Wyss & Tai, 2010). Yet they do not provide as much background as to what may influence women to enter a particular doctoral field, such as the physical sciences, based on prior motivation and background factors.

Due to the gaps in the literature regarding females with doctorates in the physical sciences, this review provides a comprehensive overview of the factors that are examined in this dissertation based on general STEM studies, while also providing a background on the paucity of literature that does exist about women in the physical sciences. Specifically, existing STEM research studies pinpoint that motivation and background factors such as interest (Maltese & Tai, 2010; Tai et al., 2006), family support (Small, 2005; Turner et al., 2004), academic achievement (Hyde et al., 2008; Pajares, 1996, 2005), postsecondary experiences (Tai & Sadler, 2001; Carlone & Johson, 2007), and demographic factors (Denecke, 2004; Hill et al., 2010; Lewis et al., 2009) may interact with and influence student persistence and career choice. The research questions presented in this dissertation are based on the assumption that these underlying factors may interact with one another and also be associated with and differentiate career choice and time to Ph.D. degree attainment of female physical scientists. As this chapter provides an extensive evaluation of these STEM factors, it is important to note that some of the variables and topics discussed will not be included in the analyses presented in this study. This literature review is organized in chronological order, starting with interest in science dating, potentially, to prior to grade school and ending with postsecondary experiences and a review of demographic factors.

Interest

According to basic social cognitive career theory (SCCT; Lent, Brown, & Hackett, 1994), Holland's (1959) vocational choice theory, and STEM educational research (Lent, Larkin, & Brown, 1989; Nauta, Epperson, & Kahn, 1998), interest development (Dewey, 1913; Hidi & Harackiewicz, 2000) is a critical factor for both academic success and career choice.

The concept of interest was historically based on Dewey's (1913) belief that interest development begins with early childhood play and learning that, with age, becomes higher-level activities and adult intellectual interests. Dewey defined an interested person as "being engaged, engrossed, or entirely taken up with some activity because of its recognized worth" (p. 160). His concept included the delineation of *direct* and *indirect interests*. Direct interests originate from personal or instant experience, while teachers, guardians, or role models provide indirect interests. According to Dewey, interest development is fundamentally important because of its connection with children's understanding, needs, and future adult intellectual pursuits.

Historically, early interest was based on theoretical arguments and hypotheses about its influence on adult career choice. A seminal study by Tai et al. (2006), however, examined the influence of early interest in science on later college degree completion. This analysis was based on the National Educational Longitudinal Study of 1988 (NELS) and examined 12,000 eighth graders' hypothesized career interest at the age of 30. Final data were collected from this longitudinal study in 2000, including the students' college majors. A logistic regression model was used to examine the outcome variable of college science versus nonscience majors while controlling for demographics and academic achievement. The study found that students who indicated an interest in a science related career field as early as eighth grade were three times more likely to have majored in a degree related to science as opposed to those who did not express interest.

While interest has been linked to early career choice, it has also been hypothesized to influence persistence in the sciences. Lindahl (2007) conducted a longitudinal study with a mixed methods approach of interviews and surveys of 70 students in Sweden aged 12 to 16. Results indicated that students reported a link between interest and persistence in science in school. Additionally, their career choice in science began as early as age 12. Further studies examined why students later remain in or exit STEM majors in college. Interview and focus group data of 400 students who remained in STEM majors revealed that a strong personal interest fueled their motivation to persist in their field of study (Seymour & Hewitt, 1997).

Specific work has also been done that examines female factors in career choice and interest in science, engineering, and mathematics. One such study examined a web survey developed by the Royal Society (2004) in England. Of 1,100 participants, 63% responded that they had formed an initial science interest in a STEM career prior to the age of 14. Interestingly, women retrospectively reported interest in a science career a few years later than men.

Students forming their career choices early may also base their decision-making on something other than sole interest in science. For example, an interview study of 69 students in the United Kingdom investigated why they had decided to enter science fields (Cleaves, 2005). These interviews were conducted at four different times, beginning in Grade 9 and ending in Grade 11. It was discovered that the students reported a STEM career choice based on the flexibility that such a career could provide as opposed to interest or exciting academic experiences in secondary science. Students who chose not to pursue a career in science were deterred by negative educational experiences that made them not want to persist into higher level mathematics and science classes. Further research by Lyons (2006) reviewed multiple qualitative studies of student interest and showed that when science is taught but not connected to the real world in the classroom, students are more likely to avoid higher level classes and less likely to pursue careers in science.

Few studies have examined participants who are in a doctoral program in the physical sciences and asked them to reflect on their persistence and career choice factors. Nazier (2010) developed an open-ended, one-question survey and distributed it to 300 professors in science and engineering departments, including physics and chemistry, of a major research university. Of these participants, 10% were women and representative of the current populations in academic science and engineering. Participants were asked to write about the factors in their lives that had influenced their decision to pursue a career in STEM. Responses indicated that an early interest based on formative science experiences outside of school influenced their persistence and career choices in science and engineering. In 2006, Feist conducted a close-ended survey of 114 professional members of the National Academies of Science. Results showed that the mean age at which participants reported knowing they wanted to pursue a career in science was 14. Both surveys demonstrated that an interest in science as a career choice began early and persisted with these professionals.

Research examining only physical scientists' early career choice factors includes a qualitative study by Maltese and Tai (2010) that examined the interview data set from the greater Project Crossover mixed-methods study. An analysis of 116 interviews of doctoral students and physical scientists was run based on the source, timing, and nature of their early interest in science. Results indicate that the majority of interviewees reported that their interest in science began prior to middle school. Gender findings showed that women were more likely to specify that school experiences influenced their initial interest, whereas men were more likely to report that independent unstructured science activities influenced their initial interest. Key to these results was that they were based on physical sciences students and scientists, including women, and interest was reported to be a mediating factor in their subsequent academic persistence and career choice.

The studies above examined student career choice in science from middle school to postsecondary experiences based on initial interest (Tai et al., 2006), timing (Lindahl, 2007; Tai et al., 2006; Royal Society, 2004), and reasons for persistence (Cleaves, 2005; Lyons, 2006; Seymour & Hewitt, 1997). In addition, two pieces of recent qualitative research studied career choice factors of physical sciences doctorates and professionals. Findings indicate that doctorates who remain in the field report an early interest in science (Maltese & Tai, 2010; Nazier, 2010). Of particular interest to this research is the study by Maltese and Tai (2010) that showed that women's initial interest in the physical sciences may be based on such factors as structured academic experiences, which differ from those cited by males. In addition, Royal Society (2004) findings indicate that women often have a somewhat later initial interest than men in STEM careers. Specific to this research project, no large scale quantitative studies exist that examine and differentiate women physical science doctorates based on early factors such as first interest in general science and first interest in, specifically, physical sciences.

Family Influence

Researchers have also examined how external support may influence student persistence in the STEM pipeline. Bandura (1971) originally hypothesized that children learn from watching others and modeling their behaviors. This theory has been tested by a variety of methodologies in STEM fields. For example, one survey method was used to examine 267 former students of specialized STEM schools (Small, 2005). A logistic regression analyzed the outcome of a STEM or non-STEM major based on a variety of supports. Results indicated that multiple external influences, such as teacher and parental support, could influence the likelihood of a STEM major or career choice.

Family is often a fundamental influence on early childhood interest in science. Parental encouragement has been connected with motivation toward science-related careers (Lent et al., 1994; Ferry, Fouad, & Smith, 2000). One such study examined 318 sixth graders with a pathway analysis based on the Science scale of the Revised Unisex American College Testing Interest Inventory (UNIACT) and an abbreviated version of the Fennema-Sherman Mathematics Attitude Scales (FSMA; Turner et al., 2004). A variety of results was found including the fact that support from the mother and/or father, as well as gender stereotyping and family dynamic, single or separated, influenced student mathematics self-efficacy. Mathematics outcomes were associated with maternal support and career gender stereotyping. When mathematics outcomes and student self-efficacy were examined together, they predicted student mathematics and science career choices.

While family support is associated with career choice, family experiences may be influential as well. When young children participate with parents in science-related activities, they have a proclivity toward science later. A study of 7,980 students from the NELS dataset examined the infleunce of parent and teacher influence on student science attitudes (George & Kaplan, 1998). Parental influence is shown to have both direct and indirect impacts on student attitudes by providing students with exposure to science activities such as museums and library visits. These findings indicate the importance of the opportunities that parents provide for their children, and, therefore, the subsequent influence that they have on their attitudes toward science. Another study examined a random sample of 391 pupils from the U.K. with a survey (Breakwell & Beardsell, 1992). In this research, boys had a stronger positive attitude toward science, participated in more science activities outside of school, and reported doing better academically in school science. Positive beliefs about science were more related to males, positive reinforcement from parents, and participation in extracurricular activities.

Parents may be influential in STEM career choice; however, their influence may be detrimental as well. Career theory by Eccles et al. (1983) hypothesizes that career choice is influenced by many factors, including whether an individual thinks they will succeed at a goal. Specific to this was that external messages sent by either society or key role models such as parents may influence female persistence in STEM fields. One such survey examined the effect of 1,500 mothers' perceptions and influence with their children's self-confidence about being successful in mathematics (Jacobs & Eccles, 1992). Researchers found that mothers form their beliefs about their children's ability to succeed based on their own personal gender beliefs. Women were more likely to think that their sons were more capable mathematics students than their daughters, regardless of their ability level. In addition, this maternal belief system regarding their children's personal ability was associated with the children's self-confidence in their own ability to succeed in mathematics.

Specific to women in the field of STEM, additional studies have shown that a mother's self-confidence about how well a female will succeed also interacts with female career choice. Bleeker and Jacobs (2004) conducted a survey study of 1,007 adults. Results showed that maternal prediction of their daughter's success in mathematics is correlated with their likelihood to enter STEM fields. Maternal self-confidence in their son's ability to succeed in mathematics, however, had no correlation with their likelihood to enter a field of STEM. This study reinforced the importance of parental support, specifically mothers, when it comes to influencing female entrance into STEM career paths. This result is also consistent with research literature that shows that general pre-college parental support is a critical factor in female underrepresented minority (URM) interest and persistence in the sciences (Russell & Atwater, 2005).

Overall research has examined parental influence on student career choice in science or STEM (Small, 2005), mathematics self-efficacy and outcomes (Turner, Stewart, & Lapan, 2004), hands-on experiences (George & Kaplan, 1998; Breakwell, 1992), attitudes toward science (George & Kaplan, 1998; Breakwell & Beardsell, 1992), academic achievement (Breakwell & Beardsell, 1992), and in particular female self-confidence and career choice in science (Bleaker & Jacobs, 2004; Jacobs & Eccles, 1992; Russel & Atwater, 2005). This dissertation examines the highest level of education completed by guardians or parents, and family past interest in science. Research studies already completed show the impact of parental influence in science or STEM, particularly with regard to female self-confidence and career choice in science. None of these studies, however, examines the association of the highest level of education completed by guardians or parents and family past interest in science with regard to female entrance and persistence in physical sciences doctoral fields.

Academic Achievement

While interest has been connected with family influence and career-choice factors (Small, 2005; Tai et al., 2006), it has also been linked to later academic performance across various subjects (Hulleman & Harackiewicz, 2009; Rathunde & Csikszentmihalyi, 1993; Schiefele, 1994). A longitudinal study examined the relationship between students' interest level and their success in mathematics, science, music, and art by investigating students' attention, concentration, self-assessments, transcripts, and enjoyment in challenging class work (Rathunde & Csikszentmihalyi, 1993). The outcome demonstrated that student interest level was correlated positively with personal achievements in mathematics and science. Similarly, Schiefele (1994) examined the relationship between interest, motivation, and achievement and their connection to students' experience in mathematics, biology, English, and history. The researchers found that interest predicts self-esteem, intrinsic motivation, skills, experiences, and student grades in these courses. Encouraging interest can help students have successful academic experiences and therefore develop new occupational choices (Brown & Lent, 1996).

A primary research focus has been on task and environmental factors in schools in order to promote interest and academic achievement. Ames (1992) discovered that interest in learning is more likely to be facilitated through tasks with variety and diversity. Furthermore, projects that are relevant, familiar, and interesting encourage people to work harder and longer while making deeper connections (Resnick et al., 1998). Hulleman and Harackiewicz (2009) conducted a randomized field experiment of high school relevance, which encouraged student connections between science coursework and their personal lives. The study showed that students with low self-efficacy experienced a significant increase in course grades and interest in science. In a review of research on interest and learning, Tobias (1994) concluded that "working on interesting, compared to neutral, materials may engage deeper cognitive processing and arouse a wider, more emotional, and more personal associative network" (p. 37).

Unfortunately, gender differences in self-efficacy are found in STEM subjects as early as middle school. Females repeatedly report less self-confidence in such subjects as science and mathematics early on and this disparity in confidence widens as they enter high school and college (Pajares, 2005). Studies have shown that when academic ability and learning opportunities are controlled for, gender differences in regard to self-efficacy with STEM subjects dissipate (Lent, Brown, & Larkin, 1986; Pajares, 1996, 2005). Pajares (2005) examined the self-efficacy beliefs of 66 gifted students and 232 regular education students in a middle school algebra class. A path analysis showed that self-efficacy of gifted students regarding ability to solve algebra problems connected with higher achievement levels, lower mathematics anxiety, and higher grade point averages. Of importance is the finding that students tend to be overconfident of their abilities. However, gifted students' beliefs were more accurately based on their actual ability, except for females, who tended to be under-confident. Postsecondary work has shown the connection of self-efficacy of 105 undergraduates attending a career-planning course in science and engineering (Lent et al., 1986). A hierarchical regression mode of analysis indicated that students with greater self-efficacy achieved higher grades, persisted in their field of study, and maintained more career options in STEM fields. Overall, students who lack self-efficacy at any point in the educational system are less likely to persist in STEM subjects and more likely to enter other fields of study and occupation.

Academic success in the field of mathematics is seen as essential to persistence and entrance into STEM fields. Historically, female self-confidence and academic success in mathematics was low in comparison to males. Today, females are shown to be on an equal footing with males with regard to success in mathematics and numbers of courses in science and mathematics in high school (U.S. Department of Education, 2007). Specifically, Hyde et al. (2008) showed, through an analysis of NAEP data of students in Grades 2 to 11, that a gender difference no longer exists academically between males and females in mathematics. Men are still shown, however, to score higher on standardized tests and to take more STEM-related AP exams (Halpern et al., 2007). Lubinski and Benbow (2006) reviewed data from the Study of Mathematically Precarious Youth (SMPY). Results from a 20-year longitudinal follow up of three cohorts showed that among the highest scoring students in mathematics, females are making gains in representativeness with regard to SAT scores, yet males still outnumber females in this area as well (Halpern et al., 2007; Lubinski & Benbow, 2006). While women are making gains academically when it comes to mathematics, some factors must remain that are preventing them from entering the physical sciences.

One area where extensive research exists is gender-limiting factors such as personal preferences in academic fields (Hartung, Porfeli, & Vondracek, 2005; Low, Yoon, Roberts, & Rounds, 2005). Females tend to be more attracted to language arts and humanities, while men are more interested in mathematics and science compared to other fields. One research study examined 111 students, 68 girls and 43 boys, from four classrooms in a Midwestern school district (Low et al., 2005). It used a survey based on 45 careers from Hollands' six career codes. Results show that differences in career choice begin in early adolescence, where girls are less interested in science and mathematics careers than boys. These findings also exist in studies examining inner city youth (Turner et al., 2008) and gifted students (Lubinski & Benbow, 2006). One such study tracked 320 gifted middle school students for 10 years and found that men maintained a preferred interest in mathematics, while women preferred language arts and the humanities (Lubinski, Webb, Morelock, & Benbow, 2001).

Gender disparities are later reflected in research on vocational choices, where it was discovered that men tend to work more in science and mathematics fields while women prefer people-oriented careers (Holland, 1996). Specific to the physical sciences, research has shown that females report gender bias and isolation in as early as secondary physics coursework, and that this may later impact their career choice (McDonnell, 2005). McDonnell (2005) completed a qualitative study of eight girls and nine boys from nine physics classrooms in the Northeast. Results showed that females often reported gender stereotyping from males in the classroom and therefore felt that they must conform to the male classroom atmosphere or face isolation from their peers. These findings connect with later research that has indicated that females feel that certain occupations in STEM fields are also less gender appropriate, and therefore they are less likely to pursue them (Hartung et al., 2005; Low et al., 2005). A meta-analysis of stability of vocational interests, from adolescence to adulthood, showed that STEM vocational interest and beliefs are persistent for both males and females (Low et al., 2005). Interest in a career choice is stable through adolescence and then peaks in early adulthood, where it is constant for the next 20 years. Therefore, research shows that early interest and beliefs are tenacious, especially with regard to women, and important to career choice in STEM fields.

In summary, literature on academic achievement examines such variables as interest (Rathunder & Csikszentmihalyi, 1993; Schiefle, 1994), environmental factors (Hulleman & Harackiewcz, 2009; Resnick et al., 1998), self-efficacy (Lent et al., 1986; Pajares, 1996, 2005), academic success (Halpern et al., 2007; Hyde et al., 2008; Lubinski & Benbow, 2006), gender career preferences (Low et al., 2005; Lubinski et al., 2001; Lubinski & Benbow, 2006; Turner et al., 2008), and finally gender bias (Hartung et al., 2005; Low et al., 2005; McDonnell, 2005). These research findings show that females are now on an equal footing in mathematics and science in middle and high school, but gender career preferences and stereotyping may influence their later career choice in STEM fields. This dissertation examines average grades in high school and undergraduate studies in the physical sciences and their association with female career choice in the physical sciences. It is important, however, to keep in mind that a wide range of factors outside of academic achievement may influence career choice in STEM, based on this literature review.

Postsecondary Experiences

According to Maines (1983), a high level of interest in science and mathematics leads to students who are more likely to major and persist in these fields than students with a low interest level. Research has emphasized the importance of early interest acquisition (Dewey, 1913; Tai et al., 2006) and parental influence (Rathunde & Csikszentmihalyi, 1993; Schiefle, 1994) on academic success and science related fields. Factors in postsecondary experiences are critical, however, to whether students in STEM fields of study remain in or exit the STEM pipeline.

Studies have indicated that gender differences may exist in the type of postsecondary STEM experiences that students prefer. Poock and Love (2001) examined 180 doctoral students in higher education programs between 1995 and 1996. Males and females were found to be similar in their postsecondary preferences, but women indicated that they preferred rigorous academic institutions that were well accredited. In addition, methods of instruction have been shown to influence female academic performance in U.S. universities. One such study analyzed the differences among 15,000 college students from 16 universities in physics course achievement based on gender (Tai & Sadler, 2001). Findings include that women were higher achievers than men when found to be comparable on their high school algebra, not calculus, background. More importantly, women performed higher than men in slow-paced physics courses that focus on content, while men performed higher in fast-paced courses that had fewer hands-on activities.

Academic performance is necessary for student success in STEM college degrees, but often there is a large rate of attrition of students from these degree programs. Differences exist based on gender as to why females or males may exit a STEM degree. Specifically, Subotnik and Steiner (1993) found that women tend to leave STEM postsecondary fields due to an impersonal nature of instruction and overcrowding of classes. Men were more likely, however, to exit because of a lack of challenging content or poor classroom instruction. Universities often vary their courses and content. Research has reinforced that a preferred method of instruction may differ based on the individual student, aside from gender. One study of 1,478 students in STEM degree programs from Europe examined components as to why students would persist into STEM fields (Woolnough, 1995). Many factors arose as to what influenced students' persistence, and these factors were often associated with the specific type of STEM degree students were obtaining. Students enrolled in chemistry degree programs were positively reinforced by classroom activities, while students enrolled in physics degree programs were positively influenced by their future career options.

Studies of at-risk groups of women have shown that early development and sustained identity in postsecondary education as a research scientist leads to a greater persistence in the field of science. One qualitative study followed the career path of 15 women with Hispanic, African American, Native American, or Asian American racial and ethnic backgrounds (Carlone & Johnson, 2007). This longitudinal research spanned undergraduate through graduate studies and ended with these females' selected career choices. Ethnographic interviews were used to gain initial knowledge of the participants' undergraduate experiences and included a sixth-year follow-up interview. What was found is that science identity, manifesting either as a passion for the field of science or the ability to use science in an altruistic manner, accounted for the persistence of these female participants.

The studies above indicate that gender differences exist in the postsecondary experiences of students seeking to pursue STEM degrees. Specifically, females prefer more academically rigorous institutions (Poock & Love, 2001), slow-paced content-based courses (Tai & Sadler, 2001), smaller classroom settings (Subotnik & Steiner, 1993), and the development of a sustained identity as a research scientist (Carlone & Johnson, 2007). Men, on the other hand, prefer fast-paced courses that included challenging content and instruction (Tai & Sadler, 2001). Of particular interest to this study are the differences that exist between women and men with regard to coursework preferences and reasons for pursuing a degree in science. This research examines women's self-report of their personal experiences in undergraduate physical science and how this, in turn, associates with their career choice and time to degree attainment. Based on the research above, potential findings for this dissertation will take into account the significant differences that may exist regarding not only gender, but specific individual factors associated with a positive or negative experience in a degree program.

Demographic Influences

In addition to interest, parental influence, academic achievement, and postsecondary experiences, research has repeatedly shown that demographic influences are associated with career choice and persistence in STEM fields. This section of the literature review examines what studies and data exist in relation to such demographic factors as age, parental education, and race and ethnicity, all of which are included in this research study.

Age

Research studies reviewed thus far have focused on specific age groups nested in certain periods of time, even with regard to longitudinal data (Lindahl, 2007; Low et al., 2005; Rathunde & Csikszentmihalyi, 1993). Age is examined in this dissertation, as the existing survey data will include females from many generations that may have experienced very different graduate school experiences based on the time period. Hill et al.'s (2010) review of factors influencing females, such as interest and academic achievement, show the change in female participation in the physical sciences over a span of 40 years. This review, however, does not take into account historical changes in physical sciences programs that may have influenced a difference in the number of females entering doctoral fields of study. Research studies reviewed above of female chemists and physicists examine these women's experiences in their actual doctoral degree program and career during a certain period of time. Due to the paucity of research focusing on women across generations with regard to motivational and background factors, this study examines and controls for age of female participants in the research variables.

