

**PERSISTENCE OF UNDERGRADUATE
WOMEN IN STEM FIELDS**

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ABSTRACT

The underrepresentation of women in science, technology, engineering, and mathematics (STEM) is a complex problem that continues to persist at the postsecondary level, particularly in computer science and engineering fields. This dissertation explored the pre-college and college level factors that influenced undergraduate women's persistence in STEM. This study also examined and compared the characteristics of undergraduate women who entered STEM fields and non-STEM fields in 2003-2004. The nationally representative Beginning Postsecondary Students Longitudinal Study (BPS:04/09) data set was used for analysis. BPS:04/09 study respondents were surveyed three times (NPSAS:04, BPS:04/06, BPS:04/09) over a six-year period, which enabled me to explore factors related to long-term persistence. Astin's Input-Environment-Output (I-E-O) model was used as the framework to examine student inputs and college environmental factors that predict female student persistence (output) in STEM. Chi-square tests revealed significant differences between undergraduate women who entered STEM and non-STEM fields in 2003-2004. Differences in student demographics, prior academic achievement, high school course-taking patterns, and student involvement in college such as participation in study groups and school clubs were found. Notably, inferential statistics showed that a significantly higher proportion of female minority students entered STEM fields than non-STEM fields. These findings challenge the myth that underrepresented female minorities are less inclined to enter STEM fields. Logistic regression analyses revealed thirteen significant predictors of persistence for undergraduate women in STEM. Findings showed that undergraduate women who were

younger, more academically prepared, and academically and socially involved in college (e.g., lived on campus, interacted with faculty, participated in study groups, fine arts activities, and school sports) were more likely to persist in STEM fields. This longitudinal study showed that both pre-college and college level factors influenced undergraduate women's persistence in STEM. The research findings offer important implications for policy and practice initiatives in higher education that focus on the recruitment and retention of women in postsecondary STEM fields.

To my loving husband, Chris,
and my beautiful sons, Vincent and Charlie,
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CHAPTER 1

INTRODUCTION

Although women make up half of the nation's workforce, women are underrepresented in science, technology, engineering, and mathematics (STEM) fields. Over the past forty years, the representation of women in STEM has increased, particularly in fields such as biology and chemistry (National Science Foundation, 2008). However, women continue to hold less than twenty-five percent of the nation's STEM jobs. Higher education is a critical bridge between secondary education and the STEM workforce. According to a recent study released by the U.S. Department of Education's National Center for Educational Statistics (NCES), nearly half of students pursuing bachelor's degrees in STEM will leave the field before graduation (NCES, 2013). In efforts to increase our STEM workforce and to promote equity, STEM recruitment and retention initiatives at the postsecondary level have placed an emphasis on targeting underrepresented groups, specifically minorities and women (U.S. Department of Education, 2009).

Researchers and policymakers often use the leaky pipeline metaphor to address the underrepresentation of women in STEM (Blickenstaff, 2005; Cannady, Greenwald, & Harris, 2014; Dasgupta & Stout, 2014; Metcalf, 2014). The pipeline metaphor is a linear model that focuses on the loss of women at specific junctures along the STEM pathway (e.g., transition from secondary to undergraduate level, undergraduate to graduate level, and graduate to career level) (Ceci, Williams, & Barnett, 2009; Maltese & Tai, 2011; Xie & Shauman, 2003). Although the leaky pipeline framework is prevalent in the literature,

critics reveal the pitfalls of relying on such a simplistic model to address inequities in STEM (Blickenstaff, 2005; Cannady et al., 2014; Kimmel, Miller, and Eccles, 2012; Metcalf, 2014). Cannady et al. (2014) argue:

The pipeline metaphor...offers little opportunity to scrutinize contextual factors, and, in particular, those factors that may contribute to the low participation of underrepresented minorities in STEM: Simply front-loading women and underrepresented minorities into the “pipe” at the beginning does not mean that they will end up in the “cup” at the end. (p. 447)

In order to uncover why there are so few women in the STEM workforce, it is important to understand the barriers that impact postsecondary women in STEM fields. However, economic forecasts are too often used as the basis for STEM policy initiatives.