Parental Education

Studies have shown that several factors may be associated with student career choice in STEM fields (Horn & Carroll, 1997). Included among theses studies is the variable of parental education (Denecke, 2004; Golde, 2000), which is often viewed to be interchangeable with socioeconomic status, as a higher level of education is often correlated with a higher salary (Horn & Carroll, 1997). Furthermore, parental education is often associated with student entrance into graduate school, and therefore is included as a demographic factor.

Race and Ethnicity

Research findings exist that have discovered generalized racial differences in students' interest and careers in STEM fields (Lewis et al., 2009). These studies indicate that URM have significantly lower rates of interest in mathematics and science. Research is still being developed regarding the concept of interest and motivation and URM interventions (Summers & Hrabowski, 2006). In order to provide successful interventions for female minorities, a more thorough knowledge and understanding of the factors leading to an increase or decrease of students' interest and subsequent entrance into STEM fields must be thoroughly researched and measured.

Specific to gender, research usually does not examine gender, race, and ethnicity with regard to STEM professions all at once. Gender, race, and ethnicity, however, may interact in regard to gender participation in STEM fields (Hill et al., 2010). The majority of research studies have predominately measured Caucasian females in the context of STEM occupations, therefore producing a skewed representation of women with regard to STEM (Hill et al., 2010). For instance, Hanson (2004) and Fouad and Walker (2005) found that African American females are more likely to have interest in STEM-related fields than Caucasian women. Researchers have speculated that this may be due to personality characteristics, such as self-confidence, that are more reinforced in African American homes for women (Fouad & Walker, 2005; Hanson, 2004). Yet the percentage of African American women still is significantly lower in STEM fields compared to Caucasian females, indicating that something other than self-confidence and interest is affecting this group's desire to enter the profession (Fouad & Walker, 2005; Hanson, 2004).

Research has indicated that female minorities, aside from Asians, are underrepresented in higher education levels of science (Pearson, 2005). These findings are based on statistics from the NSF's (2008) report on the demographic backgrounds of women in the sciences. African American, Hispanic, and Native American females comprise just 9.7 % of chemistry graduate students. In addition, females who are African American, Hispanic, or Native American comprise just 4.4% of physics graduate students. Due to the limited number of URM women in physical sciences graduate degree programs (NSF, 2008b), race is also included as a control variable in this study.

The data in this dissertation allow for the examination of interest, parental influence, academic achievement, and postsecondary experiences and their interaction with the subsequent variables of age, socioeconomic status, and race and ethnicity. More importantly, this study focuses on the outcomes of female career choice in the physical sciences and subsequent timing to degree completion.

Summary of Existing Research

General STEM research studies are reviewed above with regard to what motivational and background factors may be associated with career choice and persistence. Multiple factors were examined in this chapter, including such variables as interest, potentially prior to school, as well as academic experiences, ranging from elementary school through college, and finally, an overview of demographic factors. What is revealed in this literature review is the complex interaction between these variables, as well as their potential to build on one another developmentally from childhood to adulthood.

Studies show that career choice is based on student interest and can potentially be formed prior to high school (Tai et al., 2006). Furthermore, students report that interest is connected to motivation not only to pursue, but also to persist into fields of science. Gender research on professional scientists indicates that men tend to form an earlier initial interest in science than women (Royal Society, 2004). In addition, female physical scientists reported that structured school-based activities were more likely to support this initial interest.

Family influence and activities have also been connected with initial interest and career choice in science (George & Kaplan, 1998; Small, 2005). Parental support has been associated with mathematics self-efficacy, and academic achievement is correlated with science based career decisions (Turner et al., 2004). Specific to gender, parent self-confidence in their children's mathematical ability interacts with female student ability in mathematics as well as subsequent STEM career choices (Bleeker & Jacobs, 2004; Jacobs & Eccles, 1992).

Academic achievement also interacts with interest, family influence, and career choice factors. Specifically, interest is associated with student academic performance in secondary schools (Rathunde & Csikzentmihalyi, 1993; Schiefele, 1994). Females are found to be equal to males in the number of courses taken in science and mathematics, as well as academic success in mathematics (Hyde et al., 2008). Females, however, report a lower level of self-efficacy as early as middle school, which widens as they continue into higher education (Pajares, 2005). This self-efficacy, or gender stereotyping, may be reflected through females' preference for language arts and humanities over mathematics, beginning in middle school and continuing into later career choices (Low et al., 2005; Lubinski et al., 2001; McDonnell, 2005).

Finally, in postsecondary science, women's persistence in a STEM degree is often very different from men's. Specifically, women prefer more slow-paced content courses with smaller class sizes (Subotnik & Steiner, 1993). Female reasons for persistence in their STEM programs of choice are often linked to the belief that they can use their skills in an altruistic manner (Carlone & Johnson, 2007). In the physical sciences, both males and females prefer a career in chemistry based on positive classroom activities, as opposed to physics career decisions, which tend to be based on potential job opportunities (Woolnough, 1995).

This literature review justifies the use of the variables interest, parental support, academic achievement, and postsecondary experiences to examine female student career choice decisions and persistence in STEM fields.

Limitations of Existing Research

The studies reviewed here have some major limitations that are relevant to this research. First, one focus is the examination of motivational and background factors in reference to generalized STEM outcomes. The majority of these articles have looked at both males and females in reference to a combination of one or two variables regarding

STEM career choice or persistence. For example, research by Small (2005) examined the association of parental influence on the outcome variable of college STEM versus non-STEM major. Yet these studies did not separate groups of participants by specific field of study in STEM. Research in this area has included large sample sizes that are generalizable. In contrast, this dissertation seeks to understand the specific experiences of women doctorates in the physical sciences; there is a paucity of research with regard to this specific subpopulation of women.

Second, studies that specifically examine women in the physical sciences are based on qualitative analysis or small sample sizes. For example, Nazier (2010) studied 30 women out of 300 individuals with regard to their career choice factors in engineering and science fields. In addition to the small numbers of participants, these studies are based on one career outcome in STEM and not a comparative analysis between chemistry and physics, in contrast to the research design used in this dissertation.

Third, the majority of these research studies look at gender-based differences. Specifically, men are compared to women with regard to timing of interest in science (Royal Society, 2004), self-confidence and mathematical ability (Bleeker & Jacobs, 2004; Hyde et al., 2008; Jacobs & Eccles, 1992), career choice and gender sterotyping (Low et al., 2005; Lubinski et al., 2001; McDonnell, 2005), and, finally, university and instructional preferences (Poock & Love, 2001; Subotnik & Steiner, 1993). Literature predominately focuses on a comparison of men to women, but no studies exist comparing women in the sciences to each other, based on their career choices and persistence factors.

Finally, these studies may also include weaknesses related to data collection, sample characteristics, or research methodologies. The resounding message, however, is that there is a lack of relevant research literature about motivational and background factors with regard to female doctorates in the physical sciences. Specifically, none of these studies compares women among themselves in order to find out what is associated with and what differentiates their career choices and time to degree completion.

CHAPTER 3

METHODOLOGY

This dissertation examines the research questions listed below through a series of statistical methods consisting of descriptive analyses, variable correlations, logistic regression analyses, and multiple regression analyses.

1. On average, do females who select chemistry or physics doctoral programs differ in their reported personal motivations and background factors prior to entering the field?
2. Do such variables as racial and ethnic background, age, highest level of education completed by guardians/parents, citizenship status, family interest in science, first interest in general science, first interest in the physical sciences, average grades in high school and undergraduate studies in the physical sciences, and experiences in undergraduate physical science courses explain a significant amount of variance in female physical scientists’ years to Ph.D. completion?

These questions are analyzed through the Project Crossover survey, which was designed to examine the transition from graduate student to independent researcher in chemistry and physics. Specifically, the data from the Project Crossover survey in this study come from all sets of female respondents: chemistry and physics doctorates, industrial scientists, tenured faculty, and individuals who have left the physical sciences altogether. The description of Project Crossover below explains the mixed-methods development of the survey used in these analyses, as well as the final data collection approach and the specific sample of participants. In addition, this chapter details the analytic methods of logistic regression and multiple regression used to analyze results from the two research questions. Finally, this chapter examines the outcome, control/demographic, and predictor variables in this study, and includes a thorough consideration of missing variables and research hypotheses.

Project Crossover Study

Project Crossover was a progressive mixed methodological study that consisted of a primary interview component that was later used to develop the Project Crossover survey.[1] The initial study design implemented an interview protocol specifically for students who were attending or had graduated from chemistry or physics doctoral programs in the U.S. This interview protocol was semistructured and examined individuals' graduate-school experiences. The semistructured nature of the interviews allowed respondents to emphasize portions of their programs that they felt were significant to their development as scientists in the field. In addition, the interviewers had the freedom to probe questions that seemed particularly meaningful to the interviewees. Based on the open nature of these interviews, researchers were able to provide more background and depth for the nature of these participants' personal experiences in their physical-science doctoral programs.

Participants in the interview portion of this study included men and women who had the opportunity to describe their experiences either retrospectively, if they had

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[1] Wyss (2008) provided extensive detail on the Project Crossover survey development that was referenced for this dissertation.

graduated, and introspectively, if they were still in a physical sciences doctoral program. Purposeful sampling was used to select individuals from a variety of universities based on school size and background. This method of purposeful sampling consisted of gathering participants from alumni lists of universities and Internet searches. Participants were then e-mailed. After they agreed to participate in the study, respondents were asked at the end of the interview if they could provide any other peer contacts for further interviews. This method of snowball sampling allowed the researchers to gain access to individuals that otherwise might not have been available from the aforementioned alumni lists and online searches.

One hundred twenty-five participants were individually interviewed over the course of a half hour to several hours, depending upon their responses regarding their graduate school experiences. Interviewees all agreed to participate and were informed of the confidentiality of the study through a consent form. All of the interviews were gathered and kept in a locked location and stripped of any identifying information in the transcription process. A paid contractor transcribed the audiotaped interviews, and all completed transcriptions were reviewed and approved by the individuals who took part in them. If any changes needed to be made based on the interviewees' responses, the transcripts were reviewed again by the respondents. In addition, in order to further maintain confidentiality, only members of the research team were able to access the interview audiotapes and transcriptions.

Based on the resulting interview transcriptions, the research team developed the Project Crossover survey, which will be examined in this research study. As stated above, the survey was designed for U.S. chemistry and physics doctorates, industrial scientists, tenured faculty, and individuals who had left the physical sciences altogether. The questionnaire was intended to ask similar queries to the interview component of this study, regarding the transition process from graduate school to independent practicing scientist in the field. The development process of the survey was cyclical and included periodic meetings of the research team to review the existing interview transcriptions and background research regarding the transition process of graduate students to practicing researchers. Questions that were developed from these meetings were examined for relevance, significance, and rigor regarding physical sciences doctoral experiences. The initial version of the survey was test piloted among a group of physical sciences graduate students, scientists, and researchers in the field to get their feedback regarding question formation and implementation. In addition, respondents provided feedback regarding any suggestions to either edit or add to the existing group of survey questions. Feedback, as well as further research group meetings and reviews, allowed for the development of a final Project Crossover survey. Description of the final data collection process for the Project Crossover survey and sample examined in this study is provided below prior to the discussion of the analyses that were conducted in this dissertation.

Data Collection

From the results of the interview phase, as well as existing research, the Project Crossover survey was developed. The survey included 145 questions covering topics ranging from background variables, early science motivations, undergraduate and graduate school experiences, and career events after the end of graduate school. Lists of potential participants were obtained from two professional scientific organizations: the American Chemical Society (ACS) and the American Physics Society (APS). In 2007, an initial random sample that included 17,500 ACS and APS members were mailed hard copies of the surveys as well as information to access a password protected online version of the survey. Four reminder mailings followed periodically over the next 6 months for those who had not responded. Of the 17,500 initial surveys mailed, approximately 550 were returned as undeliverable and 3,600 responses were determined to be nonapplicable, since the recipients did not have the proper background in science (non-science degree-holders). It was determined that 13,350 surveys were mailed to qualified potential survey takers. From this group, 4,285 physical science doctoral students, physicists, chemists, and other doctoral holders in the physical sciences returned completed surveys. The overall response rate was 32.1%. To assess the representativeness of the final dataset, an analysis was carried out to compare respondents' demographic backgrounds (race and/or ethnicity and gender) and employment sectors (universities, federal agencies, nonprofit, for-profit, or other employment not fitting these categories) with the nationally representative sample found in NSF's WebCASPAR database. The Project Crossover sample was found to be similar in proportional representation across these demographic and employment groupings to the WebCASPAR data (Hazari, Potvin, Tai, & Almarode, 2010; see Appendix A). A summary of the demographic variables in the Project Crossover survey is found in Table 3-1.

The series of analyses presented in this paper focused solely on data collected from female respondents among physical sciences graduate students and scientists. The Project Crossover survey is particularly relevant to this series of analyses due to its large sampling of females in the physical sciences. As seen from Table 3-1, females represent 28.5%, or 1,221, of the participants. Table 3-2 contains the percentages of female physical sciences graduate students and scientists responding to the survey. Female participants included 234 chemistry doctoral students, 81 physics doctoral students, 558 chemistry scientists, and 277 physics scientists. In addition, 20 female graduate students and 51 female scientists had missing data, or did not provide a response, based on their specific field of physical science. The final sample for this study consisted of 1,137 female participants due to listwise deletion of missing data for 71 participants based on career outcome and 13 participants who had multiple responses for individual control and predictor variables (see Table 3-3). Female proportions in the sample included 234 female chemistry doctoral students, 80 female physics doctoral students, 552 female chemistry scientists, and 271 female physics scientists. Procedures for how missing data were handled for control and predictor variables in this study will be examined at the end of this chapter. Most importantly, based on the sampling of females in both fields of the physical sciences, the Project Crossover survey provides one of the most extensive data sources to date for female physical scientists' educational experiences prior to elementary school through undergraduate education.

Not only does the Project Crossover survey provide a large sampling of female physical scientists in the field of chemistry and physics, it also contains variables based on questions that are particularly relevant to this study. Data in the survey include extensive variables regarding demographics and education, personal motivations, and early doctoral scientific career events. Specific to demographics and education are questions regarding gender, racial and ethnic background, age, highest level of education completed by guardians/parents, and citizenship status. Personal motivation variables include family interest in science, first interest in general science, first interest in the physical sciences, average grades in high school physical sciences, average grades in undergraduate studies in the physical sciences, and experiences in undergraduate physical sciences. Finally, scientific career events measured in the survey include career choice and timing or years to doctoral completion. Further description of variables chosen for portions of this series of analyses is reviewed after an initial discussion of the analytic approach.

Analytic Approach

Analytic approaches contained in this study include descriptive analyses, variable correlations, logistic regression analyses, and multiple regression analyses. A description of each method of analysis and the reason for its selection in this study is detailed below.

Descriptive Analyses

Descriptive analyses were run for demographics and background variables for all participants in this study. Furthermore, these analyses were used to determine central tendency and to check for assumptions regarding multivariate analysis prior to using the analytic methods of logistic and multiple regression analysis. Assumptions regarding multivariate analysis include univariate and multivariate outliers, univariate normality, multivariate normality, homogeneity of between group variance/covariance matrices, and the assumption of linearity (Pedhazur, 1997; Stevens, 2009).

Variable Correlations

Following a series of descriptive analyses, all control and predictor variables were checked for potential collinearity, or significant correlations, in the data. Significant correlations in the variables could influence the significance of the predictors, in addition to any potential outcome of any subsequent logistic and multiple regression analyses

(Pedhazur, 1997). Therefore, collinearity was examined through cross tabulation with a series of Pearson correlations. Composite variables were created where appropriate due to the unique nature and representativeness of the factors in the dataset.

Logistic Regression Analyses

The first research question in this study seeks to examine whether there is a difference in background and motivation factors between females who select a career in chemistry or physics. Differences between females in the physical sciences were not only sought, but also included whether these differences influenced or predicted group membership. Based on the need to differentiate between females in the physical sciences on descriptive background and motivational variables that were dichotomous and continuous, logistic regression analysis is the most accurate method of analysis in order to answer these questions (Pedhazur, 1997). In addition, logistic regression analysis is more lenient with multivariate assumptions regarding the predictors within each outcome variable group (Grimm & Yarnold, 1995; Pedhazur, 1997; Tabachnick & Fidell, 1996). Therefore, due to ability to account for all predictor and control variables in the model as well as greater flexibility with multivariate assumptions, the data for the first research question were examined through two logistic regression analyses. These logistic regression models were completed with the use of SPSS 19.0.

Logistic regression analysis imparted several strengths to this study. First, the results provided parsimony to the description of females in the physical sciences, and, second, the interpretation of this data was quite clear. In regard to the Project Crossover survey, 16 variables were examined for potential descriptives in discriminating what factors predicted whether women would enter the field of chemistry or physics. Second, logistic regression analysis singled out the variables in the model that have significant residuals through significance tests. Significant control and predictor variables were reported with relevant odds ratios that provide the reader with a better understanding of how these variables predict female career choice in the physical sciences (Pedhzur, 1997). Protoypical odds ratios were created from the relevant odds ratios to depict hypothetical women in the field of physical science. Finally, interactions were examined of control and predictor variables to ensure that the significant predictor variables were associated with the physical sciences career outcomes in the models (Pedhazur, 1997).

Logistic regression analyses were used in this study with the two outcome groups, female chemists and female physicists. One logistic regression model focused on the career outcome of female chemists as opposed to physicists and a second logistic regression model focused on the career outcome of female physicists as opposed to female chemists. The two logistic regression models contained the full sample of participants and examined the following descriptive background and motivation predictors: race and ethnicity, age, highest level of education completed by guardians/parents, citizenship, family interest in science, first interest in general science, first interest in physical sciences, average grades in high school chemistry, average grades in high school physics, average grades in undergraduate physical sciences, and average experiences in undergraduate physical sciences. Altogether, with dummy-coded variables for race and ethnicity and citizenship, these analyses included 16 variables. The large number of variables selected for these analyses was not a concern because of the relatively large sample size (1,137) in comparison (see Table 3-3). Given that the sample size to variable ratio was quite large (1,137 to 16, or 71 to 1), the resulting standard coefficients and correlations were stable and provided for more reliable descriptive analyses (Barcikowski & Stevens, 1975; Grimm & Yarnold, 1995; Stevens, 2009).

Multiple Regression Analyses

The second research question seeks to examine whether female physical scientists' background and motivation factors explain a significant amount of variance in years to Ph.D. completion (Pedhazur, 1997). Multiple regression allowed for each analysis to examine several predictor variables on a dependent variable, in this case the amount of years to doctoral completion. Most importantly, multiple regression analysis helped determine which background and motivational factors of female physical scientists were the best predictors of years to Ph.D. completion.

Based on the Crossover sample and research question two, the respondents were split so that two multiple regression models were run. One multiple regression model was composed of female chemists, and the other of female physicists. The creation of these subsamples and separate regressions is supported by research that shows that doctoral program type may influence time to degree completion (Council of Graduate Schools, 2008). Doctoral program type and higher education in the physical sciences has also been shown to interact with the predictor variables in this analysis, including interest, academic achievement, and reported experiences (House, 2000; Maltese & Tai, 2010; Nazier, 2010; Zeegers, 2004). Most importantly, splitting the sample by program type in the multiple regression models allowed for a better comparison of how selection of a specific physical science, chemistry or physics, based on the series of predictor variables may influence variance in time to doctoral degree completion. The data in the Crossover survey subsample provided for a safe analysis of these predictors based on the large ratio of respondents to predictor variables (Barcikowski & Stevens, 1975; Grimm & Yarnold, 1995; Stevens, 2009). Specifically, the ratio for the female chemist model was 786 to 16, or 49 to 1, and the female physicist model was 351 to 16, or 22 to 1 (see Table 3-3).

Concerns regarding the coding of predictors in these multiple regression models included the use of continuous and categorical variables. Some questions in the regression required variables to be recoded as continuous variables. For example, Crossover survey Question 17 examines *Family Interest* in science. As shown in Figure 3-1, the survey asked participants to mark all that applied regarding statements describing past family interest in science. Of interest to this analysis was the number of statements marked for this question, except for the statement "Science was not a family interest." Therefore, the data were coded for the remaining four statements as an additive continuous variable ranging from 1 to 4 based on how many statements were marked by the respondent. Put another way, if the respondents were to mark only one of the remaining four statements, then they were coded as a 1, and if they marked two statements they were coded as a 2, and so on. This continuous variable was used as a predictor in the analysis. Further concerns regarding categorical variables included demographic questions such as those concerning race and ethnicity in Crossover survey Question 13 (see Figure 3-2). These variables were coded in the data based on a continuous variable, which did not make sense in the existing regression equation as a predictor variable. Therefore, for each race or ethnic group, the variable was dummy-coded as 1 or 0 based on race or ethnicity. If a participant was African-American, they were coded as a 1, not they were coded as a 0. Similar codes existed for Latino/Hispanic and Asian participants. Caucasian participants were coded if all three racial groups were coded as a 0.

Following preliminary descriptive analyses and recoding of the data, variables were entered in the multiple regression with a hierarchical approach. This was based on research indicating that ordering of variables in a regression equation can influence the resulting variance between the variables (Pedhazur, 1997). A hierarchical regression approach allowed for the determination of how each variable added to the prior variables influenced the regression equation outcome, or R^2 (Pedhazur, 1997). Prior research was consulted in order to influence the determination of the sequence of the variables in the equation. Based on previous literature, demographic variables were entered first, such as racial and ethnic background, year of birth, highest level of education completed by guardians/parents, and citizenship status (deValero, 2001; Jacobs, Finkens, Griffin, & Wright, 1998; Tai et al., 2006; Xie & Shauman, 2003). Next, initial interest and then educational experiences were entered in the following order: family interest in science, first interest in general science, first interest in chemistry/physics, average grades in high school chemistry and physics, undergraduate average grades in the physical sciences, and general undergraduate experiences in the physical sciences (Breakwell, 1992; Brown & Lent, 1996; Dewey, 1913; Hulleman & Harackiewicz, 2009; Krapp et al., 1992; Rathunde & Csikszentmihalyi, 1993; Schiefele, 1994; Tai et al., 2006). These multiple regression analyses were completed with the use of SPSS 19.0.