As the United States faces economic hardship, a national agenda has been put forth to increase the number of STEM undergraduates (National Research Council, 2011). In a recent report, the President’s Council of Advisors on Science and Technology (PCAST) found that, “economic forecasts point to a need for producing, over the next decade, approximately 1 million more college graduates in STEM fields” (PCAST, 2012). Critics of these economic forecasts question the validity of the crisis discourse (Bianchini, 2013; Mansfield, Welton, & Grogan, 2014). The economic basis for STEM initiatives fails to address the sociocultural barriers that contribute to the attrition of underrepresented women in STEM.

Policymakers, educational researchers and science educators need to understand the individual and institutional level factors that influence the retention of undergraduate

women in STEM in order to diversify and increase our nation's STEM workforce. The weed-out culture of STEM courses, the chilly climate of STEM departments (peers and faculty), and lack of faculty role models can influence undergraduate women's decision to persist in STEM fields (Astin & Sax, 1996; Hill, Corbett, & St. Rose, 2010; Johnson, Brown, Carlone, & Cuevas, 2011; Margolis & Fisher, 2002). Influences external to the classroom such as family expectations, peer relationships, and science identity also play a role in the retention of postsecondary females in STEM (Shapiro & Sax, 2011). This study examines pre-college (e.g., sociodemographics, prior academic preparation and achievement) and college level factors (e.g., academic and social involvement, institutional characteristics) that influence STEM persistence of undergraduate women to further unpack the gender gap issue in postsecondary STEM fields.

Significance of the Study

Over the past few decades, more women have declared science and technology majors and entered related professions. However, despite recent progress, there is still an underrepresentation of women in STEM at the postsecondary level, particularly in computer science and engineering fields. Based on a 2011 U.S. Department of Commerce report, women hold approximately 14% of the engineering positions and 27% of the computer and mathematical positions (US Department of Commerce, 2011). A relatively high number of women are majoring in biology and entering health related fields, however a gender gap still exists in engineering, physics, mathematics, and computer science fields (Hill et al., 2010; Shapiro & Sax, 2011).

In 2013, President Obama went on record stating, "We need to have more girls interested in math, science, and engineering. We have half the population way under-

represented in those fields. That means that we have all that talent downstream that is not being encouraged” (White House, 2013). By examining the characteristics of women who enter postsecondary STEM fields, the current study shows that underrepresented minority women enter STEM fields at a higher rate than non-STEM fields. Despite underrepresented minority women’s interest to pursue STEM, relevant studies have shown that these women are not persisting at the postsecondary level (Anderson & Kim, 2006; Carlone & Johnson, 2007; Gayles & Ampaw, 2014). I attempt to uncover the pre-college and college level factors that influence undergraduate women’s persistence in STEM. The knowledge gained from this research will contribute to higher education practice and policy initiatives that set out to recruit and retain undergraduate women in STEM. Higher education is a bridge to the STEM workforce, in which women represent less than twenty-five percent. Diversification of the STEM workforce is key to meeting national policy objectives.

During the 2011 State of the Union Address, President Obama issued a national challenge to recruit 100,000 STEM educators. In partnership with industries, universities, and foundations, coalitions are being formed to increase the number of STEM degrees earned at the postsecondary level across the nation. A National Science Foundation (NSF) study showed that the number of U.S. undergraduate students majoring in STEM fields is significantly lower than students abroad such as China and South Korea (NSF, 2009).

A recent survey released by the Lemelson-MIT Invention Index (2012) revealed that young adults believe that schools are not preparing them to become a part of the STEM workforce. The sentiments of these young adults demonstrate how barriers at the

secondary and postsecondary level are hindering our potential STEM workforce. Much of the science and mathematics education literature places a focus on factors that affect the motivation, achievement, and engagement of students at the K-12 level. For example, Britner and Pajares (2001) showed that science self-efficacy is a strong predictor of science achievement among middle school students. Singh, Granville, and Dika (2002) analyzed the effects of motivation, attitude, and engagement on mathematics and science achievement among eighth-grade students. Young and Lee (2005) found that elementary students exposed to inquiry-based science kits scored significantly higher on science achievement tests than those exposed to traditional methods of instruction. In addition to the elementary and middle school level literature, there is an abundance of STEM research that focuses on the experiences of secondary students.