The rest of this chapter will examine the outcome, control, and predictor variables used in the logistic and multiple regression models, as well as a discussion of missing data and the study's hypotheses. See Appendix B for a complete review of the SPSS 19.0 syntax for all variables, as well as analyses.

Outcome Variables

Female Chemist or Female Physicist

When examining female background demographics and motivations in the sciences, studies usually compare females to males rather than in gender comparisons (Stewart, 1998; Weinburg, 1995; Whitelegg, 2001). Comparative analysis based on demographic and motivational factors have previously been used as methods to inform educational public policy in the STEM fields (Tai et al., 2006; Xie & Shauman, 2003). The Crossover dataset provided the unique ability to examine and compare women in the physical sciences of chemistry and physics based on both demographic and early motivational variables. Not only did the Crossover survey provide a question that differentiated based on gender (see Figure 3-3), it also had respondents indicate whether their doctoral program was in chemistry or physics (see Figure 3-4).

Caution should be used in the interpretation of this as a logistic regression outcome variable, as the results are an indication of a correlation and not a causal study. Furthermore, there are multiple factors beyond demographics and early motivational factors that could contribute to an individual's selection into a physical sciences field. Other variables examined in the literature as influential to female selection into fields of science include: prior educational experiences, research background, marital status and family, financial support, gender, and degree requirements (Blickenstaff, 2005). However, as there is a shortage of women in science, especially in the physical sciences (NCES, 2009), this outcome variable could provide educators and educational researchers with ways to better understand female early experiences prior to their entrance into either physics or chemistry.

Time to Ph.D. Degree Completion

A pure comparison approach to demographic and motivation variables and female entrance into the physical sciences provides the reader with a way to better differentiate or classify women in these fields. However, a measurable outcome also indicates some mode of persistence and success. This dissertation examined time to degree completion, which has often been used as an outcome measure for both undergraduate and graduate degrees (deValero, 2001). Since early motivation and background measures have been examined as means to career choice, it therefore follows that they might also influence time to Ph.D. degree completion (Tai et al., 2006). Furthermore, prior research has shown that a variety of factors may influence time to degree completion such as demographics, motivation, educational experiences, financial support, and departmental factors (de Valero, 2001; Maher, Ford, & Thompson, 2004). This study's primary focus was demographic, motivational, and educational achievement and experiences, but it provided an additional layer to preexisting research by examining female choice in the physical sciences, either chemistry or physics, as separate multiple regression analyses and whether this impacted time to Ph.D. degree completion as well.

Time to degree completion has also been shown to be an indicator of likelihood of degree completion. Thus, the longer one takes to receive the degree, the more likely they are to exit their departmental program (de Valero, 2001; Epenshade & Rodriguez, 1997; Maher et al., 2004). Research indicates that women still lag behind when it comes to doctoral completion in the physical sciences (Council of Graduate Schools, 2008).

Furthermore, this lag can lead to decreased pay and render women less likely to make substantial contributions to their field (Maher et al., 2004).

Project Crossover provided a question that examines the years to doctoral completion ranging from noncompletion to eight or more years (see Figure 3-5).

Control/Demographic Variables

The following control or demographic variables from the Project Crossover survey were examined for the outcome variables presented above: racial/ethnic group (see Figure 3-2), year of birth (see Figure 3-6), highest level of education completed by guardians/parents (see Figure 3-7), and citizenship status (see Figure 3-8). As mentioned earlier, race and ethnicity was recoded as dummy variables in this series of regression analyses. Citizenship status was also recoded from continuous to dummy variables in this dataset. Green card or temporary visa holders were coded if both of the citizenship groups were coded as a 0. An additional composite variable of highest parent education was created from the highest mother and father education variables due to high Pearson correlations.

Decisions about which control variables to include in these statistical analyses were based on the literature surrounding the association of these variables with STEM career interest (Tai et al., 2006), female participation in the physical sciences (Jacobs et al., 1998; Xie & Shauman, 2003), and time to degree completion (deValero, 2001).

Predictor Variables

Predictor variables in this study included family interest in science (see Figure 3-1), first interest in general science (see Figure 3-9), first interest in chemistry/physics (see Figure 3-10), average grades in high school chemistry (see Figure 3-11), average grades in high school physics (see Figure 3-12), average grades in undergraduate chemistry (see Figure 3-13), average grades in undergraduate physics (see Figure 3-14), experiences in undergraduate chemistry (see Figure 3-15), and experiences in undergraduate physics (see Figure 3-16). The literature shows that early interest, academic success, and academic experiences influence student career choice and persistence in degree programs.

According to Dewey (1979[1913]), interest serves different functions based on age. Family interest may play an influential role in generating early interest (Small, 2005; Turner, Stewart, & Lapan, 2004). Interest in young children has an expansive effect that may develop, as they become adults, into specific intellectual pursuits and careers (Dewey, 1913; Krapp et al., 1992). Tai et al. (2006) further reinforced this theory through a study showing that eighth graders with a declared interest in science related careers were more likely to receive life science, physical sciences, or engineering degrees. Research has emphasized the importance of early interest acquisition in science related fields. These analyses examined family interest in science, first interest in general science, and first interest in chemistry/physics. As mentioned previously, family interest was recoded as a continuous variable in both the logistic and multiple regressions. Due to a focus on early interest in the research literature and in this study, first interest in general science and first interest in chemistry/physics were dummy coded as a 1 for prior to fifth grade and a 0 for interest development past the fifth grade.

Multiple studies indicate that interest is linked to academic performance across various subjects (Hulleman & Harackiewicz, 2009; Rathunde & Csikszentmihalyi, 1993; Schiefele, 1994). These researchers have found that interest predicts self-esteem, intrinsic motivation, skills, experiences, and student grades in science and mathematics courses. In addition, academic achievement in the physical sciences has been linked to persistence in the field (House, 2000; Zeegers, 2004). Average grades in high school chemistry, average grades in high school physics, average grades in undergraduate studies in chemistry, average grades in undergraduate studies in physics, experiences in undergraduate chemistry, and experiences in undergraduate physics were examined in this series of analyses as separate predictor variables. They were entered below the interest predictor variables in the regressions, however, based on prior research showing that early interest is predictive of academic achievement. In addition, experiences were dummy-coded in the model so that a strongly positive or somewhat positive experience was recoded as a positive experience, or a 1, and a strongly negative experience or somewhat negative experience was recoded as a negative experience, or a 0. Participants who did not take an undergraduate course in the physical sciences were represented if respondents indicated a 0 for both a negative and positive response. All undergraduate academic achievement and experience variables were entered into the logistic and multiple regression models based on a career choice in either chemistry or physics. Specifically, the chemist models contained undergraduate academic achievement and experiences in chemistry and the physicist models contained undergraduate academic achievement and experiences in physics.

Missing Values

Missing data in any statistical study are a concern. Therefore, all outcome, control and demographic, and predictor variables of the sample were examined for missing values prior to any logistic regression or multiple regression analyses. The missing-data percentages based on the study control and predictor variables are reported in Table 3-4. Missing-data analysis was used to determine whether the data were not missing at random, missing at random, or missing completely at random. Recommendations by Enders (2010) and Rubin (1987) were then consulted, based on the nature of the missing-data, in order to determine an appropriate missing-data procedure.

Specific to these predictor and control variables, mean comparisons of age, highest parent education, citizenship status, general science interest by K5, physical science interest by K5, high school chemistry grade, high school physics grade, undergraduate chemistry grade, undergraduate physics grade, chemistry undergraduate experience, and physics undergraduate experience did not differ based on the outcome variables of career choice in the physical sciences or time to Ph.D. completion. Therefore, it was determined that there was no systematic bias in the data. This, in addition to the relatively low percentages of missing data, indicated that there was no need to utilize missing-data procedures.

Hypotheses

Prior to any data analyses and formulation of the results, a series of hypotheses were formed based on the outcome of each form of the logistic and multiple regressions. As the logistic regressions were run on a comparative outcome of female chemist or female physicist, with both sets of respondents in the dataset, it was expected that content-specific outcomes would better predict or differentiate a female career choice in the physical sciences. Therefore, the female chemist logistic regression model was estimated to have significant predictors in high school chemistry grade, undergraduate chemistry grade, and positive undergraduate chemistry experience. In addition, the female physicist logistic regression was hypothesized to have significance for the following predictor variables: high school physics grade, undergraduate physics grade, and undergraduate positive physics experience. These content-specific variables were thought to have more of an influence on entry into a specific field of physical science by females. In addition, prior research has shown a connection between interest and academic achievement (Rathunde & Csikzentmihalyi, 1993; Schiefele, 1994); therefore, achievement variables in the models may subsume interest. However, the odds ratios were predicted to be low, as there are so many similarities between chemistry and physics in their rigor and requirements for entrance into undergraduate and, later, doctoral degree programs.

Multiple regression outcomes were hypothesized to differ based on a split dataset, with one model composed of only female chemists and the other of only female physicists, based on an outcome of years to Ph.D. completion. Here it was predicted that variables that influence overall persistence in the physical sciences might play a greater role, such as family interest, personal interest, and first interest in physical science. The types of interest measured in these models were thought to be more individual and long-term than situational or fleeting. Consistent with prior STEM research findings (George & Kaplan, 1998; Small, 2005; Tai et al., 2006), it was expected that early interest might play a role in female career choice in the physical sciences. Therefore, a comparison between the outcomes would show a similar set of predictors in the models, indicating that early interest could have long-term influences on career choice and persistence in physical science doctoral degree programs. Finally, it was hypothesized that females already in content-specific physical sciences doctoral programs or fields would be less likely to differ in their academic achievement or experiences that may influence them to enter the field in the first place.

Analyses and results are examined in Chapter 4. Conclusions based on the results are discussed in Chapter 5, with a connection to preexisting literature and educational policy.

Table 3-1

Project Crossover Survey Summary Comparison of Demographic Variables

Gender	Percentage
Male	67.3%
Female	28.5%
Corresponding Total	95.8%
Race/Ethnicity	
Caucasian	70.8%
African American	2.4%
Asian	16.7%
American Indian	0.1%
Latino/Hispanic	2.8%
Other	4.9%
Mixed	2.2%
Corresponding Total	100.0%
Sample Size	N = 4,285

Table 3-2

Project Crossover Survey Summary of Female Physical Sciences Graduate Students and Scientists

Female Graduate Students	n
Chemistry	234
Physics	81
Missing	20

Female Scientists	n
Chemistry	558
Physics	277
Missing	51

Sample Size	N = 1,221

Table 3-3

Study Sample of Project Crossover Female Physical Sciences Graduate Students and Scientists

Female Graduate Students	n
Chemistry	234
Physics	80
Percentage of Sample	27.6%

Female Scientists	n
Chemistry	552
Physics	271
Percentage of Sample	72.4%

Sample Size	N = 1,137

Table 3-4

Project Crossover Missing-Data Proportions

Variable	Percentage Missing
Race/Ethnicity	0.0
Age	1.6
Highest Parent Education	7.1
Citizenship Status	0.5
Family Interest in Science	0.0
General Interest in Science by K-5	0.0
Interest in Physical Science by K5	1.1
High School Chemistry Grade	1.3
High School Physics Grade	1.7
Undergraduate Chemistry Grade	1.0
Undergraduate Physics Grade	0.9
Undergraduate Chemistry Experience	1.4
Undergraduate Physics Experience	1.8

Figure 3-1. Question #17 from the Project Crossover Survey on Family Past Interest in Science

17. Which of the following statements best describes your family's past interest in science?
Please mark ALL that apply.

- ○ Science was involved in at least one parent's job.
- ○ Science was a diversion or hobby.
- ○ Science was viewed as a pathway to a better career.
- ○ Science was encouraged to the same degree as other academic pursuits.
- ○ Science was not a family interest.

Figure 3-2. Question #13 from the Project Crossover Survey on Racial/Ethnic Group

13. To which racial or ethnic group(s) do you MOST identify? *Please mark ALL that apply.*

- ⬭ African-American Non-Hispanic
- Asian/Pacific Islander:
  - ⬭ a. Chinese (ROC)
  - ⬭ b. Chinese (PRC)
  - ⬭ c. Indian
  - ⬭ d. Other Asian/Pac. Isl.
- ⬭ Latino/Hispanic
- ⬭ Native American/Aleut/Aboriginal Peoples
- ⬭ White Non-Hispanic
- ⬭ Other ____________

Figure 3-3. Question #9 from the Project Crossover Survey on Gender

9. What is your gender? ○ Female ○ Male

Figure 3-4. Question #2 from the Project Crossover Survey on Physical Science Field

2. Please indicate if your doctoral graduate program was in a field of chemistry or physics.

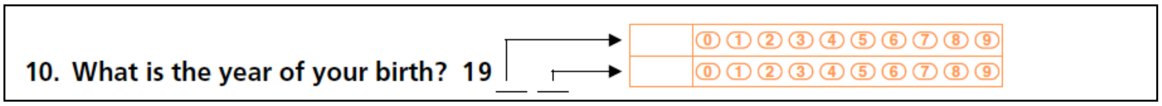
- Chemistry
- Physics

Figure 3-5. Question #39 from the Project Crossover Survey on Time to Doctoral Degree Completion

39. From the time you first enrolled in a doctoral program, how many years did it take you to complete your PhD? (Please round to the nearest year.)

○ <3   ○ 3   ○ 4   ○ 5   ○ 6   ○ 7   ○ 8 or more   ○ Did not complete

Figure 3-6. Question #10 from the Project Crossover Survey on Year of Birth



10. What is the year of your birth? 19 __ __

0 1 2 3 4 5 6 7 8 9

0 1 2 3 4 5 6 7 8 9

Figure 3-7. Question #12 from the Project Crossover Survey on Highest Level of Education Completed by Parents/Guardians

12. What is the highest level of education completed by your guardians/parents?

Father/ Male Guardian	Mother/ Female Guardian	
○	○	Less than High School Diploma
○	○	High School Diploma/G.E.D.
○	○	Some College/Associate Degree
○	○	Baccalaureate
○	○	Master's
○	○	Doctorate

Figure 3-8. Question #14 from the Project Crossover Survey on Citizenship Status

14. What is your United States citizenship status?

- ⬭ U.S.-born Citizen
- ⬭ Naturalized U.S. Citizen
- ⬭ Permanent U.S. Resident ("Green Card")
- ⬭ Temporary U.S. Visa Holder

Figure 3-9. Question #18 from the Project Crossover Survey on First Interest in General Science

18. When did you first become interested in science, in general?

○ K–5th grade	○ 9th–10th grade	○ During first 2 years of undergraduate study
○ 6th–8th grade	○ 11th–12th grade	○ After second year of undergraduate study

Figure 3-10. Question #19 from the Project Crossover Survey on First Interest in Chemistry/Physics

19. When did you first become interested in chemistry/physics?

○ K–5th grade	○ 9th–10th grade	○ During first 2 years of undergraduate study
○ 6th–8th grade	○ 11th–12th grade	○ After second year of undergraduate study

Figure 3-11. Question #22 from the Project Crossover Survey on Average Grade in High School Chemistry Course

22. Please indicate your average grade in your CHEMISTRY course(s) during high school.

○ A+ ○ A ○ A- ○ B+ ○ B ○ B- ○ C+ ○ C ○ C- ○ D ○ F ○ N/A

Figure 3-12. Question #23 from the Project Crossover Survey on Average Grade in High School Physics Course

23. Please indicate your average grade in your PHYSICS course(s) during high school.

○ A+ ○ A ○ A- ○ B+ ○ B ○ B- ○ C+ ○ C ○ C- ○ D ○ F ○ N/A

Figure 3-13. Question #24 from the Project Crossover Survey on Average Grade in Undergraduate Chemistry Course

24. Please indicate your average grade in your CHEMISTRY course(s) during undergraduate studies.

○ A+ ○ A ○ A- ○ B+ ○ B ○ B- ○ C+ ○ C ○ C- ○ D ○ F ○ N/A

Figure 3-14. Question #25 from the Project Crossover Survey on Average Grade in Undergraduate Physics Course

25. Please indicate your average grade in your PHYSICS course(s) during undergraduate studies.

○ A+ ○ A ○ A- ○ B+ ○ B ○ B- ○ C+ ○ C ○ C- ○ D ○ F ○ N/A

Figure 3-15. Question #26 from the Project Crossover Survey on Experiences in Undergraduate Chemistry Course

26. On average, how would you characterize your experiences in undergraduate chemistry?
Please choose a number on the scale, with 1 being "Strongly negative/discouraging" and 4 being "Strongly positive/encouraging".

Strongly negative/discouraging → ① ② ③ ④ ← Strongly positive/encouraging

◯ I did not take any undergraduate chemistry courses.

Figure 3-16. Question #28 from the Project Crossover Survey on Experiences in Undergraduate Physics Course

28. On average, how would you characterize your experiences in undergraduate physics?

Strongly negative/discouraging → ① ② ③ ④ ← Strongly positive/encouraging

○ I did not take any undergraduate physics courses.

CHAPTER 4

RESULTS AND CONCLUSIONS

Analyses of female physical science doctoral students and scientists in this chapter are divided into the following sections: descriptive analyses, variable correlations, logistic regression analyses, and multiple regression analyses. Descriptive analyses include a report of the sample and variables, which examine demographics, interest, achievement, experiences, physicist or chemist career choice, and time to doctoral degree completion. Variable correlations assess collinearity and connections prior to regression analyses. Logistic regression analyses examine female motivation and background factors associated with a career choice in chemistry or physics. Finally, multiple regression analyses describe female motivation and background factors associated with years to doctoral degree completion.

Descriptive Analyses

This section will provide a review of the sample and a series of descriptive analyses regarding all control, predictor, and outcome variables in this study. These background factors are examined as a means to provide the reader with an understanding of the variables, including general distribution and trends. Sample representation of variables is not meant for causal or associative purposes, but instead to provide a basic knowledge of the variables that will be used in the logistic and multiple regression analyses later examined in this study.

Sample

The sample analyzed in this dissertation is composed of data from the female physical sciences doctoral students and scientists from the Project Crossover survey. Project Crossover had a 32% (*n*= 4,285) response rate of male and female physical sciences graduate students, chemists, physicists, and other doctorate holders in the physical sciences (see Table 3-1). In the greater Project Crossover dataset, the female respondents from both physical sciences doctoral students and scientists totaled 1,221 (see Table 3-2). Specific to the series of analyses in this study, 71 cases were listwise deleted due to missing variables for the outcome variable of female chemist or physicist. An additional 13 of these cases were listwise deleted due to multiple answers for control or predictor variables. Therefore, the final sample consists of a subset of 1,137 female physical sciences doctoral students and scientists (see Table 3-3). This study sample included 234 female chemistry doctoral students, 80 female physics doctoral students, 552 female chemistry scientists, and 271 female physics scientists. Since the primary focus of this dissertation is whether females choose a career in physics or chemistry, the demographics and interest, achievement, and experience variables will be examined as a percentage with sample size reported for the total sample (n_{total}) and the subsample of chemists ($n_{\text{chemistry}}$) and physicists (n_{physics}) in each respective variable. The descriptive analyses of these variables based on female responses in the physical sciences will be provided as a preliminary overview to this study and not be examined for causal or associative purposes. Furthermore, descriptives are reported as a valid percentage, aside from missing data (see Table 3-3), as missing variables were not included from the control, predictor, and outcome variables in the subsequent logistic regression and multiple regression analyses.

Demographics

The race and ethnicity distribution for this study is provided in Table 4-1. Seventy-two percent (n_{total} = 813, $n_{chemistry}$ = 551, $n_{physics}$ = 262) of respondents were Caucasian, 19% (n_{total} = 212, $n_{chemistry}$ = 153, $n_{physics}$ = 59) were Asian/Pacific Islander, 5% (n_{total} = 51, $n_{chemistry}$ = 42, $n_{physics}$ = 9) were African American, 4% (n_{total} = 47, $n_{chemistry}$ = 31, $n_{physics}$ = 16) were Latino/Hispanic, and Native American and those who selected the Other option comprised 1% (n_{total} = 14, $n_{chemistry}$ = 9, $n_{physics}$ = 5) of the sample. Ages of the sample, shown in Table 4-2, ranged from 21 to 102, with the majority (n_{total} = 757, $n_{chemistry}$ = 545, $n_{physics}$ = 212) of respondents being age 25 to 44. Mean age of the sample respondents was 38, with a standard deviation of 13. A composite variable was created for the highest reported education between the mother and father of each participant (see Table 4-3). Highest parent education had a slight negative skew. Three percent (n_{total} = 32, $n_{chemistry}$ = 21, $n_{physics}$ = 11) of the sample reported their parent did not finish high school and 16% (n_{total} = 166, $n_{chemistry}$ = 114, $n_{physics}$ = 52) had a parent who did finish high school. Sample participants indicated that 13% (n_{total} = 137, $n_{chemistry}$ = 106, $n_{physics}$ = 31) had a parent with at least some college education and 26% (n_{total} = 278, $n_{chemistry}$ = 201, $n_{physics}$ = 77) reported that their parent had at least a bachelor's degree. In regard to citizenship, the majority of the sample, or 67% (n_{total} = 763, $n_{chemistry}$ = 546, $n_{physics}$ = 217), reported being a U.S. citizen (see Table 4-4). Twenty-three percent (n_{total} = 265, $n_{chemistry}$ = 178, $n_{physics}$ = 87) of respondents had either a green card or temporary visa and 9% (n_{total} = 103, $n_{chemistry}$ = 60, $n_{physics}$ = 43) were naturalized citizens of the U.S.

Interest, Achievement, and Experiences

Family interest was reported as a continuous variable in this analysis, ranging from 0 to 4. Here participants were asked to mark all statements that applied to their family's past interest in or support of science. Therefore, if a participant marked a 0 then they reported no family interest in science, whereas a 4 would indicate four specific types of family interest in science. Twenty-two percent (n_{total} = 254, $n_{\text{chemistry}}$ = 170, n_{physics} = 84) of the sample reported that their family had no interest in science (see Table 4-5). Respondents with one instance of family interest in science comprised 45% (n_{total} = 511, $n_{\text{chemistry}}$ = 369, n_{physics} = 142) of the sample. Nineteen percent (n_{total} = 221, $n_{\text{chemistry}}$ = 151, n_{physics} = 70) reported two circumstances of family support in science and 11% (n_{total} = 122, $n_{\text{chemistry}}$ = 77, n_{physics} = 45) indicated three types of family interest in science. Finally, only 3% (n_{total} = 29, $n_{\text{chemistry}}$ = 19, n_{physics} = 10) of the sample reported the highest level, or four separate types, of family interest in science.

Aside from family interest, personal science interest was reported with regard to both general science and the physical sciences. The series of analyses here focus on respondents that showed an early interest in these two forms of science prior to the fifth grade. Specific to this sample, a large percentage of participants, 41% (n_{total} = 468, $n_{\text{chemistry}}$ = 312, n_{physics} = 156), indicated a general interest in science before fifth grade (see Table 4-6). Therefore, 59% (n_{total} = 669, $n_{\text{chemistry}}$ = 474, n_{physics} = 195) did not indicate a general interest in science before the fifth grade. With regard to physical sciences interest, only 8% (n_{total} = 88, $n_{\text{chemistry}}$ = 54, n_{physics} = 34) of participants reported an interest prior to the fifth grade (see Table 4-7) and 92% (n_{total} = 1,036, $n_{\text{chemistry}}$ = 722, n_{physics} = 314) did not report an interest in the physical sciences by fifth grade.

Subsequent to variables of interest, academic achievement, or grades, were examined. This study focused on academic achievement in high school chemistry (see Table 4-8) and physics (see Table 4-9). Sample respondents indicated that their high school chemistry grades were distributed as 84% achieved an A (n_{total} = 948, $n_{\text{chemistry}}$ = 655, n_{physics} = 293), 11% achieved a B (n_{total} = 120, $n_{\text{chemistry}}$ = 85, n_{physics} = 35), and 2% achieved a C, D, or F (n_{total} = 22, $n_{\text{chemistry}}$ = 20, n_{physics} = 2). In addition, 3% (n_{total} = 32, $n_{\text{chemistry}}$ = 15, n_{physics} = 17) of the sample did not report a grade in high school chemistry. High school physics grades showed a similar trend, with participants indicating that 72% achieved an A (n_{total} = 805, $n_{\text{chemistry}}$ = 517, n_{physics} = 288), 16% achieved a B (n_{total} = 177, $n_{\text{chemistry}}$ = 148, n_{physics} = 29), and 2% achieved a C, D, or F (n_{total} = 20, $n_{\text{chemistry}}$ = 17, n_{physics} = 3). Furthermore, 10% (n_{total} = 116, $n_{\text{chemistry}}$ = 90, n_{physics} = 26) of the sample did not report a grade in high school physics.

A similar trend was found in the distribution of undergraduate grades in chemistry (see Table 4-10) and physics (see Table 4-11). Specific to undergraduate chemistry, 61% of the sample had an A (n_{total} = 687, $n_{\text{chemistry}}$ = 514, n_{physics} = 173), 27% had a B (n_{total} = 308, $n_{\text{chemistry}}$ = 238, n_{physics} = 70), and 2% had a C, D, or F (n_{total} = 26, $n_{\text{chemistry}}$ = 17, n_{physics} = 9). In addition, 9% (n_{total} = 104, $n_{\text{chemistry}}$ = 8, n_{physics} = 96) of respondents did not report a grade in chemistry as a postsecondary student. Sample participants also indicated that their distribution of undergraduate physics grades were: 57% had an A (n_{total} = 639, $n_{\text{chemistry}}$ = 377, n_{physics} = 262), 35% had a B (n_{total} = 391, $n_{\text{chemistry}}$ = 310, n_{physics} = 81), and 6% had a C, D, or F (n_{total} = 67, $n_{\text{chemistry}}$ = 66, n_{physics} = 1). Furthermore, 3% (n_{total} = 30, $n_{\text{chemistry}}$ = 24, n_{physics} = 6) of respondents did not report a grade in entry-level physics.

Next, this study examined whether participants reported a general negative or positive experience in their undergraduate chemistry (see Table 4-12) and physics (see Table 4-13) courses. Sample respondents indicated the following about their undergraduate chemistry course: 75% (n_{total} = 843, $n_{\text{chemistry}}$ = 682, n_{physics} = 161) indicated a general positive experience, whereas 17% (n_{total} = 187, $n_{\text{chemistry}}$ = 89, n_{physics} = 98) reported a negative experience, and 8% (n_{total} = 91, $n_{\text{chemistry}}$ = 2, n_{physics} = 89) reported that they did not take an undergraduate chemistry course. Furthermore, sample participants indicated the following about their undergraduate physics course: 65% (n_{total} = 727, $n_{\text{chemistry}}$ = 428, n_{physics} = 299) had a general positive experience, 33% (n_{total} = 367, $n_{\text{chemistry}}$ = 321, n_{physics} = 46) had a negative experience, and 2% (n_{total} = 23, $n_{\text{chemistry}}$ = 20, n_{physics} = 2) did not take an undergraduate course in physics.

Chemist or Physicist

Analyses reported in the descriptive statistics have been examined as a total sample and in the perspective of whether females choose a career in either chemistry or physics. A more in-depth look at the percentage of students and scientists in chemistry and physics (see Table 4-14) may provide a better understanding of the sample as a whole. Descriptive analyses indicate that 28% (n_{total} = 314, $n_{\text{chemistry}}$ = 234, n_{physics} = 80) of the participants were doctoral students at the time of survey completion, while 72% (n_{total} = 823, $n_{\text{chemistry}}$ = 552, n_{physics} = 271) were scientists with a completed Ph.D.

Time to Ph.D. Degree Completion

Time to Ph.D. degree completion was an outcome variable in the multiple regression analyses in this study and ranged from less than three years to eight years or unlikely to complete. The mean of sample participants' responses was 4.65 years to doctoral completion, with a standard deviation of 1.67 years. Sample respondents indicated that their years to Ph.D. completion (see Table 4-15) were as follows: 1% (n_{total} = 11, $n_{chemistry}$ = 8, $n_{physics}$ = 3) in less than three years, 5% (n_{total} = 48, $n_{chemistry}$ = 30, $n_{physics}$ = 18) in three years, 15% (n_{total} = 165, $n_{chemistry}$ = 120, $n_{physics}$ = 45) in four years, 38% (n_{total} = 404, $n_{chemistry}$ = 298, $n_{physics}$ = 106) in five years, 18% (n_{total} = 193, $n_{chemistry}$ = 102, $n_{physics}$ = 91) in six years, 7% (n_{total} = 71, $n_{chemistry}$ = 25, $n_{physics}$ = 46) in seven years, 4% (n_{total} = 40, $n_{chemistry}$ = 18, $n_{physics}$ = 22) in eight years, and 12% (n_{total} = 133, $n_{chemistry}$ = 122, $n_{physics}$ = 11) did not expect to complete their doctoral degrees.

Variable Correlations

Significant correlations, or collinearity, between variables could potentially make it hard to determine the significance of these variables in the logistic and multiple regression analyses. Due to this concern, a series of Pearson correlations were run for all control and predictor variables in the dataset. Correlations and relationships do not indicate any association or causation in this study. Instead, this analysis is meant to provide a basic representation of the data and a need for composite variables where appropriate. Only one set of variables, mother and father’s highest level of education, were combined due to a significant correlation (.466, $p < 0.01$). These variables were combined so that the highest level of education reported between the mother and father remained in the dataset under a new variable labeled highest parent education.

Race/ethnicity and citizenship status variables also included the following significant correlations: Asian and U.S. citizenship status (.508, $p < 0.01$) and Asian and green card/temporary visa status (.418, $p < 0.01$). Further significant correlations were found for Caucasian and U.S. citizenship status (.553, $p < 0.01$) and Caucasian and green card/temporary visa status (.436, $p < 0.01$). Due to this series of correlations, race and ethnicity were further examined in relation to citizenship status of participants (see Figure 4-1). Female physical scientists who were U.S. citizens showed the following race and ethnicity representation: 87% ($n_{total} = 667$) were Caucasian, 4% ($n_{total} = 29$) were Asian/Pacific Islander, 3% ($n_{total} = 25$) were African American, 2% ($n_{total} = 17$) were Latino/Hispanic, and 3% ($n_{total} = 25$) were Native American/Other. Green card and temporary visa holders were more widely represented, with 37% ($n_{total} = 98$) being Caucasian, 46% ($n_{total} = 122$) were Asian/Pacific Islander, 6% ($n_{total} = 15$) were African American, 6% ($n_{total} = 15$) were Latino/Hispanic, and 6% ($n_{total} = 15$) were Native American/Other. Naturalized citizens in the sample were distributed as: 35% ($n_{total} = 36$) Caucasian, 43% ($n_{total} = 44$) Asian/Pacific Islander, 4% ($n_{total} = 4$) African American, 11% ($n_{total} = 11$) Latino/Hispanic, and 8% ($n_{total} = 8$) Native American/Other. While the connection between race and ethnicity and citizenship status provides a greater understanding of the representation of female participants, the variables were not combined due to their unique demographic measurement and representation in the dataset.

Final significant correlations were uncovered among variables regarding undergraduate academic achievement and experiences. Specifically, undergraduate grade in chemistry was significantly correlated with positive experience in undergraduate chemistry (.549, $p < 0.01$). In addition, undergraduate grade in physics was significantly correlated with positive experience in undergraduate physics (.438, $p < 0.01$). A more in-depth look showed that participants with positive undergraduate chemistry experiences reported the following grade distribution: 72% ($n_{total} = 609$) achieved an A, 26% ($n_{total} =$

216) achieved a B, 1% (n_{total} = 5) achieved a C or less, and 1% (n_{total} = 12) did not report a grade in chemistry. Participants with a negative undergraduate chemistry experience had the following distribution of grades: 40% (n_{total} = 75) had an A, 49% (n_{total} = 91) had a B, 10% (n_{total} = 19) had a C or less, and 1% (n_{total} = 2) did not report a chemistry grade. Seventy-one percent (n_{total} = 515) of participants with a positive experience in undergraduate physics achieved an A, 27% (n_{total} = 199) achieved a B, 1% (n_{total} = 6) achieved a C or less, and 1% (n_{total} = 7) did not report a physics grade. Participants with a negative undergraduate physics experience had the following distribution of grades: 31% (n_{total} = 113) had an A, 52% (n_{total} = 191) had a B, 16% (n_{total} = 58) had a C or less, and 1% (n_{total} = 5) did not report a physics grade. Overall, participants with positive undergraduate experiences had a greater percentage of higher grades as undergraduate students in either chemistry or physics. In addition, participants with negative undergraduate experiences had a greater percentage of Bs or Cs. Undergraduate experiences and grades in chemistry or physics were not combined, due to their ability to paint a more detailed picture in the analyses that followed.

Logistic Regression Analyses

Two logistic regression analyses were developed using the outcome variable of either female career choice in chemistry or physics. Demographic variables for both models included race/ethnicity, age, highest parent education, and citizenship. Predictor variables for the female chemist outcome model focused on early education experiences, in addition to chemistry undergraduate academic achievement and experiences. These variables included level of parent support, early interest in general science, early interest in physical sciences, high school grade in chemistry, high school grade in physics, undergraduate grade in chemistry, and positive undergraduate experience in chemistry. Results from this analysis are displayed in Table 4-16. Meanwhile, predictor variables for the female physicist outcome model focused on early education experiences and undergraduate physics academic achievement and experience. These variables included level of parent support, early interest in general science, early interest in physical sciences, high school grade in chemistry, high school grade in physics, undergraduate grade in physics, and positive undergraduate experience in physics. Results from this analysis are displayed in Table 4-18. The following sections will review the outcomes of these specific models in addition to relevant odds ratios, prototypical odds ratios, and potential interactions regarding female career choice in the physical sciences.

Female Chemist

Focusing on the chemist model (see Table 4-16), results indicate a variety of achievement and experience factors that are associated with female career choice in the physical sciences. As a reminder, chemistry career choice was coded as an outcome of 1 and physics career choice was coded as an outcome of 0. Therefore, all results will be reviewed as a career choice predictor of chemistry as opposed to a career choice in physics. Specific predictor variables in the chemist model that were significant predictors, or differentiate between a career choice in chemistry or physics, are high school grade in chemistry, high school grade in physics, undergraduate grade in chemistry, and a positive undergraduate experience in chemistry.

Odds ratios of these significant predictors provide a greater understanding of the ability of these variables to differentiate a female career choice in chemistry as opposed to one in physics. Results indicate that participants with a high school grade of A as opposed to a B in chemistry had a 1.087 times higher odds of reporting a career choice in chemistry. High school physics grade had a negative impact on the model where females with an A as opposed to a B in physics had a 0.877 times odds of going into the field of chemistry. Respondents who achieved an A instead of a B in undergraduate chemistry had a 1.160 times higher odds of reporting a career choice in chemistry as opposed to one in physics. What is most striking about this model is that participants reporting a general positive experience in undergraduate chemistry had a 5.566 times higher odds of choosing a career in chemistry. Therefore, the logistic regression shows that high school and undergraduate academic achievement and experience in chemistry has a positive association with a career choice in chemistry after controlling for background demographic variables.

Background demographic variables that show a connection with career choice in chemistry include age and highest parent education. These variables did not positively influence the chemist model, most likely due to a negative skew in female chemist age and highest parent education. Therefore, participants reporting an increase in age of a year had a 0.968 times odds of entering the field of chemistry, and those with an increased level of highest parent education had a 0.863 times odds of entering the field of chemistry.

Next, a series of interactions was developed by crossing significant background demographic variables with high school grade in chemistry, high school grade in physics, undergraduate grade in chemistry, and a positive undergraduate experience in chemistry in the model. Variables examined in these interactions included age and highest parent education, which were individually incorporated into the chemist logistic regression model. First, age was examined as an interaction with high school grade in chemistry, then high school grade in physics, then undergraduate grade in chemistry, and then positive undergraduate experience in chemistry, respectively, in the model. No appreciable change was found from these interactions with respective outcomes to warrant the added complexity of the model. Next, a series of interaction variables was created among highest parent education with high school grade in chemistry, high school grade in physics, undergraduate grade in chemistry, and positive undergraduate experience in chemistry. None of these interactions was found to be individually significant in the chemist logistic regression model.

The final step in this series of analyses included creation of prototypical odds ratios from the relevant odds ratios reported in the chemist model. Prototypical odds ratios allow for the creation of a hypothetical female chemist through a combination of relevant odds ratios. This allows for a better understanding of how these odds ratios may compound, as opposed to being reported in isolation, and influence a female to enter the field of chemistry. Prototypical odds ratios can be formed through the multiplication of odds ratios reported in the logistic regression model. Specifically, for this model, four prototypes of female chemists were created, including those with a lower grade in high school and undergraduate chemistry and a negative experience in undergraduate chemistry; a higher grade in high school and undergraduate chemistry and a negative experience in undergraduate chemistry; a lower grade in high school and undergraduate chemistry and a positive experience in undergraduate chemistry; and a higher grade in high school and undergraduate chemistry and a positive experience in undergraduate chemistry. For these prototypical odds ratios, a higher grade was an A and a lower grade was a B in high school and undergraduate physical sciences. Compounded odds ratios, calculated by the multiplication of specific odds ratios from the chemist logistic regression model (see Table 4-16), are reported in Table 4-17.

Prototypical odds ratios describe an interesting interaction between chemistry grades and experiences of female chemists. A female reporting a lower grade in high school and undergraduate chemistry and a negative experience in undergraduate chemistry had a baseline, or 1.000 times odds, of going into the field of chemistry. A woman with higher grades in high school and undergraduate chemistry and a negative experience in undergraduate chemistry had a 1.261 times greater odds of being a chemist. A female with lower grades in high school and undergraduate chemistry and a positive experience in undergraduate chemistry had a 5.566 times greater odds of being a chemist. Finally, the most striking result is a female with higher grades in high school and undergraduate chemistry and a positive experience in undergraduate chemistry. This female, when compared to the baseline prototype, had a 7.019 times higher odds of being a chemist as opposed to a physicist.

Female Physicist

A second logistic regression model was run focusing on female physicist career choice (see Table 4-18). For this model, a career choice as a physicist was coded as an outcome of 1 and a chemistry career choice was coded as an outcome of 0. Due to the coding of this outcome variable, all results are reviewed in reference to whether women made a career choice in physics as opposed to one in chemistry. The physicist model indicated a variety of predictor variables that were significant and could differentiate or predict a career choice in physics compared to chemistry. Significant predictor variables included high school grade in chemistry, high school grade in physics, undergraduate grade in physics, and a positive undergraduate experience in physics.

Odds ratios of positive significant predictor variables were examined to show how these variables differentiated between a physics career choice when compared to one in chemistry by female scientists. High school chemistry grade had a negative impact on the model where females with an A, as opposed to a B, in chemistry had a 0.895 times odds of going into the field of physics. Respondents with a physics high school grade of A instead of a B had a 1.070 times higher odds of reporting a career in physics. In addition, participants with an undergraduate physics grade of A instead of a B had a 1.298 times higher odds of having a career in physics instead of one in chemistry. Striking in this model is that females who said their undergraduate physics course provided a positive experience had a 3.467 times higher odds of going into the field of physics. Overall, female physics academic achievement in high school and postsecondary studies and positive experiences in undergraduate physics courses was significant for a career choice in physics after controlling for demographic variables in this physicist logistic regression model.

Demographic variables were examined in the model to see if there was any connection with a physics career choice. Significant background variables that had a negative impact on the model were Asian race and ethnicity and U.S. citizenship, whereas the variable of age had a positive influence on the model. If a participant reported that they were Asian, they had a 0.571 times odds of becoming a physicist, and U.S. citizens had a 0.612 times odds of becoming a physicist. An increase in age positively influenced a respondent to have a 1.035 times odds of entering the field of physics.

Next, a series of interactions was run to ensure that the reported predictor variables were influencing the outcomes in the female physicist model. Race, ethnicity, and citizenship status were not examined, as these demographic variables were beyond the scope of this study. Age was the primary demographic variable examined with interactions in these models. Interactions were created by crossing age with high school grade in chemistry, high school grade in physics, undergraduate grade in physics, and a positive undergraduate experience in physics in the model. The four age-based interactions were not found to be independently significant in the physicist logistic regression model.

A series of prototypical odds ratios were created to better understand how the combination of significant odds ratios might positively influence a female to enter the field of physics. Four prototypes of female physicists were developed through the multiplication of odds ratios. Prototypes included a lower grade in high school and undergraduate physics and a negative experience in undergraduate physics; a higher grade in high school and undergraduate physics and negative experience in undergraduate physics; a lower grade in high school and undergraduate physics and a positive experience in undergraduate physics; and a higher grade in high school and undergraduate physics and a positive experience in undergraduate physics. The compound odds ratio was developed with a higher grade being an A and a lower grade being a B in high school and undergraduate physical science. Female physicist prototypical odds ratios were calculated by the multiplication of odds ratios from the physics logistic regression model (see Table 4-18) and are reported in Table 4-19.

Compounded odds ratios depict the connection between female physicists' academic achievement and experiences. A baseline prototype was created of a female in physics with a lower grade in high school and undergraduate physics and a negative experience in undergraduate physics. This individual had a 1.000 times odds of reporting going into physics. A female who had higher grades in high school and undergraduate physics, in addition to a negative experience in physics, had a 1.389 times greater odds of being a physicist as compared to a chemist. On the other hand, a female with lower grades in high school and undergraduate physics and a positive undergraduate experience had a 3.467 times higher odds of entering the field of physics. Lastly, a female with higher grades in high school and undergraduate chemistry and a positive experience in undergraduate chemistry had a 4.816 times higher odds of entering the field of physics instead of chemistry.

Multiple Regression Analyses

Two multiple regression analyses were created to separately examine background factors and predictor variables that contribute to Ph.D. completion by female chemists and physicists. Given the nature of these two models, the dataset was split so that one model was created of only female doctoral students and scientists in chemistry (n= 786) and another model of only female doctoral students and scientists in physics (n= 351). For a description of the representation of these two groups, see Table 3-3. Background demographic variables for both models were race/ethnicity, age, highest parent education, and citizenship. The model of female chemists had the following predictor variables:

level of parent support, early interest in general science, early interest in the physical sciences, high school grade in chemistry, high school grade in physics, undergraduate grade in chemistry, and positive undergraduate experience in chemistry. Results from this analysis are presented in Table 4-20. The model of female physicists included the following predictor variables: level of parent support, early interest in general science, early interest in the physical sciences, high school grade in chemistry, high school grade in physics, undergraduate grade in physics, and positive undergraduate experience in physics. Results from this analysis are presented in Table 4-21. The sections below will discuss model significance and whether the predictors are meaningful in respective groups of female chemists and physicists.

Female Chemist

The multiple R^2 of the female chemist model, or the squared multiple correlation of years to Ph.D. completion, with the predictor variables, is 0.065. R^2 is created through division of the regression sum of squares by the total sum of squares. Here R^2 indicates that 6.5% of the variance in time to Ph.D. completion is accounted for by the background demographics and predictor variables of female chemists. Significance of the R^2 can be evaluated by looking at the actual model $F_{(14,642)}$ value of 3.166 in comparison to its $F_{(14,642)}$ critical value of 1.707. The F critical value indicates that the R^2 of the model is significant. While the R^2 of this model is relatively small, R^2 shrinkage is still likely to have occurred in the model. This is because the multiple regression is based on sample data, therefore maximizing the sampling error and not the error from the actual population of female chemists. The adjusted R^2 in the model is 0.044 and allows for the ability to eliminate shrinkage in the model. Consequently, if the female chemist model were based on the actual population as opposed to sample data, it would represent 2.1% (0.065-0.044) less variance in the outcome.