In terms of the STEM “pipeline,” extensive literature examines how academic preparation, motivation, and achievement in STEM at the secondary level influences students at the postsecondary level (Adelman, 2006; Maltese & Tai, 2011; Riegler-Crumb, King, Grodsky, & Muller, 2012; Wang, Eccles, & Kenny, 2013). Hill, Corbett, and St. Rose (2010) found:

Girls are earning high school math and science credits at the same rate as boys and are earning slightly higher grades in these classes...however the transition between high school and college is a critical moment when many young women turn away from a STEM career path. (pp. 3,5)

Maltese and Tai (2011) used data from the National Educational Longitudinal Study of 1988 (NELS:88) and found that completing advanced science and mathematics coursework in high school does not necessarily increase the number of students entering

STEM at the postsecondary level. Riegle-Crumb et al. (2012), in their longitudinal study on gender differences in entry into STEM majors contend, “We have offered powerful evidence that long-standing underachievement arguments fail to provide the answer to the question of gender inequality in representation in STEM postsecondary fields” (p. 1068). Studies that further our understanding about the secondary to postsecondary juncture in the STEM pipeline are crucial to improving the state of science and mathematics education in the United States. By examining the student inputs and college environments of undergraduate women in STEM fields, this study revealed factors related to entry into and persistence in postsecondary STEM fields. In terms of developing a diverse STEM workforce, it is vital for researchers to analyze the complexities of higher education STEM programs. Although the gender gap is closing at the secondary level, retaining female students in STEM at the postsecondary level still needs to be addressed.

The present study uses the Beginning Postsecondary Students Longitudinal Study (BPS:04/09), sponsored by the National Center for Education Statistics (NCES) to explore factors that influence the persistence of undergraduate women in STEM. Aside from the NCES publications, few researchers have used the BPS:04/09 study to examine STEM persistence (Chen & Soldner, 2013; Radford, Berkner, Wheelless, & Shepherd, 2010). BPS:04/09 is a nationally representative study that captures the experiences of both traditional and nontraditional students (e.g., delayed enrollment, older, single parent, financially independent). A recent NCES (2012) document reported the following:

BPS cohort studies provide longitudinal data that allow examination of persistence, progress, and attainment after entry into postsecondary

education and also workforce entry. Inclusion of students who are not direct entrants to postsecondary education from high school is a unique aspect of the BPS cohort studies. (BPS-2)

The use of the BPS:04/09 longitudinal data set to examine STEM persistence of undergraduate women fills a gap in the college persistence literature. Much of the STEM persistence literature focuses on traditional students using either cross-sectional, single institution, or qualitative data analysis (LeBeau, Harwell, Monson, Dupuis, Medhanie, & Post, 2012; Palmer, Maramba, & Dancy, 2011; Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). For example, Soldner et al. (2012) studied first-year students and found that living-learning programs may influence the persistence of students in STEM disciplines. LeBeau et al. (2012) conducted a cross-sectional study to examine STEM degree completion among students from a single postsecondary institution in the Midwest. Palmer et al. (2011) studied the persistence of students of color in STEM at a predominantly White institution using qualitative analysis. The current study addresses gender equity issues in STEM through the use of a longitudinal data set that includes a diverse set of students and institutions. In addition, this research strives to provide key policy recommendations to promote the persistence of undergraduate women in STEM.

Purpose of the Study

The purpose of this study is to examine the student inputs and college environmental factors that predict the persistence of female bachelor's degree students in STEM fields. Persistence can be defined in many different ways (Hilton & Lee, 1988; Rayman & Brett, 1995; Seymour & Hewitt, 1997). For this study, STEM persistence will be defined as undergraduate women who entered a STEM field in 2003-2004 and either

attained a bachelor's degree in a STEM field by 2009 or remained enrolled in a STEM field by 2009. STEM and non-STEM fields were aggregated based on previous works that utilized BPS:04/09 data to study STEM attrition (Chen & Soldner, 2013). This study uses secondary data from a nationally representative sample to analyze how student inputs (e.g., age, race/ethnicity, income level, prior academic achievement) and college environments (e.g., academic integration, social integration, institutional selectivity) relate to the persistence of female bachelor's degree students in STEM. Significant predictors of STEM persistence will be analyzed using theory and model robustness to determine the practical significance of the findings.