A significant R^2 indicates that at least one of the predictor coefficients in the regression is significant. Predictors can be examined for significance through the use of *t*-ratios, which are developed by dividing predictor regression coefficients by their standard errors. The female chemist model indicates that the following two predictors are significant: U.S. citizenship with a *t*-test of 4.015 at $p < 0.001$ and physics high school grade with a *t*-test of -2.163 at $p < 0.05$. These results show that U.S. citizenship status of female chemists may associate with an increase in years to Ph.D. completion, while a higher high school physics grade does not. The rest of the predictors in the model are not significant. U.S. citizenship is a demographic/control variable in the model, and therefore will not be reported in the conclusion of this study. High school physics grade will be examined in the female physicist model to see whether parallel findings exist. Furthermore, associations of the significant predictors should be examined in light of the multiple R^2 value, which indicates that the model accounts for 6.5% of the variance in years to Ph.D. completion of the sample of female chemists.

Female Physicist

The female physicist regression model multiple R^2 is 0.106. This R^2 means that demographic and predictor variables of female physicists in the regression account for 10.6% of the variance in time to Ph.D. completion. The model $F_{(14,285)}$ value of 2.424 can be compared to the $F_{(14,285)}$ critical value of 1.727. The F critical value indicates that the model R^2 is significant. The model shows an adjusted R^2 of 0.063, which allows for the determination of model shrinkage. Therefore, a model composed of the actual population of female physicists, as opposed to the sample data, would have 4.3% (0.106-0.063) less variance in the outcome.

Based on the significant R^2, the model has at least one significant regression coefficient. T-ratios were examined in the model in order to test which predictors were significant. Two citizenship predictors in the female physicist model were determined to be significant. U.S. citizenship has a *t*-test of 4.429 at $p < 0.001$, and naturalized citizens had a *t*-test of 2.105 at $p < 0.05$. These results indicate that U.S. and naturalized citizenship status may associate with an increase in years to Ph.D. completion of female physicists. All other predictors in the model were not significant. U.S. and naturalized citizenship are demographic/control variables in the model, and therefore will not be reported in the conclusion of this study. Once again, associations with female physicist time to Ph.D. completion should be examined in respect to the multiple R^2, showing that this model represents 10.6% of the change in years to Ph.D. completion of the sample.

Summary of Findings

Two research questions were examined through the results of this study. Prior to examining these research questions, a series of descriptive analyses and correlations were examined of the control, predictor, and outcome variables. Descriptive analyses showed a normal distribution of all variables, except a slight negative skew among participant age and highest parent education. Chemistry doctoral students and scientists showed a greater percentage of positive experiences in chemistry and negative experiences in physics. In addition, physics doctoral students and scientists showed a higher response rate to negative experiences in chemistry and positive experiences in physics. Collinearity in the data led to a composite variable of highest parental education among mother and father's education. Significant correlations were found among citizenship and race/ethnicity, in addition to undergraduate academic achievement and experiences in chemistry and physics. These variables were also found to interact in logistic regression analyses examining the first research question.

Research question one sought to discover what differentiates female career choice in chemistry or physics based on background demographics, interest, experiences, and motivations. Chemist and physicist models were created to look at career predictors. Significant predictors in the chemist model that positively differentiate between a career choice in chemistry as opposed to physics are: high school grade in chemistry, undergraduate grade in chemistry, and a positive undergraduate experience in chemistry. Chemistry demographic and predictor factors that were significant and negatively influenced the model included age, highest parent education, and high school physics grade. Significant predictors in the physics model that positively differentiate between a career choice in physics as opposed to chemistry included high school grade in physics, undergraduate grade in physics, and a positive undergraduate experience in physics. High school chemistry grade was significant in the model but had a negative association with a career choice in physics. Demographic factors that were significant in the physics model included age, race, and citizenship. Specifically, age had a positive association with the model outcome, while Asian race/ethnicity and U.S. citizenship did not.

Research question two examined whether the same background demographics and interest, experiences, and motivations, when examined in female chemists or physicists, were associated with time to doctoral degree completion. Two models were created: one with only chemistry doctoral students and scientists and another with only physics doctoral students and scientists. Both models had significant multiple R^2, yet these R^2 were small and therefore accounted for little differentiation in the outcome of time to doctoral completion. The chemist model had U.S. citizenship and physics high school grade as significant predictors, while the physics model had U.S. and naturalized citizenship as significant predictors. Significant variables included demographic/control variables and high school physics grade, which were not parallel in the two models. Due to these findings and small multiple R^2, the multiple regression models will not be examined based on these variables in the conclusion. Multiple regression models will instead be discussed in light of the predictor variables that were not found to be significant in the models.

A connection between demographics (Denecke, 2004; Hill et al., 2010; Lewis et al, 2009), academic achievement (Hyde et al., 2008; Pajares, 1996, 2005), and experiences (Tai & Sadler, 2001; Carlone & Johson, 2007) has been shown through research literature to associate with a career choice in STEM. The two research questions studied in light of these research outcomes provide a better understanding of the career choice among women in the physical sciences. Further discussion and implications of these findings will be examined in the next chapter.

Table 4-1

Race and Ethnicity Distribution by Physical Science

	Race and Ethnicity			
	Chemistry	Physics	Total	
	n	n	n	%
Caucasian	551	262	813	72
Asian/Pacific Islander	153	59	212	19
African American	42	9	51	5
Latino/Hispanic	31	16	47	4
Native American/Other	9	5	14	1
Total	786	351	1137	101

Total percentage may not equal 100 due to rounding.

Table 4-2

Age Distribution by Physical Science

Age	Chemistry	Physics	Total	
	n	n	n	%
20-24	58	11	69	6
25-29	241	54	295	26
30-34	145	82	227	20
35-39	94	34	128	11
40-44	65	42	107	10
45-49	42	29	71	6
50-54	51	32	83	7
55-59	33	15	48	4
60-64	19	19	38	3
65-69	12	12	24	2
70+	13	16	29	3
Total	773	346	1119	98

Total percentage may not equal 100 due to rounding.

Table 4-3

Highest Parent Education Distribution by Physical Science

Highest Parent Education				
	Chemistry	Physics	Total	
	n	n	n	%
Didn't finish HS	21	11	32	3
High School	114	52	166	16
Some College	106	31	137	13
Bachelor's	201	77	278	26
Master's	152	71	223	21
Doctoral	142	78	220	21
Total	736	320	1056	100

Total percentage may not equal 100 due to rounding.

Table 4-4

Citizenship Status Distribution by Physical Science

Citizenship Status				
	Chemistry	Physics	Total	
	n	n	n	%
U.S. Citizenship	546	217	763	67
Green Card/Temporary Visa	178	87	265	23
Naturalized Citizen	60	43	103	9
Total	784	347	1131	99

Total percentage may not equal 100 due to rounding.

Table 4-5

Family Interest Level Distribution by Physical Science

	Family Interest Level			
	Chemistry	Physics	Total	
	n	n	n	%
0	170	84	254	22
1	369	142	511	45
2	151	70	221	19
3	77	45	122	11
4	19	10	29	3
Total	786	351	1137	100

Total percentage may not equal 100 due to rounding.

Table 4-6

General Interest in Science K5 Distribution by Physical Science

General Interest in Science K5				
	Chemistry	Physics	Total	
	n	n	n	%
Yes	312	156	468	41
No	474	195	669	59
Total	786	351	1137	100

Total percentage may not equal 100 due to rounding.

Table 4-7

Interest in Physical Science K5 Distribution by Physical Science

Interest in Physical Science K5				
	Chemistry	Physics	Total	
	n	n	n	%
Yes	54	34	88	8
No	722	314	1036	92
Total	776	348	1124	100

Total percentage may not equal 100 due to rounding.

Table 4-8

Average Grade in High School Chemistry Distribution by Physical Science

Average Grade in High School Chemistry				
	Chemistry	Physics	Total	
	n	n	n	%
A	655	293	948	84
B	85	35	120	11
C, D, or F	20	2	22	2
Not Applicable	15	17	32	3
Total	775	347	1122	100

Total percentage may not equal 100 due to rounding.

Table 4-9

Average Grade in High School Physics Distribution by Physical Science

Average Grade in High School Physics				
	Chemistry	Physics	Total	
	n	n	n	%
A	517	288	805	72
B	148	29	177	16
C, D, or F	17	3	20	2
Not Applicable	90	26	116	10
Total	772	346	1118	100

Total percentage may not equal 100 due to rounding.

Table 4-10

Average Grade in Undergraduate Chemistry Distribution by Physical Science

Average Grade in Undergraduate Chemistry				
	Chemistry	Physics	Total	
	n	n	n	%
A	514	173	687	61
B	238	70	308	27
C, D, or F	17	9	26	2
Not Applicable	8	96	104	9
Total	777	348	1125	99

Total percentage may not equal 100 due to rounding.

Table 4-11

Average Grade in Undergraduate Physics Distribution by Physical Science

Average Grade in Undergraduate Physics				
	Chemistry	Physics	Total	
	n	n	n	%
A	377	262	639	57
B	310	81	391	35
C, D, or F	66	1	67	6
Not Applicable	24	6	30	3
Total	777	350	1127	101

Total percentage may not equal 100 due to rounding.

Table 4-12

Experience in Undergraduate Chemistry Distribution by Physical Science

Experience in Undergraduate Chemistry				
	Chemistry	Physics	Total	
	n	n	n	%
Positive	682	161	843	75
Negative	89	98	187	17
Not Applicable	2	89	91	8
Total	773	348	1121	100

Total percentage may not equal 100 due to rounding.

Table 4-13

Experience in Undergraduate Physics Distribution by Physical Science

	Experience in Undergraduate Physics			
	Chemistry	Physics	Total	
	n	n	n	%
Positive	428	299	727	65
Negative	321	46	367	33
Not Applicable	20	3	23	2
Total	769	348	1117	100

Total percentage may not equal 100 due to rounding.

Table 4-14

Doctoral Student/Scientist Distribution by Physical Science

	Doctoral Student/Scientist			
	Chemistry	Physics	Total	
	n	n	n	%
Doctoral Student	234	80	314	28
Scientist	552	271	823	72
Total	786	351	1137	100

Total percentage may not equal 100 due to rounding.

Table 4-15

Time to Ph.D. Degree Completion Distribution by Physical Science

	Time to Ph.D. Degree Completion			
	Chemistry	Physics	Total	
	n	n	n	%
< 3 years	8	3	11	1
3 years	30	18	48	5
4 years	120	45	165	15
5 years	298	106	404	38
6 years	102	91	193	18
7 years	25	46	71	7
8 or more years	18	22	40	4
Not Expected	122	11	133	12
Total	723	342	1065	100

Total percentage may not equal 100 due to rounding.

Table 4-16

Female Chemist Logistic Regression Model Summary with Odds Ratio

Chemist Logistic Regression Model	B	Sig.	SE	Odds Ratio
Background Demographics				
Intercept	0.192	n.s.	0.640	1.212
Asian	0.483	n.s.	0.253	1.622
Hispanic	0.194	n.s.	0.432	1.214
African American	0.808	n.s.	0.448	2.244
Age	-0.032	***	0.006	0.968
Highest Parent Education	-0.148	*	0.060	0.863
U.S. Citizenship	0.411	n.s.	0.227	1.509
Naturalized Citizen	-0.237	n.s.	0.321	0.789
Interest, Achievement, and Experiences				
Family Interest	0.015	n.s.	0.085	1.015
General Interest in Science K5	-0.056	n.s.	0.177	0.946
Interest in Physical Science K5	-0.219	n.s.	0.309	0.803
High School Chemistry Grade	0.084	*	0.041	1.087
High School Physics Grade	-0.131	***	0.033	0.877
Undergrad Chemistry Grade	0.148	***	0.032	1.160
Positive Undergrad Chemistry Exp	1.717	***	0.200	5.566

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant

Table 4-17

Female Chemist Prototypical Odds Ratio

Chemist Prototypical Odds Ratio		
	Negative Experience	Positive Experience
Lower Grades	1.000	5.566
Higher Grades	1.261	7.019

Table 4-18

Female Physicist Logistic Regression Model Summary with Odds Ratio

Physicist Logistic Regression Model	B	Sig.	SE	Odds Ratio
Background Demographics				
Intercept	-5.168	***	0.733	0.006
Asian	-0.560	*	0.239	0.571
Hispanic	-0.439	n.s.	0.420	0.645
African American	-0.787	n.s.	0.435	0.455
Age	0.034	***	0.006	1.035
Highest Parent Education	0.093	n.s.	0.057	1.097
U.S. Citizenship	-0.491	*	0.214	0.612
Naturalized Citizen	0.259	n.s.	0.305	1.296
Interest, Achievement, and Experiences				
Family Interest	0.011	n.s.	0.079	1.011
General Interest in Science K5	0.247	n.s.	0.166	1.281
Interest in Physical Science K5	0.211	n.s.	0.285	1.235
High School Chemistry Grade	-0.111	**	0.040	0.895
High School Physics Grade	0.068	*	0.030	1.070
Undergrad Physics Grade	0.261	***	0.051	1.298
Positive Undergrad Physics Exp	1.243	***	0.201	3.467

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant

Table 4-19

Female Physicist Prototypical Odds Ratio

Physicist Prototypical Odds Ratio		
	Negative Experience	Positive Experience
Lower Grades	1.000	3.467
Higher Grades	1.389	4.816

Table 4-20

Female Chemist Multiple Regression Model

Chemist Multiple Regression Summary

R	R Square	Adjusted R Square	Std Error of Estimate	ANOVA			
				F	df1	df2	Sig. F
0.254	0.065	0.044	1.763	3.166	14	642	0.000

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Background Demographics	B	SE B	β		
(Constant)	4.349	0.661		6.580	***
Asian	0.172	0.221	0.037	0.779	n.s.
Hispanic	0.124	0.343	0.014	0.361	n.s.
African American	0.439	0.310	0.055	1.416	n.s.
Age	-0.002	0.006	-0.011	-0.284	n.s.
Highest Parent Education	0.011	0.052	0.009	0.217	n.s.
U.S. Citizenship	0.813	0.203	0.206	4.015	***
Naturalized Citizen	0.151	0.312	0.021	0.483	n.s.
Interest, Achievement, and Experiences					
Family Interest	-0.072	0.074	-0.040	-0.972	n.s.
General Interest in Science K5	0.284	0.153	0.077	1.858	n.s.
Interest in Physical Science K5	-0.474	0.287	-0.068	-1.652	n.s.
High School Chemistry Grade	0.070	0.040	0.077	1.737	n.s.
High School Physics Grade	-0.053	0.024	-0.094	-2.163	*
Undergrad Chemistry Grade	-0.058	0.045	-0.053	-1.271	n.s.
Positive Undergrad Chemistry Exp	0.086	0.224	0.015	0.383	n.s.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant

Table 4-21

Female Physicist Multiple Regression Model

Physicist Multiple Regression Summary							
R	R Square	Adjusted R Square	Std Error of Estimate	ANOVA			
				F	df1	df2	Sig. F
0.326	0.106	0.063	1.384	2.424	14	285	0.003

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Background Demographics	B	SE B	β		
(Constant)	3.558	0.732		4.863	***
Asian	0.141	0.238	0.037	0.595	n.s.
Hispanic	0.239	0.458	0.030	0.522	n.s.
African American	0.631	0.506	0.071	1.248	n.s.
Age	-0.001	0.006	-0.010	-0.160	n.s.
Highest Parent Education	0.034	0.061	0.035	0.554	n.s.
U.S. Citizenship	0.958	0.216	0.322	4.429	***
Naturalized Citizen	0.634	0.301	0.143	2.105	*
Interest, Achievement, and Experiences					
Family Interest	0.014	0.082	0.010	0.167	n.s.
General Interest in Science K5	0.245	0.178	0.085	1.380	n.s.
Interest in Physical Science K5	-0.324	0.288	-0.068	-1.124	n.s.
High School Chemistry Grade	0.037	0.034	0.067	1.090	n.s.
High School Physics Grade	-0.043	0.030	-0.089	-1.449	n.s.
Undergrad Physics Grade	0.015	0.050	0.018	0.298	n.s.
Positive Undergrad Physics Exp	0.032	0.243	0.008	0.133	n.s.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant

Figure 4-1. Race and Ethnicity Percentage by Citizenship Status

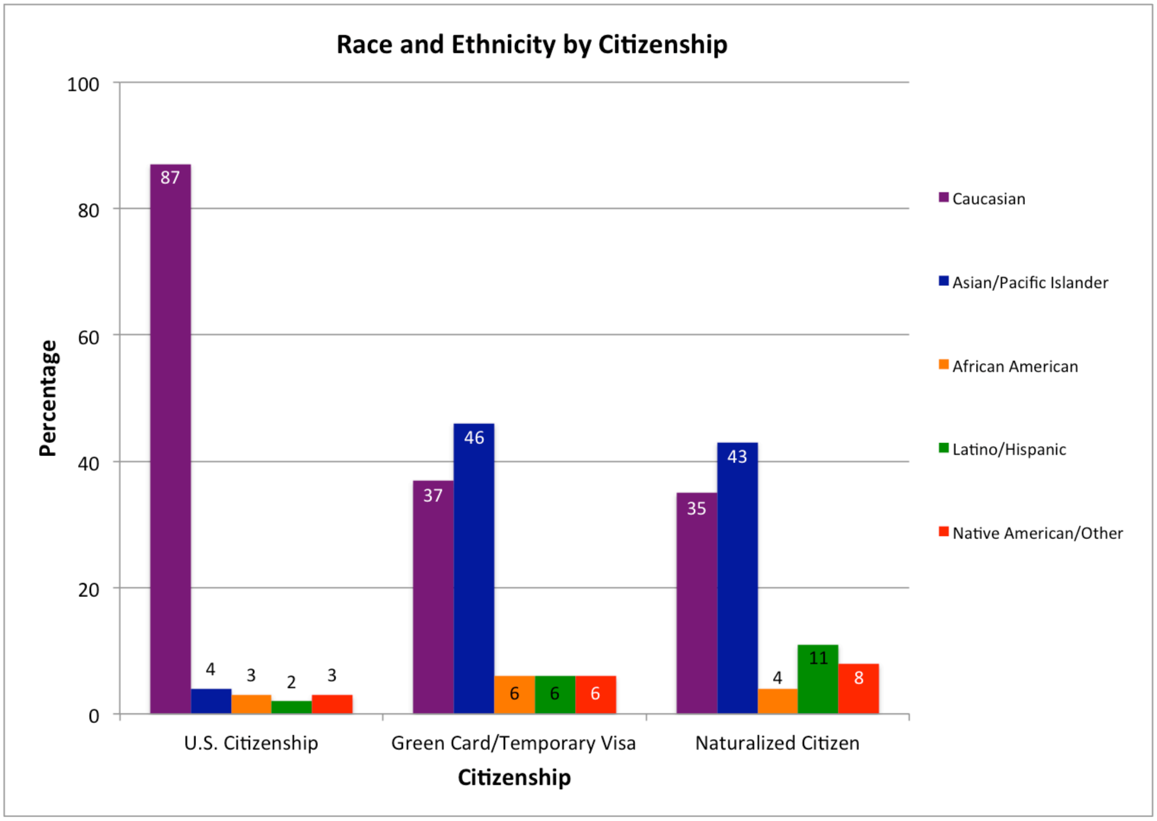


Figure 4-2. Percentage of Undergraduate Chemistry Grades Percentage by Chemistry Classroom Experience

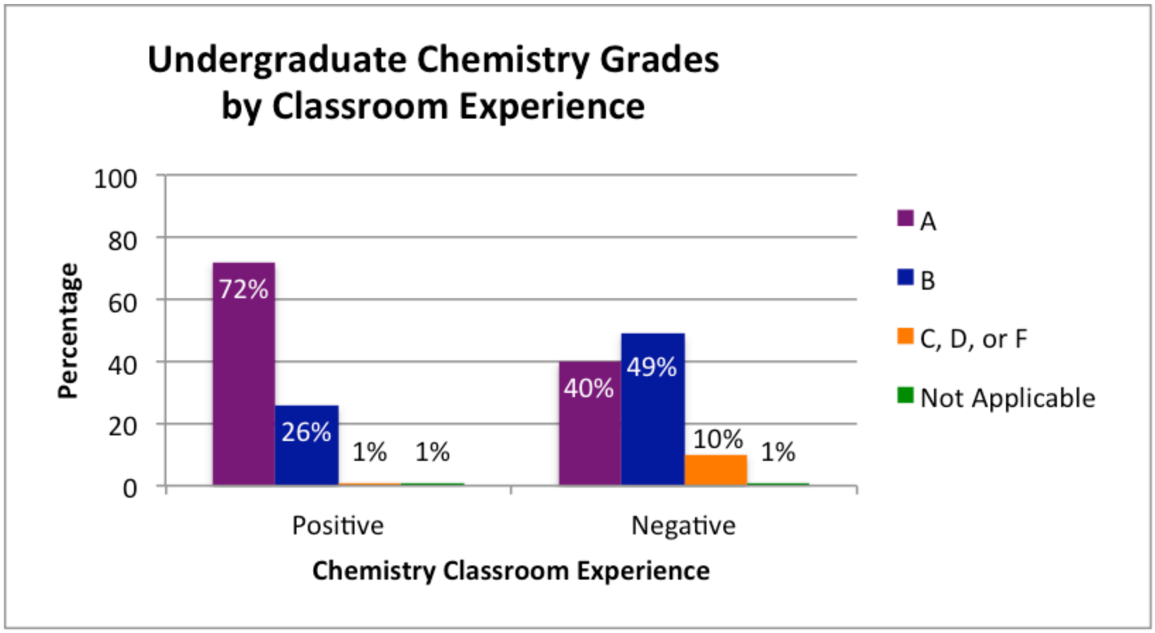
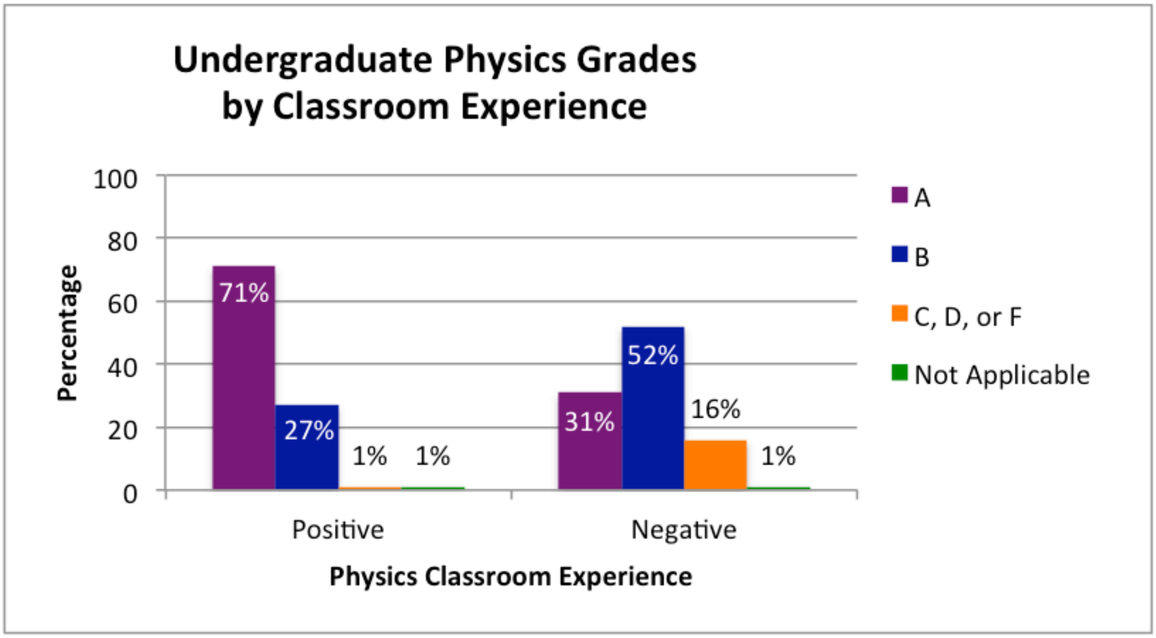


Figure 4-3. Percentage of Undergraduate Physics Grades Percentage by Physics Classroom Experience



CHAPTER 5

DISCUSSION AND IMPLICATIONS

United States economic concerns and educational public policy have made the STEM workforce and education a critical focus (NAS, 2007; U.S. Department of Education, 2006). Women and other underrepresented minorities have been an intrinsic part of this focus in regard to career choice and persistence (Hill et al., 2010; NAS, 2007). Research shows that females are entering the field of chemistry at a faster rate than the field of physics through bachelor's and doctoral degrees (National Science Foundation, 2008a). However, STEM studies primarily compare women to men or examine them as a single entity. Therefore, a paucity of research exists that examines what may differentiate women in certain critical fields of STEM education, such as the physical sciences.

The focus of this study is to examine differences among women in the physical sciences based on background demographics and motivational factors. The research questions sought to discover whether female career choice in physical sciences could be differentiated based on these factors. In addition, background and motivational variables were examined to see whether they predicted female persistence or time to doctoral degree completion in chemistry or physics. A subset of female physical sciences doctoral students and scientists were analyzed from the Project Crossover survey. Research questions were examined through a series of descriptive analyses, variable correlations, logistic regression analyses, and multiple regression analyses. Descriptive analyses examined women as a total sample of physical scientists and then as subsamples of chemists or physicists. Variable correlations provided better understanding of any collinearity in the data and allowed for the creation of certain composite variables prior to any regressions. Logistic regression models differentiated between female career choice in chemistry or physics based on their prior background and educational variables. Finally, multiple regressions of female chemists and physicists allowed for an understanding of how these variables may influence time to Ph.D. completion.

This study is unique in its ability to examine what may differentiate female career choice and persistence in the physical sciences. Variables include demographic influences, family interest, interest in science, interest in the physical sciences, academic achievement, and experiences. These variables range from prior to entering school through secondary education in the United States. One strength of this study lies in its ability to examine what may predict female career choice in the physical sciences as opposed to examining women in comparison to men or as a whole. In addition, the ability to examine these factors in regard to persistence, or time to Ph.D. completion, provides a greater picture of the influence of these factors. This chapter discusses the research findings based on the descriptive analyses, logistic regression analyses, and multiple regression analyses in order to shed light on the career choice and persistence factors that may differentiate women in the physical sciences today. Finally, it will conclude with a series of educational recommendations based on the implications of this research study in addition to any potential limitations of these findings.

Descriptive Analyses

Descriptive analyses examined the sample of female physical sciences doctoral students and scientists as a whole and then in subsamples based on their field of chemistry or physics. These analyses were used to provide a better understanding of the participants' representation in specific variables examined through later regression analyses. While the results were not causative or associative, they do deliver an interesting description of the participants' demographics, interest, academic achievement, and experiences.

Demographic variables included race and ethnicity, age, highest parent education, and citizenship. Race and ethnicity distribution of participants showed an equal representation based on chemistry and physics career choice, with the majority of respondents being Caucasian. As a reminder, the Project Crossover survey sample was determined to be representative based on participants' demographics (race and/or ethnicity and gender) and employment groupings with the NSF's WebCASPAR database (Hazari, Potvin, Tai, & Almarode, 2010; see Appendix A). The age variable contained a slight negative skew for both chemistry and physics participants. Specifically, 70% of females in chemistry were in the age range of 20-39 and 73% of females in physics were in the age range of 20-49. Therefore, the average chemistry participant was younger, based on year of birth at the time the Project Crossover survey was taken. This ties in with research showing that the number of females in the physical sciences is slowly increasing, with the majority of growth occurring in the last 40 years (NSF, 2008a). In regard to highest parent education, chemists and physicists showed equal representation; however, there was a slight negative skew, with the majority of respondents' parents having a bachelor's degree or less for their highest level of education. In addition, the majority of participants were U.S. citizens, which was not surprising for a U.S. based survey.

Predictor variables included interest, academic achievement, and experiences. Parent interest was reported by the majority of participants ranging from no support to at least two types of science-based support at home. General interest in science prior to fifth grade was almost equal to interest that developed after fifth grade for all respondents. The majority of participants reported initial interest in the physical sciences after the fifth grade, which makes sense, as these subjects are often first taught in high school. Both female chemists and physicists were equally represented based on average grade in high school chemistry; however, a higher grade in high school physics was reported by a greater number of female physicists. This distribution of representation grew in postsecondary education, where female chemists reported a higher grade in undergraduate chemistry and female physicists reported a higher grade in undergraduate physics. In addition, 28% of female physicists reported that they did not receive a grade in undergraduate physics. This could be potentially due to advanced high school placement courses. Most obvious of all in these descriptive analyses is the experience in undergraduate chemistry or physics as reported by female chemists and physicists. Overall, female chemists reported greater positive experiences in undergraduate chemistry, while female physicists reported greater positive experiences in undergraduate physics.

Could females' academic achievement and experiences be associated with their career choice in the physical sciences? This question was examined in the logistic regression portion of the results, which will be discussed next. Finally, the majority of female chemists graduated from their doctoral programs in five years, while the majority of female physicists graduated in six years. What demographic background and motivation variables may influence female persistence in the physical sciences will be discussed in the multiple regression portion of this chapter.

Logistic Regression Analyses

Logistic regression models were used with female career choice in chemistry or physics as an outcome, in addition to a series of background and educational predictor variables. Certain findings provide a picture of the associations between these variables and female career choice in the physical sciences that may better inform the field of STEM education. A comparative discussion of the results will be reviewed by first the predictor and then the control variables in these two logistic regression models, with a focus on the career outcome of chemistry or physics.

Female career choice in chemistry as opposed to physics indicated significant predictor variables above and beyond demographic control variables. First, academic achievement in chemistry and physics played a role in the differentiation of women into the field of chemistry. Specifically, females with a higher high school chemistry grade had a 1.087 times higher odds of going into the field of chemistry. One predictor variable that did have a negative role in the model of predicting a career choice in chemistry was high school physics grade. Women with a higher high school physics grade had a 0.877 times odds of going into to the field of chemistry. The positive influence on the model of chemistry further extended to postsecondary studies, where females with a higher grade in undergraduate chemistry had a 1.160 times higher odds of going into the field of chemistry as opposed to physics. Finally, females with positive undergraduate experiences in chemistry had a 5.566 times higher odds of pursuing a doctoral degree in chemistry.

A similar picture is painted by predictor variables in the female physicist model in regard to academic achievement and experiences in high school and postsecondary physics. Women with a higher grade in high school physics had a 1.070 times higher odds of going into the field of physics. High school grade in chemistry had a negative impact on the physicist model. Therefore, females with a higher grade in high school chemistry had a 0.895 times odds of going into to the field of physics. An examination of undergraduate achievement in physics showed that females with a higher grade in undergraduate physics had a 1.298 times higher odds of going into the field of physics, as opposed to chemistry. The most influential predictor variable in this model was positive undergraduate experiences in physics. Women with positive physics experiences had a 3.467 times higher odds of pursuing and obtaining a doctoral degree in physics.

These results are based on women who made a career choice of chemistry as opposed to physics, or vice versa, so it follows that academic achievement in high school and postsecondary classes will indicate a greater likelihood to enter a specific career field. Research has shown that women are now equal to men in regard to STEM courses taken in high school and subsequent academic success (U.S. Department of Education, 2007). However, this study indicates that high school and undergraduate academic achievement among women in the physical sciences differentiates and is associated with later career choice. These results, while supporting the hypotheses of this study, are surprising, as it would be expected that women who enter the physical sciences would achieve equally in both chemistry and physics courses due to the academic rigor and requirement necessary to receive a degree in the physical sciences. Prior research on academic achievement has been linked to variables such as interest, environmental factors, and career preferences based on gender (Hulleman & Harackiwcz, 2009; Low et al., 2005; Lubinski et al., 2001; Lubinski & Benbow, 2006; Rathunde & Csikszentmihalyi, 1993; Resnick et al., 1998; Schiefle, 1994; Turner et al., 2008).

Environmental factors were also taken into account in these models through the examination of experiences in undergraduate physical science. Research has shown that academic achievement can be promoted through the use of novel and relevant activities (Ames, 1992; Hulleman & Harackiewicz, 2009; Resnick et al., 1998; Tobias, 1994). This study further supports prior hypotheses by showing a connection between positive experiences in chemistry or physics and a differentiation in career choice by females in the physical sciences. Project Crossover does not specify what these positive experiences are for females, so it would benefit the education community to further examine what is occurring in chemistry or physics classrooms that provides a positive experience for females. Previous research has shown that compared to men, women often report a gender bias or isolation in high school and undergraduate physical science classrooms (Hartung et al., 2005; Low et al., 2005; McDonnell, 2005). This may influence females to believe that STEM fields are less friendly toward women and therefore choose a career in alternative fields (Hartung et al., 2005; Low et al., 2005; McDonnell, 2005). However, as this study compares women to women, it can only be conjectured what may influence these negative or positive experiences in the physical sciences. What we do know is that this experience is critical and is strong associated with the likelihood of a woman's choice of one of the physical sciences rather than another.

Control variables in the female chemist model show that age and highest parent education negatively associate with a career choice in chemistry. Several factors may influence this effect in the chemist model. First, both of these variables have a negative skew in the sample. Therefore, women, especially in the field of chemistry, reported being younger when the survey was taken. Age was controlled for in the model, as the participants were cross-generational, in order to account for any differences that may have occurred due to a period in history. What we do know is that women are entering the field of doctoral studies in chemistry at a faster rate than at any other time (NSF, 2008a). In addition, highest parent education had a slight negatively skewed effect, by being more represented by parents that had an education level ranging from not finishing high school to receiving a bachelor's degree. Parent education was taken into account in this model as a proxy for socioeconomic status, and because of its previous positive association with female entrance into graduate studies (Denecke, 2004; Golde, 2000; Horn & Carroll, 1997). Further interactions based on age and highest parent education showed no influence on the association of predictor variables with female career choice in chemistry. In the end, a wide range of factors could have influenced the role that these demographic variables played in this study and are beyond the capabilities of this model.

Interestingly, control variables in the female physics model varied from those discussed in the chemist model. Here, Asian race and ethnicity and U.S. citizenship were significant and had a negative influence on a career choice in physics. Examination of variable correlations showed a significant overlap in the measurement between Asian race and U.S. citizenship status ($p < 0.01$). Prior race and ethnicity findings have indicated general race differences based on a career choice in STEM (Lewis et al., 2009). However, little research exists to examine how gender, race, ethnicity, and citizenship may interact to influence career choice in the physical sciences. While these control outcomes are of interest, they are, again, beyond the scope of this study to consider as a relevant predictor variable in regard to female career choice in the physical sciences. This is not to say, however, that future research should not examine what influences women, based on these demographic factors, to enter certain fields of STEM. Aside from race, ethnicity, and citizenship, age was significant in the physics model. When compared to the chemist model, age had an opposite association or a positive influence on career choice in physics. Once again, age provided a description of the participants in this study and was examined to control for any cross-generational effects. It is important to keep in mind that in this dataset, women in physics had a higher age on average as compared to chemists. Interactions were run on age and the relevant physics academic achievement and experience predictors, and no significance was found to merit the added complexity of this physicist model.

Overall, outcomes of the chemist and physicist models show that content-based high school and undergraduate academic achievement and postsecondary experiences differentiate female career choice in the physical sciences. Descriptive analyses indicate a difference in the distribution of this data by female career choice in either chemistry or physics. Pearson correlations also show a further connection between academic achievement and positive or negative experiences in undergraduate physical science. Undergraduate grade in chemistry correlated with positive experience in undergraduate chemistry ($p < 0.01$) and undergraduate grade in physics correlated with a positive experience in undergraduate physics ($p < 0.01$). While these variables were not combined due to their unique representation of data in the Project Crossover survey and data analyses, the variables do indicate a connection between academic achievement and experiences in physical science. These findings further reinforce research that shows the connection between gender, academic achievement, classroom experiences, and career choice (Hulleman & Harackiwcz, 2009; Low et al., 2005; Lubinski et al., 2001; Lubinski & Benbow, 2006; Rathunde & Csikszentmihalyi, 1993; Resnick et al., 1998; Schiefle, 1994; Turner et al., 2008).

This series of analyses does not answer the question of whether academic achievement influences a student to have a positive experience, or whether positive experiences promote student academic achievement at the postsecondary level. What it does indicate is that there needs to be a greater emphasis on the classroom experiences that are provided to females in gateway physical science courses. Females may not be pursuing doctoral degrees in physical science due to the experiences that are provided to them in these early undergraduate courses. This raises the question: What forms of classroom instruction and activities lead to a positive experience for women in the physical sciences? Prior research shows that females in STEM, when compared to males or examined as a whole, prefer slower-paced, content-based classes (Tai & Sadler, 2001), smaller classroom settings (Subotnik & Steiner, 1993), and a personal identity as an altruistic research scientist (Carlone & Johnson, 2007). In addition, studies indicate that males and female are motivated to attain physical sciences degrees based on type of classroom activities in chemistry and on career options in physics (Woolnough, 1995).

While these studies do not differentiate between women in chemistry or physics, it does provide some perspective as to what may influence female experiences in the classroom based on career choice and what future research could examine.

Factors associated with persistence in STEM fields were further examined through a series of multiple regression analyses.

Multiple Regression Analyses

Persistence of females in the physical sciences was examined through two multiple regression models. One multiple regression model examined a subsample of chemists, while the other model examined a subsample of physicists. These models were developed with a series of background and educational predictors. Results are reviewed based on career choice by predictor and then control variables in these two multiple regression models with a focus on the career outcome of time to Ph.D. completion.

Both the female chemist and physicist models had significant multiple R^2; however, this multiple R^2 accounted for little of the differentiation in the outcome, or time to Ph.D. completion. The female chemist model had one significant predictor, physics high school grade, which had a negative impact on the model. In addition, the chemist model had U.S. citizenship as a significant control variable, while the physics model had U.S. and naturalized citizenship as significant control variables. Significant control and predictor variables were not parallel between the two models. This, paired with the relatively small multiple R^2, leads to a discussion of the results in reference to predictor variables that were not significant in the two models.

Demographic and early motivation variables in the model were not time to doctoral degree completion as hypothesized in this study. Prior research and theories attribute attrition of women from STEM based fields based on a lack of interest (Lubinski & Benbow, 2006), chilly climate (Acker & Feuerrverger, 1996; Barres, 2006; Ferreira, 2002; Gunter & Stambach, 2005; Menges & Exum, 1983; Prentice, 2000; Settles, Cortina, Malley, & Stewart, 2006), lack of critical mass of women (Girves & Wemmerus, 1988; Kleinman, 2003), and conflicts between family and work life (Wyss & Tai, 2010). Unfortunately, the majority of these studies focused on doctoral experiences, not early motivational variables, and fail to examine persistence of women in specific STEM doctoral fields. Future research may look at how early motivation, when combined with doctoral degree experiences, may be associated with female time to Ph.D. completion in the physical sciences.

Final Thoughts

Overall, these logistic and multiple regression analyses show that background and early motivational variables differentiate female career choice in the physical sciences, but is not associated with persistence or time to degree completion. Variables were examined, ranging from prior to elementary school through undergraduate studies, to determine what might better influence entrance into and long-term career choice in the physical sciences. Persistence or time to degree completion may be influenced by factors and life experiences that occur once females are in doctoral programs. A combination of the early interest, academic achievement, and experience variables with later doctoral study variables may provide a better understanding of time to Ph.D. completion.

While this study paints a picture of what differentiates and predicts female career choice in the physical sciences, it does not look at where females are employed once they receive doctoral degrees. As stated above, women are less likely to obtain academic positions and tenure and often receive lower salaries in comparison to men (Hill et al., 2010; National Center for Science and Engineering Statistics, 2010; NORC, 2011). Future research might examine what career choices women make once they receive their doctoral degrees and what educational factors may influence their employment choices. Finally, the results of this study show that women are not a single entity that should be examined as a whole group or in comparison to men, but that women can instead be differentiated in physical science. Statistics show that women are entering chemistry at a faster rate than physics at both bachelor's and doctoral levels (NSF, 2008a). However, chemistry and physics are closely aligned- as fields within the physical sciences- in their admissions standards, such as prerequisites in science and mathematics, and overall rigor. Based on this similarity of educational training, women could potentially be compared to one another instead of men to see what influences their differences in educational experiences and career choice not only in the physical sciences, but also STEM based fields and other academic areas of study. Further research could also draw on this comparative analysis for underrepresented race and ethnicity groups in STEM.

Recommendations

A review of the analyses performed in this study may be used to provide recommendations regarding females in physical science and STEM as a whole. These recommendations are discussed below.

> ***Recommendation 1:*** Increased attention should be given to what classroom instructional strategies and activities create positive experiences for women in the physical sciences.

Recommendation 2: Further examination of factors supporting female academic achievement in high school and undergraduate physical sciences is necessary as these factors may play an important role in increasing the numbers of females entering the physical sciences.

Recommendation 3: Caution should be exercised when examining demographic factors such as race/ethnicity, age, highest parent education, and citizenship which may interact and influence female academic achievement, experiences, and career choice in physical science.

Recommendation 4: Continued research on what differentiates and is associated with female and other underrepresented minorities' career choice and persistence in STEM is necessary to better inform educational policy.

Recommendations are based on descriptive analyses, variable correlations, logistic regression analyses, and multiple regression analyses in light of the research questions examined in this study. These recommendations are not only meant to be informative regarding classroom instruction, but also valuable for educational policymaking and future research based on the results from this study. While the recommendations provide a starting point for the examination of what differentiates female experiences and career choice in the physical sciences, it is merely a starting point to better understand female demographics, interest, academic achievement, and experiences in STEM.

Results and recommendations are examined in light of the limitations of this research in the final section of this chapter.

Limitations

Limitations of this study are reviewed not only in regard to the dataset and analyses but also the generalizability of these findings to females in the U.S. education system. The primary limitation of this research is the implications of its findings. All results examined were associative and not causal. Therefore, academic achievement and positive experiences in physical science associated with female career choice, but was not causal. While these findings are not causal in nature, they provide a better picture of what is happening in the U.S. education system today when it comes to women entering and persisting in the physical sciences. These results can also inform future research regarding what differentiates women in STEM based research.

Second, when using any survey as a tool to analyze data, there are limitations to the detail that such as survey can provide. The Project Crossover survey had a rich dataset of females in the physical sciences and included the following factors: demographic, interest, academic achievement, and experiences prior to elementary school through postsecondary education. This made the Project Crossover dataset invaluable to this study and its series of analyses. Data showed the association of academic achievement and positive experiences with female career choice in the physical sciences. Yet what influenced females in terms of positive academic achievement and experiences was beyond the scope of this survey. Future research can build on findings from the Project Crossover survey to examine the factors that influence female academic achievement and experiences in high school and undergraduate physical sciences.

Finally, the Project Crossover survey provides a wide variety of variables that may differentiate and be associated with female career choice and persistence. This study examines a smaller and specific portion of these demographic and motivation factors. At times, the possibilities for further analyses were distracting while working on this dissertation. However as my advisor often reminded me, the results from this study and the work left to be done can serve as an inspiration to move forward with a research agenda in regard to what influences and differentiates women in STEM.

REFERENCES

Acker, S., & Feuerverger, G. (1996). Doing good and feeling bad: The work of women university teachers. *Cambridge Journal of Education, 26*, 401-422.

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84* (3), 261-271. doi: 10.1037/0022-0663.84.3.261

Bandura, S. (1971). *Psychological modeling: Conflicting theories.* Chicago: Aldine-Atherton.