The higher education literature cites several factors that impact college student persistence such as prior academic preparation and achievement and college environmental variables (e.g., peer interactions, faculty interactions, co-curricular experiences) (Astin, 1993; Reason, 2010; Tinto, 1993). Nearly fifty percent of students leave STEM within the first two years of college. In particular, undergraduate women in STEM fields choose to leave due to an unwelcoming educational environment (Figueroa, Hughes, & Hurtado, 2012; Seymour & Hewitt, 1997).

Opportunities for undergraduate women in STEM to invest energy into their college experience include meaningful peer and faculty interactions, academic involvement, faculty mentorship, peer study groups, educational and career support, and academically and socially supportive climates, which are explored in this study (Astin 1993; Szeleni, Denson, & Inkelas, 2013). Due to sociocultural barriers such as gender stereotypes, a lack of support for women in STEM departments, and unbalanced pedagogy, female students are leaving STEM fields (Hill et al., 2010; Seymour and

Hewitt, 1997). The competitive and isolating culture of college-level STEM programs offers little support for underrepresented students in STEM such as women and minorities (Espinosa, 2011). This study fills a gap in the current STEM literature by investigating which student inputs and college environmental factors are strong predictors of undergraduate women's persistence in STEM using a nationally representative data set.

Research Questions

This study explores pre-college characteristics and college environmental factors that relate to the persistence of undergraduate women in STEM using Astin's Input-Environment-Output (I-E-O) model. For the first research question, female bachelor's degree students who declared STEM and non-STEM majors are examined and compared, based on student inputs (e.g., student demographics and prior academic preparation and achievement) and college environmental variables. College environmental variables are divided into two categories: academic and social involvement factors and institutional characteristics. For the second research question, this study investigates the degree to which student inputs and college environmental variables are predictors of persistence for female bachelor's degree students in STEM fields. The research questions addressed in this study are as follows:

Research Question 1: Are there significant differences between female bachelor's degree students who enter STEM fields and those who enter non-STEM fields, based on pre-college characteristics and experiences, academic and social involvement factors, and institutional characteristics?

Research Question 2: Which pre-college characteristics and experiences, academic and social involvement factors, and institutional characteristics best predict the persistence of female bachelor's degree students in STEM fields?

Relevant literature shows that prior academic preparation and achievement and student involvement in college are critical factors that contribute to the persistence of undergraduate women in STEM (Astin, 1999; Reason, 2010). This study seeks to uncover the factors that best predict persistence in STEM. Based on Astin's I-E-O model, I expect to find that mathematics preparation in high school and interactions with peer and faculty at the college level (e.g., study groups, interactions with faculty, extracurricular activities) will be strong predictors of STEM persistence. Prior research has shown that mathematics preparation and self-confidence in mathematical abilities are related to persistence in STEM, particularly for female students (Adelman, 2006; Astin & Astin, 1992; Chen & Soldner, 2013; Kiefer & Sekaquaptewa 2007; Sax, 1994). Based on Astin's theory of involvement, I also expect to find that undergraduate women who are more academically and socially involved in college will persist in STEM (Astin, 1999). The broad concepts referred to in the above research questions (e.g., pre-college characteristics and experiences, academic and social involvement factors, and institutional characteristics) are explained in more detail in Chapter 3.

Definition of Key Terms

STEM fields: STEM fields include the following disciplines: life sciences, physical sciences, mathematics and statistics, computer and information sciences, and engineering and engineering technologies.

Non-STEM fields: Non-STEM fields include the following disciplines: humanities,

social/behavioral sciences, education, business/management, health, vocational/technical, and other technical/professional.

STEM persisters: STEM persisters include female students who entered a STEM field in 2003-2004 and either (a) attained a bachelor's degree in a STEM field by 2009; or (b) remained enrolled in a STEM field by 2009.