Barcikowski, R., & Stevens, J. P. (1975). A Monte Carlo study of the stability of canonical corelations, canonical weights and canonical variate-variable correlations. *Multivariate Behavioral Research, 10*, 353-364.

Barres, B. (2006). Does gender matter? *Nature*, *442*, 133-136.

Bleeker, M., & Jacobs, J. (2004). Achievement in math and science: Do mothers' beliefs matter 12 years later? *Journal of Educational Psychology, 96,* 97-109.

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education, 17*(4), 369-386.

Breakwell, G. M., & Beardsell, S. (1992). Gender, parental and peer influences upon science attitudes and activities. *Public Understanding of Science, 1*(2), 183-197.

Brown, S. D., & Lent, R. W. (1996). A social cognitive framework for career choice counseling. *The Career Development Quarterly, 44,* 354–366.

Carlone, H. B. and Johnson, A. (2007), Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*, 1187–1218. doi: 10.1002/tea.20237

Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education, 27*(4), 471–486.

Council of Graduate Schools (2008). Ph.D. completion rates differ by student demographics. Washington, DC: Council of Graduate Schools. Retrieved from http://www.cgsnet.org/

Crask, M. R., & Parreault, W. D. (1977). Validation of discriminant analysis in marketing research. *Journal of Marketing Research, 14,* 60-67.

Denecke, D. (2004). Ph.D. completion headlines. *CGS Communicator, 37*, 1-7. Retrieved from http://www.cgsnet.org/

deValero, Y. (2001). Departmental factors affecting time-to-degree completion and completion rates of doctoral students at one-land grant university. *Journal of Higher Education, 72*, 341-367.

Dewey, J. (1979 [1913]). Interest and effort in education. In J.A. Boydston (Eds.), *The middle works, 1899-1924: Vol. 7: 1912-1914* (pp. 153-197). Carbondale: Southern Illinois University Press. Retrieved from http://books.google.com/books

Eccles, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic values. In J. T. Spence (Ed.), *Achievement and achievement motives* (pp. 75-146). San Francisco: W. H. Freeman and Company.

Enders, C. K. (2010). *Applied missing data analysis. Methodology in the social sciences.* New York: The Guildford Press.

Epenshade, T. I., & Rodriguez, G. (1997). Completing the PhD: Comparative performances of U.S. and foreign students. *Social Science Quarterly, 78*(2), 593-605.

Fan, X., & Wang, L. (1995). *How comparable are the jackknife and bootstrap results: An investigation for a case of canonical correlation analysis*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA. (ERIC Document Reproduction Service No. ED 387 509)

Ferreira, M. (2002). The research lab: A chilly place for graduate women. *Journal of Women and Minorities in Science and Engineering, 8*, 85-98.

Ferry, T. R., Fouad, N. A. & Smith, P. L. (2000). The role of family context in a social cognitive model for career-related choice behavior: A math and science perspective. *Journal of Vocational Behavior, 57*, 348-364.

Fielding, J., & Glover, J. (1999). Women and science graduates in Britain: The value of secondary analysis of large scale data sets. *Work, Employment and Society, 13*(2), 353–367.

Fouad, N. A., & Walker, C. M. (2005). Cultural influences on responses to items on the Strong Interest Inventory. *Journal of Vocational Behavior, 66*(1), 104–23.

Fox, M. F., & Stephan, P. E. (2001). Careers of young scientists: Preferences, prospects and realities by gender and field. *Social Studies of Science, 31*(1), 109-122.

Gardner, S. K. (2008). Fitting the mold of graduate school: A qualitative study of socialization in doctoral education. *Innovative Higher Education, 33*(2), 125-138. doi: 10.1007/s10755-008-9068-x

George,R ., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS:88. *Science Education*, *82(1),* 93-109.

Girves, J., Wemmerus, V. (1988). Developing models of graduate student progress. *Journal of Higher Education*. 59(2), 163-189.

Golde, M. (2000). Should I stay or should I go? Student descriptions of the doctoral attrition process. *Review of Higher Education, 23*, 199-227.

Grimm, L.G., & Yarnold, P.R. (Eds.). (1995). *Reading and understanding multivariate statistics.* Washington D.C.: American Psychological Association.

Gunter, R., and Stambach, A. (2005). Differences in men and women scientists' perceptions of workplace climate. *Journal of Women and Minorities in Science and Engineering, 11*, 97-116.

Halpern, D. F., Benbow, C. P., Geary, D. C., Gur, R. C., Hyde, J. S., & Gernsbacher, M. A. (2007). The science of sex differences in science and mathematics. *Psychological Science in the Public Interest, 8*(1), 1–51.

Hanson, S. L. (2004). African American women in science: Experiences from high school through the post-secondary years and beyond. *NWSA Journal, 16*(1), 96–115.

Hartung, P. J., Porfeli, E. J., & Vondracek, F. W. (2005). Child vocational development: A review and reconsideration. *Journal of Vocational Behavior, 66*(3), 385–419.

Hazari, Z., Potvin, G., Tai, R., & Almarode, J. (2010). For the love of learning science: Connecting learning orientation and career productivity in physics and chemistry. *Physics Education Research, 6*(1), 1-9.

Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of EducationalResearch, 70,* 151–179.

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: AAUW. Retrieved from http://www.norc.org/projects/survey+of+earned+doctorates.htm

Holland, J. L. (1996). Exploring careers with a typology: What we have learned and some new directions. *American Psychologist, 51*, 397–406. doi: 10.1037/0003-066X.51.4.397

Horn, L. J., & Carroll, C. D. (1997). Confronting the odds: Students at risk and the pipeline to higher education. National Center for Educational Statistics. Retrieved from http://www.nces.ed.gov

House, J. (2000). Academic background and self-beliefs as predictors of student grade performance in science, engineering and mathematics. *International Journal of Instructional Media, 27*(2), 207-220.

Hulleman, C. S. & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science, 326*, 1410-1412. doi: 10.1126/science.1177067

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science, 321*, 494–95.

Jacobs, J., & Eccles, E. (1992). The impact of mothers' gender-role stereotypic beliefs on mothers' and children's ability perceptions. *Journal of Psychology and Social Psychology, 63*, 932-944.

Jacobs, J. J., Finkens, L. L., Griffin, N. L., & Wright, J. D. (1998). The career plans of science-talented rural adolescent girls. *American Educational Research Journal, 35*(4), 681-704.

Kleinman, S. (2003). Women in science and engineering building community online.

Journal of Women and Minorities in Science and Engineering, 9, 73-88.

Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning, and development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 3-25). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Lent, R.W., Brown, S.D. & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*, 79-122.

Lent, R. W., Brown, S. D., & Larkin, K. C. (1986). Self-efficacy in the prediction of academic performance and perceived career options. *Journal of Counseling Psychology, 33*(3), 265–69.

Lent, R. W., Larkin, K. C., & Brown, S. D. (1989). Relation of self efficacy to inventoried vocational interests. *Journal of Vocational Behavior, 34,* 279–288. doi: 10.1016/0001-8791(89)90020-1

Lewis, J. L., Menzies, H., Najera, E. I., & Page, R. N. (2009). Rethinking trends in minority participation in the sciences. *Science Education, 93*, 961-977. doi: 10.1002/sce.20338

Lindahl, B. (2007). *A longitudinal study of students' attitudes towards science and choice of career.* Paper presented at annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Low, K. S. D., Yoon, M., Roberts, B. W., & Rounds, J. (2005). The stability of vocational interests from early adolescence to middle adulthood: A quantitative review of longitudinal studies. *Psychological Bulletin, 131*(5), 713–37.

Lowell, B. L., Salzman, H., Bernstein, H. H., & Henderson, E. (2009). *Steady as she* *goes? Three generations of students through the science and engineering pipeline*. Paper presented at Annual Meetings of the Association for Public Policy Analysis and Management Washington, DC. Retrieved from http://www.heldrich.rutgers.edu/uploadedFiles/Publications/STEM_Paper_Final.pdf.

Lubinski, D., & Benbow, C. P. (2006). Study of mathematically precocious youth after 35 years: Uncovering antecedents for the development of math-science expertise. *Perspectives on Psychological Science, 1*(4), 316–45.

Lubinski, D., Webb, R. M., Morelock, M., & Benbow, C. P. (2001). Top 1 in 10,000: A 10-year follow-up of the profoundly gifted. *Journal of Applied Psychology, 86*, 718–729.

Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591–613.

Maher, M. A., Ford, M. E., & Thompson, C. M. (2004). Degree progress of women doctoral students: Factors that constrain, facilitate, and differentiate. *The Review of Higher Education, 27*(3), 385-408.

Maines, David R. (1983). Attrition processes out of mathematics for undergraduate students. Attrition from mathematics as a social process. (Report No. NIE-G-81-0029). Evanston, IL: Program on Women: Northwestern University. (ERIC Document Reproduction Service No. ED237342)

Maltese, A. V., and Tai, R. H. (2010). Eyeballs in the Fridge: Sources of early interest in science. *International Journal of Science Education, (32)*5, 669-685.

McDonnell, F. (2005). Why so few choose physics: An alternative explanation for the leaky pipeline. *American Journal of Physics, 73*(7), 583-586.

Menges, R.J., & Exum, W.H. (1983). Barriers to the progress of women and minority faculty. *Journal of Higher Education, 54*, 123-144.

National Academy of Sciences. (2007). Rising above the gathering storm: Energizing and employing America for a brighter future. Retrieved from http://www.nap.edu/openbook.php?isbn=0309100399

National Academy of Sciences. (2010). Rising above the gathering storm, revisted: Rapidly approaching category 5. Retrieved from http://www.nap.edu/catalog.php?record_id=12999

National Association of Colleges and Employers. (2009, Fall). Salary survey.

National Center for Educational Statistics (NCES). (2009). Student who study science, technology, engineering, and mathematics (STEM) in postsecondary education. Washington, DC: U.S. Department of Education. Retrieved from nces.ed.gov/pubs2009/2009161.pdf

National Center for Science and Engineering Statistics. (2010). Data Tables. Ed.D. Foley. NSF. Retrieved from http://www.nsf.gov/statistics/nsf09317/content.cfm?pub_id=3920&id=2

National Science Board (NSB). (2008). Science and Engineering Indicators 2008. Two volumes. Arlington, VA: National Science Foundation (Volume 1, NSB 08-01; Volume 2, NSB 08-01A). Retrieved from http://www.nsf.gov/statistics/seind08/

National Science Board (NSB). (2010). Science and Engineering Indicators 2010. Arlington, VA: National Science Foundation. Retrieved from http://www.nsf.gov/statistics/seind10/

National Science Foundation (NSF). Division of Science Resources Statistics. (2008a). *Science and engineering degrees: 1966–2006* (Detailed Statistical Tables) (NSF 08-321). Arlington, VA: Author. Retrieved from www.nsf.gov/statistics/nsf08321/pdf/nsf08321.pdf

National Science Foundation (NSF). Division of Science Resources Statistics. (2008b). Women, Minorities, and Persons with Disabilities in Science and Engineering. (Detailed Statistical Tables) (NSF 08-321). Arlington, VA: Author. Retrieved from http://www.nsf.gov/statistics/wmpd/minwomen.cfm

Nauta, M. M., Epperson, D. L., Kahn, J. H. (1998). A multiple-groups analysis of predictors of higher level career aspirations among women in mathematics, science, and engineering majors. *Journal of Counseling Psychology, 45*(4), 483-496.

Nazier, G. L. (2010). Science and engineering professors: Why did they choose science as a career? *School Science and Mathematics, 93*(6), 321-327. doi: 10.1111/j.1949-8594.1993.tb12253.x

NORC. (2011). Survey of Earned Doctorates (SED). Mary Ann Latter (Ed.). NORC, N.D. Retrieved from http://www.norc.org/projects/survey+of+earned+doctorates.htm

Pajares, F. (1996). Self-efficacy beliefs and mathematical problem-solving of gifted students. *Contemporary Educational Psychology, 21*(4), 325–44.

Pajares, F. (2005). Gender differences in mathematics self-efficacy beliefs. In A. M. Gallagher & J. C. Kaufman (Eds.), *Gender differences in mathematics: An integrative psychological approach* (pp. 294–315). Boston: Cambridge University

Press.

Pearson, W. (2005). *Beyond small numbers: Voices of African American Ph.D. chemists*. Boston: Elsevier.

Pedhazur, E. J. (1997). *Multiple Regression in Behavioral Research: Explanation and Prediction* (3rd ed.). United States: Harcourt Brace College Publishers.

Poock, M., & Love, P. (2001). Factors influencing the program choice of doctoral students in higher education administration. *NASPA Journal, 36*, 202-223.

Prentice, S. (2000). The conceptual politics of chilly climate controversies. *Gender and Education, 12*, 195-207.

Rathunde, K., & Csikszentmihalyi, M. (1993). Undivided interest and the growth of talent: A longitudinal study of adolescents. *Journal of Youth and Adolescence, 22* (4), 385-405. doi: 10.1007/BF01537720

Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., & Silverman, B. (1998). Digital manipulatives: New toys to think with. *Chi,* 18-23.

Royal Society. (2004). Taking a leading role: A good practice guide (Scientist survey). Retrieved from http://www.royalsoc.ac.uk/page.asp?id=2903

Rubin, D. B. (1987). *Multiple imputation for nonresponse in surveys.* New York: J. Wiley & Sons.

Russell, M. L., & Atwater, M. M. (2005). Traveling the road to success: A discourse on persistence throughout the science pipeline with African American students at a predominantly white institution. *Journal of Research in Science Teaching, 42*, 691–715.

Settles, I.H., Cortina, L.M., Malley, J., & Stewart, A.J. (2006). The climate for women in academic science: The good, the bad, and the changeable. *Psychology of Women*

Quarterly, 30, 47-58.

Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview.

Schiefele, U. (1994). Interest and the quality of experience in classrooms. *European \ Journal of Psychology of Education, 9* (3), 251-270.

Small, M. (2005). *College major and career choice of alumni of two specialized schools of mathematics, science, and technology* (Doctoral dissertation, University of Connecticut. Retrieved from http://search.proquest.com/pqdtft/ip?accountid=14678

Stevens, J. (2009). *Applied multivariate statistics for the social sciences (5th ed.).* Mahwah, NJ: Lawrence Erlbaum Associates.

Stewart, M. (1998). Gender issues in physics education. *Educational Research, 40*(3), 283-293.

Subotnik, R., & Steiner, C. (1993). Adult manifestations of adolescent talent in science. *Roeper Review, 15*, 164-169.

Summers, M. F., & Hrabowski, F. A. (2006). Preparing minority students and engineers. *Science, 311*, 1870-1871. doi: 10.1126/science.1125257

Tabachnick, B.G. and Fidell, L.S. (1996). *Using multivariate statistics*. New York: Harper Collins.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*, 1143-1144. doi: 10.1126/science.1128690

Tai, R., & Sadler, P. (2001). Gender differences in introductory undergraduate physics performance: University physics versus college physics in the USA. *International Journal of Science, 23*, 1017-1037.

Tobias, S. (1994). Interest, prior knowledge, and learning. *Review of Educational Research, 64* (1), 37-54. doi: 10.3102/00346543064001037

Turner, S. L., Conkel, J. L., Starkey, M., Landgraf, R., Lapan, R. T., Siewert, J. J., Reich, A., Trotter, M. J., Neumaier, E. R., & Huang, J. (2008). Gender differences in Holland vocational personality types: Implications for school counselors. *Professional School Counseling, 11*(5), 317–26.

Turner, S.L., Steward, J.C. & Lapan, R.T. (2004). Family factors associated with sixth grade adolescents’ math and science career interests. *The Career Development Quarterly, 53*, 41-52.

U.S. Department of Education. (2006). *A test of leadership: Charting the future of U.S. higher education*. Washington, DC: Author.

Whitelegg, L. (2001). Girls in science education: Of rice and fruit trees. In: M. Lederman & I. Bartsch (Eds.), *The gender and science reader* (373-382). New York: Routledge.

Woolnough, B. (1995). School effectiveness for different types of potential scientists and engineers. *Research in Science & Technological Education, 13*(1), 53-66.

Wyss, V. L. (2008). *Questioning the gender critical mass theory in physics* (Doctoral Dissertation). Retrieved from ProQuest Dissertation and Theses.

Wyss, V. L., & Tai, R. H. (2010) Conflicts Between Graduate Study in Science and Family Life. *College Student Journal*, 1-14. Retrieved from: http://findarticles.com/p/articles/mi_m0FCR/is_2_44/ai_n54035384/

Xie, Y., & Shauman, K. A. (2003). *Women in science: Career processes and outcomes.* Boston: Harvard University Press.

Zeegers, P. (2004). Student learning in higher education: a path analysis of academic achievement in science. *Higher Education Research & Development, 23*(1), 35-56.

Zumeta, W., & Raveling, J. (2002). The best and brightest: Is there a problem here? (pp. 4-6). Washington, DC: Commission on Professionals in Science and Technology. Retrieved from: http://www.cpst.org/BBIssues.pdf

Appendix A:

Measure of Sample Representativeness

The accuracy of survey data is largely dependent on survey respondents' characteristics being similar to those of the population being studied. More than 4,000 participants have completed the Project Crossover surveys, giving a total response rate of approximately 31%. Although the completed sample is large enough (i.e., greater than 1,067) to allow for the generalization of chemistry and physics populations as defined by the NSF's Characteristics of Doctoral Scientists and Engineers in the US: 2003 (2006), the issue of nonresponse error must still be addressed. Nonresponse error occurs when the characteristics of the completed sample (i.e., the population sample that completed the survey) differ from those of the population sample who did not complete the survey in such a way as to create an inaccurate dataset (Dillman, 2000). One method to determine whether the characteristics of the completed sample are representative of the sample population is to compare completed sample data to pre-collected data that are considered reflective of population characteristics.

Project Crossover samples were drawn from the membership lists of the American Chemical Society and American Physical Society, and it is assumed that the membership in these organizations are accurate reflections of the chemistry and physics populations, respectively. To validate Project Crossover data, race/ethnicity and gender data collected from Project Crossover (following 6 months of data collection) were compared to similar data collected by the NSF's Characteristics of Doctoral Scientists and Engineers in the US: 2003 (2006). These comparisons include data from all individuals who had completed the Project Crossover "Scientists" survey as of December

3, 2007, and indicated that they hold a Ph.D. degree. The first comparison between NSF and Crossover data is of the race/ethnicities of individuals in 5 sectors of employment: 1) College/University Faculty; 2) Non/Not-for-Profit Organizations; 3) For Profit Organizations/Industry; 4) Local, State, Federal Government Scientist; and 5) Other Employment (Figure 1). Gender comparisons between the NSF 2003 Survey of Doctorate Recipients data versus Project Crossover data are separated by broad field of employment (chemistry of physics; Figure 2).

Demographic similarities between NSF and Project Crossover data suggest that Project Crossover demographic data are representative of the physics and chemistry population characteristics, as defined by the NSF's Characteristics of Doctoral Scientists and Engineers in the United States: 2003 (2006). While it is difficult to determine how generalizable demographic data representativeness is to all data collected by Project Crossover, the low nonresponse error for Project Crossover demographic data suggests that other data acquired by Project Crossover is representative of the chemistry and physics populations, as well.

References:
Dillman, D.A. (2000). *Mail and Internet Surveys: The Tailored Design Method* (2nd Ed.). New York: John Wiley & Sons.
National Science Foundation, Division of Science Resources Statistics (2006). *Characteristics of Doctoral Scientists and Engineers in the United States: 2003,* NSF 06-320, Project Officer, John Tsapogas (Arlington, VA 2006).

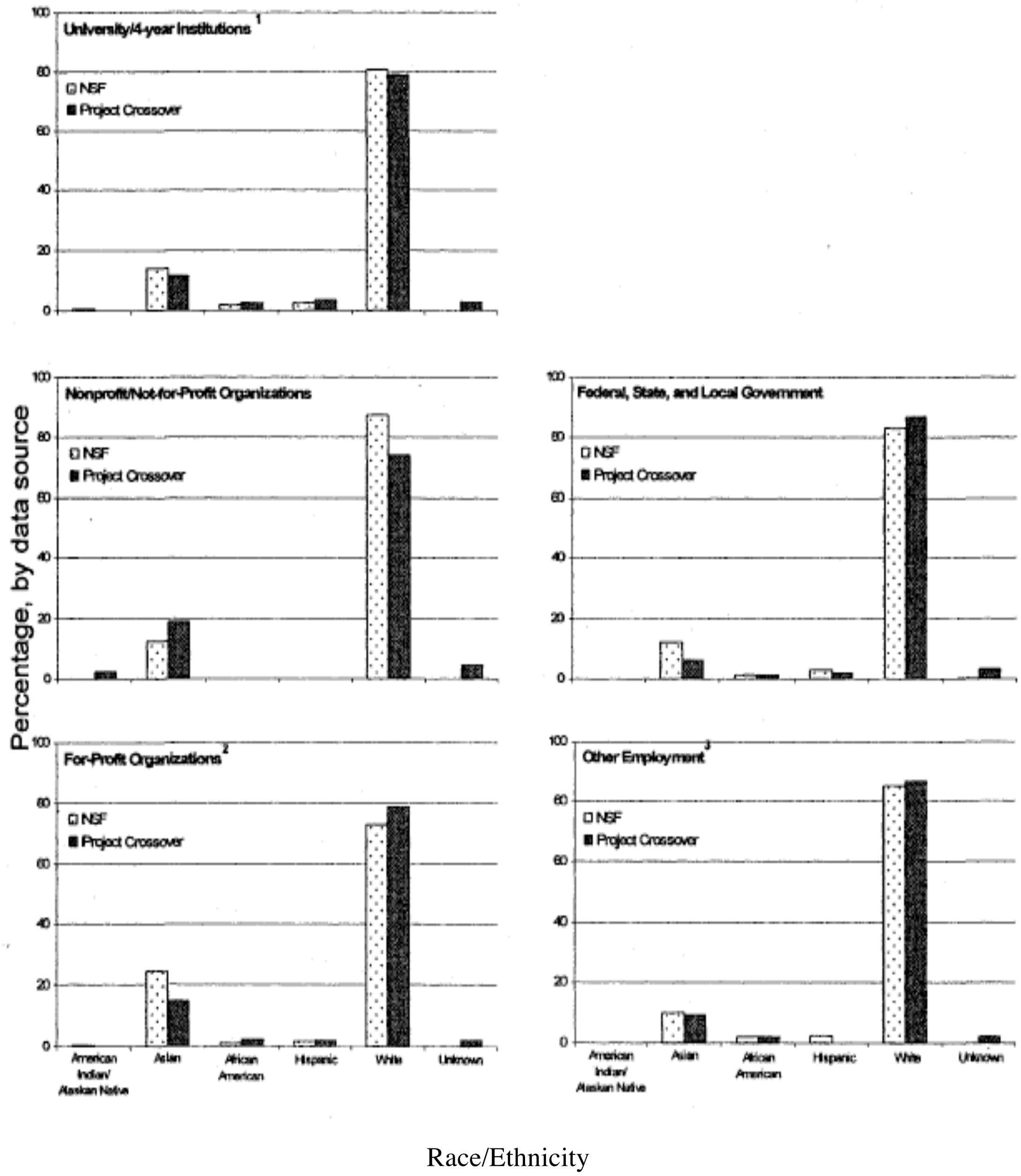


Figure 1. Comparisons of National Science Foundation (NSF) Characteristics of Doctoral Scientists and Engineers in the United States: 2003 data versus Project Crossover "Scientist" survey data (as of December 3,2007), by race/ethnicity and sector of employment.

1 NSF data include physical science PhDs who hold faculty positions at 4-year postsecondary institutions; Crossover data include physical science PhDs who hold faculty positions at 2- and 4-year postsecondary institutions.

2 NSF data include physical science PhDs who report working in private, for-profit organizations; Crossover data include individuals working in industry (for-profit).

3 NSF and Crossover data include physical science PhDs who report employment other than educational (all levels), non/not-for-profit, industry/for-profit, government-funded, and "self-employed".

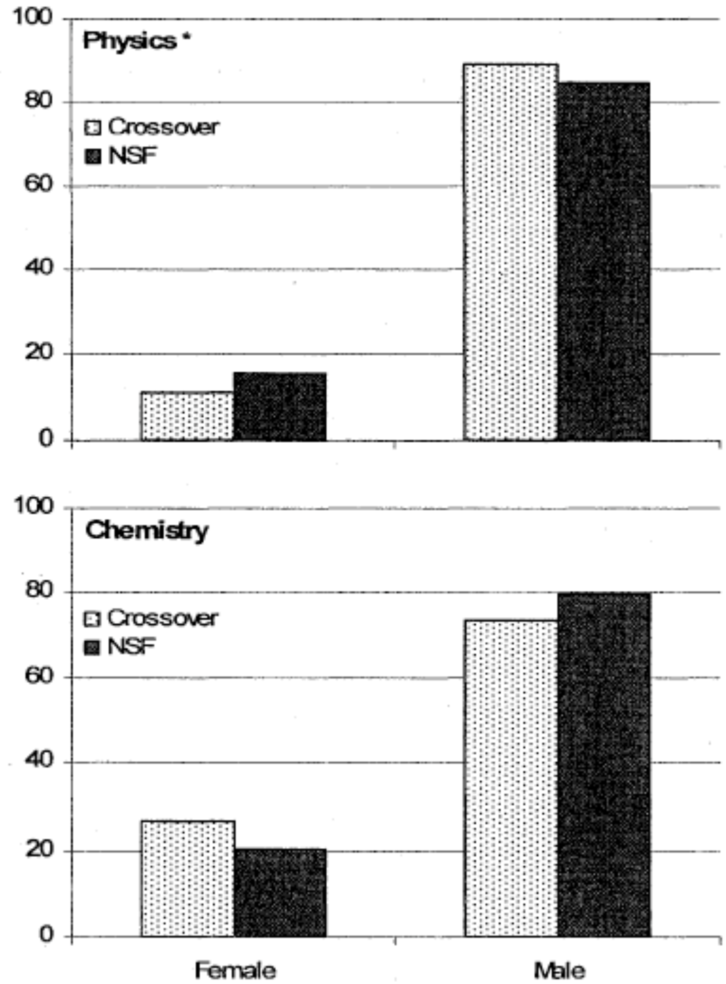


Figure 2. Comparisons of National Science Foundation (NSF) 2003 Survey of Earned Doctorates data versus Project Crossover "Scientist" survey data (as of December 3, 2007), by gender and broad field of employment.

1 Physicists in the NSF data include individuals identifying their employment as "Biophysics, Astronomy/Astrophys; Earth/Atmos/Ocean Sci; Physics; Aerospace/Astro Engineering; and Postsecondary Physics Teacher" in Characteristics of Doctoral Scientists and Engineers in the United States: 2003. Physicists in the Project Crossover data include participants from the American Physical Society membership list.

2 Chemists in the NSF data include individuals identifying their employment as "Biochemistry; Chemistry; Chemical Engineering; or Postsecondary Chemistry Teacher" in Characteristics of Doctoral Scientists and Engineers in the United States: 2003. Chemists in the Crossover data include participants from the American Chemical Society membership list.

Note: Percentage of females in Project Crossover data for physics calculated after adjusting for oversampling of females from the American Physical Society's membership list.

Appendix B:

SPSS Coding and Analyses Syntax

Crossover Variables

FAMILY_INTEREST
Figure 3-8. Question #17 from the Project Crossover Survey on family interest
RECODE q17a q17b q17c q17d (1=1) (7=0).
EXECUTE.
COMPUTE TotalFamilyInterest_Q17TotalAtoD_NEW=q17a + q17b + q17c + q17d.
EXECUTE.

ASIAN
HISPANIC
AFRICAN_AMERICAN
CAUCASIAN
Figure 3-4. Question #13 from the Project Crossover Survey on racial/ethnic demographics

PHYSICAL_SCIENCE
Figure 3-2. Question #2 from the Project Crossover Survey on physical science field
RECODE q2 (1=1) (2=0) INTO Q2_NEW.
VARIABLE LABELS Q2_NEW 'Q2_NEW'.
EXECUTE.

YEARS_TO_PHD
Figure 3-3. Question #39 from the Project Crossover Survey on time to doctoral degree completion

AGE
Figure 3-5. Question #10 from the Project Crossover Survey on year of birth

HIGHEST_PARENT_EDUCATION
Figure 3-6. Question #12 from the Project Crossover Survey on highest level of education completed by parents/guardians

```
RECODE FATHERED MOTHERED (1=1) (2=2) (3=3) (4=4) (5=5) (6=6) (SYSMIS=0) (MISSING=0) INTO
   FATHERED_NEW MOTHERED_NEW.
VARIABLE LABELS  FATHERED_NEW 'FATHERED_NEW' /MOTHERED_NEW 'MOTHERED_NEW'.
EXECUTE.
IF  (FATHERED_NEW >= MOTHERED_NEW) HIGH_PARENT=FATHERED_NEW.
EXECUTE.
```

US_CITIZENSHIP
NATURALIZED_CITIZEN
GREEN_CARD_TEMPORARY_VISA

Figure 3-7. Question #14 from the Project Crossover Survey on United States citizenship status

```
RECODE q14 (1=1) (2=0) (3=0) (4=0) INTO Q14_NEW_USCitizenship.
VARIABLE LABELS  Q14_NEW_USCitizenship 'Q14_NEW_USCitizenship'.
EXECUTE.
RECODE q14 (1=0) (2=1) (3=0) (4=0) INTO Q14_NEW_NaturalizedCitizen.
VARIABLE LABELS  Q14_NEW_NaturalizedCitizen 'Q14_NEW_NaturalizedCitizen'.
EXECUTE.
RECODE q14 (1=0) (2=0) (3=1) (4=1) INTO Q14_NEW_GreenCard_TemporaryVisa.
VARIABLE LABELS  Q14_NEW_GreenCard_TemporaryVisa
'Q14_NEW_GreenCard_TemporaryVisa'.
EXECUTE.
```

SCIENCE_INTEREST_K5

Figure 3-9. Question #18 from the Project Crossover Survey on first interest in general science

```
RECODE q18 (1=1) (5=0) (6=0) (88=0) (99=0) (2=0) (3=0) (4=0) INTO Q18Total_K5.
VARIABLE LABELS  Q18Total_K5 'Q18Total_K5'.
EXECUTE.
RECODE q18 (1=1) (5=0) (6=0) (88=0) (99=0) (2=1) (3=0) (4=0) INTO Q18Total_K8.
VARIABLE LABELS  Q18Total_K8 'Q18Total_K8'.
EXECUTE.
RECODE q18 (1=1) (5=0) (6=0) (88=0) (99=0) (2=1) (3=1) (4=0) INTO Q18Total_K10.
VARIABLE LABELS  Q18Total_K10 'Q18Total_K10'.
EXECUTE.
RECODE q18 (1=1) (5=0) (6=0) (88=0) (99=0) (2=1) (3=1) (4=1) INTO Q18Total_K12.
VARIABLE LABELS  Q18Total_K12 'Q18Total_K12'.
EXECUTE.
RECODE q18 (1=1) (6=0) (88=0) (99=0) (2=1) (3=1) (4=1) (5=1) INTO Q18Total_K14.
VARIABLE LABELS  Q18Total_K14 'Q18Total_K14'.
EXECUTE.
RECODE q18 (1=1) (88=0) (99=0) (2=1) (3=1) (4=1) (5=1) (6=1) INTO Q18Total_K15.
VARIABLE LABELS  Q18Total_K15 'Q18Total_K15'.
EXECUTE.
```

PHYSICAL_SCIENCE_INTEREST_K5

Figure 3-10. Question #19 from the Project Crossover Survey on first interest in chemistry/physics

```
RECODE q19 (1=1) (5=0) (6=0) (88=0) (99=0) (2=0) (3=0) (4=0) INTO Q19Total_K5.
VARIABLE LABELS  Q19Total_K5 'Q19Total_K5'.
EXECUTE.
RECODE q19 (1=1) (5=0) (6=0) (88=0) (99=0) (2=1) (3=0) (4=0) INTO Q19Total_K8.
VARIABLE LABELS  Q19Total_K8 'Q19Total_K8'.
```

```
EXECUTE.
RECODE q19 (1=1) (5=0) (6=0) (88=0) (99=0) (2=1) (3=1) (4=0) INTO Q19Total_K10.
VARIABLE LABELS  Q19Total_K10 'Q19Total_K10'.
EXECUTE.
RECODE q19 (1=1) (5=0) (6=0) (88=0) (99=0) (2=1) (3=1) (4=1) INTO Q19Total_K12.
VARIABLE LABELS  Q19Total_K12 'Q19Total_K12'.
EXECUTE.
RECODE q19 (1=1) (6=0) (88=0) (99=0) (2=1) (3=1) (4=1) (5=1) INTO Q19Total_K14.
VARIABLE LABELS  Q19Total_K14 'Q19Total_K14'.
EXECUTE.
RECODE q19 (1=1) (88=0) (99=0) (2=1) (3=1) (4=1) (5=1) (6=1) INTO Q19Total_K15.
VARIABLE LABELS  Q19Total_K15 'Q19Total_K15'.
EXECUTE.
```

HS_CHEM_GRADE

Figure 3-11. Question #22 from the Project Crossover Survey on average grade in high school chemistry course

```
RECODE q22 (1=3) (2=3) (3=3) (4=2) (5=2) (6=2) (7=1) (8=1) (9=1) (10=1) (11=1)
(12=1) INTO Q22_NEW.
VARIABLE LABELS  Q22_NEW 'Q22_NEW'.
EXECUTE.
```

HS_PHYSICS_GRADE

Figure 3-12. Question #23 from the Project Crossover Survey on average grade in high school physics course

```
RECODE q23 (1=3) (2=3) (3=3) (4=2) (5=2) (6=2) (7=1) (8=1) (9=1) (10=1) (11=1)
(12=1) INTO Q23_NEW.
VARIABLE LABELS  Q23_NEW 'Q23_NEW'.
EXECUTE.
```

UNDERGRAD_CHEM_GRADE

Figure 3-13. Question #24 from the Project Crossover Survey on average grade in undergraduate chemistry course

```
RECODE q24 (1=3) (2=3) (3=3) (4=2) (5=2) (6=2) (7=1) (8=1) (9=1) (10=1) (11=1)
(12=1) INTO Q24_NEW.
VARIABLE LABELS  Q24_NEW 'Q24_NEW'.
EXECUTE.
```

UNDERGRAD_PHYSICS_GRADE

Figure 3-14. Question #25 from the Project Crossover Survey on average grade in undergraduate physics course

```
RECODE q25 (1=3) (2=3) (3=3) (4=2) (5=2) (6=2) (7=1) (8=1) (9=1) (10=1) (11=1)
(12=1) INTO Q25_NEW.
VARIABLE LABELS  Q25_NEW 'Q25_NEW'.
EXECUTE.
```

UNDEGRAD_CHEM_POSITIVE
UNDERGRAD_PHYSICS_POSITIVE

Figure 3-15. Question #26 from the Project Crossover Survey on experiences in undergraduate chemistry course

```
DATASET ACTIVATE DataSet6.
RECODE q28 q26 (5=0) (1=0) (2=0) (3=1) (4=1) INTO Q28_POSITIVE_NEW
Q26_POSITIVE_NEW.
VARIABLE LABELS  Q28_POSITIVE_NEW 'Q28_POSITIVE_NEW'
/Q26_POSITIVE_NEW 'Q26_POSITIVE_NEW'.
EXECUTE.
```

UNDEGRAD_CHEM_NEGATIVE
UNDERGRAD_PHYSICS__NEGATIVE

Figure 3-16. Question #28 from the Project Crossover Survey on experiences in undergraduate physics course

```
DATASET ACTIVATE DataSet6.
RECODE q28 q26 (5=0) (1=1) (2=1) (3=0) (4=0) INTO Q28_NEGATIVE_NEW
Q26_NEGATIVE_NEW.
VARIABLE LABELS  Q28_NEGATIVE_NEW 'Q28_NEGATIVE_NEW' /Q26_
NEGATIVE_NEW 'Q26_NEGATIVE_NEW'.
EXECUTE.
```

Syntax for Logistic Regression Interaction Variables

```
DATASET ACTIVATE DataSet1.
COMPUTE Age_HSChemGrade=AGE * HS_CHEM_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE Age_HSPhysicsGrade=AGE * HS_PHYSICS_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE Age_UndergradChemGrade=AGE * UNDERGRAD_CHEM_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE Age_UndergradPhysicsGrade=AGE * UNDERGRAD_PHYSICS_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE Age_UndergradChemPos=AGE * UNDERGRAD_CHEM_POSITIVE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE Age_UndergradPhysicsPos=AGE * UNDERGRAD_PHYSICS_POSITIVE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE HPE_HSChemGrade=HIGHEST_PARENT_EDUCATION *
HS_CHEM_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
```

```
COMPUTE HPE_HSPhysicsGrade=HIGHEST_PARENT_EDUCATION *
HS_PHYSICS_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE HPE_UndergradChemGrade=HIGHEST_PARENT_EDUCATION *
UNDERGRAD_CHEM_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE HPE_UndergradPhysicsGrade=HIGHEST_PARENT_EDUCATION *
UNDERGRAD_PHYSICS_GRADE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE HPE_UndergradChemPos=HIGHEST_PARENT_EDUCATION *
UNDERGRAD_CHEM_POSITIVE.
EXECUTE.
DATASET ACTIVATE DataSet1.
COMPUTE HPE_UndergradPhysicsPos=HIGHEST_PARENT_EDUCATION *
UNDERGRAD_PHYSICS_POSITIVE.
EXECUTE.
```

Analyses

Descriptive Analyses

```
FREQUENCIES VARIABLES=ASIAN HISPANIC AFRICAN_AMERICAN WHITE
NATIVE AGE HIGHEST_PARENT_EDUCATION
   US_CITIZENSHIP NATURALIZED_CITIZEN
GREEN_CARD_TEMPORARY_VISA FAMILY_INTEREST
SCIENCE_INTEREST_K5
   Q18Total_K8 Q18Total_K10 Q18Total_K12 Q18Total_K14 Q18Total_K15
PHYSICAL_SCIENCE_INTEREST_K5
   Q19Total_K8 Q19Total_K10 Q19Total_K12 Q19Total_K14 Q19Total_K15
HS_CHEM_GRADE HS_PHYSICS_GRADE
   UNDERGRAD_CHEM_GRADE UNDERGRAD_PHYSICS_GRADE
UNDERGRAD_PHYSICS_POSITIVE UNDERGRAD_CHEM_POSITIVE
   UNDERGRAD_PHYSICS_NEGATIVE UNDERGRAD_CHEM_NEGATIVE
PHYSICAL_SCIENCE YEARS_TO_PHD SURVEY
  /STATISTICS=STDDEV VARIANCE RANGE MINIMUM MAXIMUM SEMEAN
MEAN MEDIAN SKEWNESS SESKEW KURTOSIS
   SEKURT
  /ORDER=ANALYSIS.

CROSSTABS
  /TABLES=ASIAN HISPANIC AFRICAN_AMERICAN WHITE NATIVE AGE
HIGHEST_PARENT_EDUCATION
   US_CITIZENSHIP NATURALIZED_CITIZEN
GREEN_CARD_TEMPORARY_VISA FAMILY_INTEREST
SCIENCE_INTEREST_K5
   Q18Total_K8 Q18Total_K10 Q18Total_K12 Q18Total_K14 Q18Total_K15
```

```
PHYSICAL_SCIENCE_INTEREST_K5
   Q19Total_K8 Q19Total_K10 Q19Total_K12 Q19Total_K14 Q19Total_K15
HS_CHEM_GRADE HS_PHYSICS_GRADE
   UNDERGRAD_CHEM_GRADE UNDERGRAD_PHYSICS_GRADE
UNDERGRAD_PHYSICS_POSITIVE UNDERGRAD_CHEM_POSITIVE
   UNDERGRAD_PHYSICS_NEGATIVE UNDERGRAD_CHEM_NEGATIVE
YEARS_TO_PHD SURVEY BY PHYSICAL_SCIENCE
 /FORMAT=AVALUE TABLES
 /CELLS=COUNT
 /COUNT ROUND CELL.
```

Correlations

```
DATASET ACTIVATE DataSet1.
CORRELATIONS
 /VARIABLES=ASIAN HISPANIC AFRICAN_AMERICAN NATIVE WHITE AGE
HIGHEST_PARENT_EDUCATION
   US_CITIZENSHIP NATURALIZED_CITIZEN
GREEN_CARD_TEMPORARY_VISA FAMILY_INTEREST
SCIENCE_INTEREST_K5
   PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
   UNDERGRAD_PHYSICS_GRADE UNDERGRAD_PHYSICS_POSITIVE
UNDERGRAD_CHEM_POSITIVE
   UNDERGRAD_PHYSICS_NEGATIVE UNDERGRAD_CHEM_NEGATIVE
PHYSICAL_SCIENCE SURVEY
 /PRINT=TWOTAIL NOSIG
 /MISSING=PAIRWISE.

DATASET ACTIVATE DataSet1.
CROSSTABS
 /TABLES=NEW_RACE BY Q14_NEW
 /FORMAT=AVALUE TABLES
 /CELLS=COUNT
 /COUNT ROUND CELL.

CROSSTABS
 /TABLES=UNDERGRAD_CHEM_GRADE BY UNDERGRAD_CHEM_POSITIVE
UNDERGRAD_CHEM_NEGATIVE
 /FORMAT=AVALUE TABLES
 /CELLS=COUNT
 /COUNT ROUND CELL.

CROSSTABS
 /TABLES=UNDERGRAD_PHYSICS_GRADE BY
UNDERGRAD_PHYSICS_POSITIVE UNDERGRAD_PHYSICS_NEGATIVE
 /FORMAT=AVALUE TABLES
```

```
  /CELLS=COUNT
  /COUNT ROUND CELL.
```

Logistic Regression Analysis

```
DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICS_PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_PHYSICS_GRADE
    UNDERGRAD_PHYSICS_POSITIVE
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).
```

Chemist Logistic Regression Interactions

```
DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE Age_HSChemGrade
   /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE Age_HSPhysicsGrade
   /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
```

```
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE Age_UndergradChemGrade
   /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE Age_UndergradChemPos
   /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE HPE_HSChemGrade
/CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE HPE_HSPhysicsGrade
/CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
```

```
UNDERGRAD_CHEM_POSITIVE HPE_UndergradChemGrade
/CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE HPE_UndergradChemPos
/CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).
```

Physicist Logistic Regression Interactions

```
DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICS_PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_PHYSICS_GRADE
    UNDERGRAD_PHYSICS_POSITIVE Age_HSChemGrade
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICS_PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_PHYSICS_GRADE
    UNDERGRAD_PHYSICS_POSITIVE Age_HSPhysicsGrade
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICS_PHYSICAL_SCIENCE
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_PHYSICS_GRADE
    UNDERGRAD_PHYSICS_POSITIVE Age_UndergradPhysicsGrade
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES PHYSICS_PHYSICAL_SCIENCE
```

```
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_PHYSICS_GRADE
    UNDERGRAD_PHYSICS_POSITIVE Age_UndergradPhysicsPos
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).
```

Multiple Regression Analysis

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT YEARS_TO_PHD
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_CHEM_GRADE
UNDERGRAD_CHEM_POSITIVE.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT YEARS_TO_PHD
  /METHOD=ENTER ASIAN HISPANIC AFRICAN_AMERICAN AGE
HIGHEST_PARENT_EDUCATION US_CITIZENSHIP
    NATURALIZED_CITIZEN FAMILY_INTEREST SCIENCE_INTEREST_K5
PHYSICAL_SCIENCE_INTEREST_K5 HS_CHEM_GRADE
    HS_PHYSICS_GRADE UNDERGRAD_PHYSICS_GRADE
UNDERGRAD_PHYSICS_POSITIVE.
```