STEM non-persisters: STEM non-persisters include female STEM majors who either (a) left postsecondary education by 2009; (b) changed to a non-STEM field and left postsecondary education by 2009; (c) changed to a non-STEM field and attained a degree (includes certificate, associate's degree, and bachelor's degree) in a non-STEM field by 2009; or (d) changed to a non-STEM field and remained enrolled in a non-STEM field by 2009.

The underrepresentation of women in STEM fields is an ongoing problem that warrants continuing efforts by researchers and policymakers. In order to diversify our nation's STEM workforce and promote equity, it is crucial that the STEM gender gap at the postsecondary level is addressed. The present study will provide insight into how pre-college experiences and college environmental factors influence the persistence of undergraduate women in STEM. Through the use of a nationally representative, longitudinal data set that encompasses a diverse set of students and universities, this study will expand upon the current STEM literature.

Using Astin's I-E-O model as a guiding framework, I intend to uncover the factors that predict the persistence of undergraduate women in STEM. This study seeks to provide key recommendations to policymakers, educators, and researchers on how to improve STEM recruitment and retention efforts at the postsecondary level.

CHAPTER 2

REVIEW OF LITERATURE

This chapter begins with a review of the extant literature on the factors that influence STEM persistence at the postsecondary level and concludes with an outline of the theoretical framework that drives this study. More specifically, relevant studies related to the underrepresentation of women in STEM are described and critiqued. In addition, pertinent literature on critical predictors of STEM persistence, such as pre-college characteristics (e.g., student demographics and prior academic preparation and achievement) and college environmental factors (e.g., academic and social involvement and institutional characteristics) are examined. This review is guided by Astin's (1993) input-environment-outcome (I-E-O) model.

Student Persistence

There are numerous models that help explain why students leave institutions of higher learning. Prominent educational theorists such as Spady (1970, 1971), Tinto (1975, 1993), and Astin (1984, 1993) have developed theoretical models to further understand student retention and attrition. These theoretical models are frameworks that concentrate on the environmental origins of change as opposed to the individual or internal processes of student change (Pascarella & Terenzini, 1991, 2005; Terenzini & Reason, 2005).

Spady (1970) developed one of the first widely used college retention models. Spady's conceptual framework was based on Durkheim's suicide model, and posits that academic and social integration are vital to student persistence. Prior to Spady's work,

much of the blame for student attrition was placed on the individual, as opposed to the institution. Spady (1971) empirically tested his model and found that academic performance was an important factor in student retention, while stressing the importance of social integration. Spady argues, "...full integration into the common life of the college depends on successfully meeting the demands of both its social and academic systems" (p. 39). Tinto's (1975, 1993) model of student integration expands upon Spady's model and has been extensively used in the college retention literature.

Tinto's theoretical model focuses on the integration of students into the college environment, highlighting the significance of social and academic involvement. Tinto (1993) argues:

There appears to be an important link between learning and persistence that arises from the interplay of involvement and the quality of student effort. Involvement with one's peers and with the faculty, both inside and outside the classroom, is itself positively related to the quality of student effort and in turn to both learning and persistence. (p. 71)

Although Spady and Tinto's frameworks continue to be used by researchers, there are criticisms that these models only consider "traditional" students and ignore underrepresented student populations (e.g., minorities, first generation, two-year college students) (Hurtado & Carter, 1997; Maestas et al., 2007; Pascarella & Terenzini, 2005).

Hurtado and Carter (1997) examined the effects of college transition and racial climate on the integration of Latino college students. The authors ultimately showed that more attention should be given to factors that influence the integration of minority college students. Hurtado and Carter criticized Spady and Tinto's models and argued the

following:

Spady's attempt to draw parallels between a theory that was descriptive but not predictive of college students' persistence produced a model in which some concepts were too complex to be tested empirically...Tinto's model is problematic in that it does not acknowledge that integration is complicated by racially tense environments for diverse groups of students whose responses to adversity are complex. (pp. 325, 340)

Hurtado and Carter contend that Spady and Tinto's perspectives, although influential overlooked the complexities of integration among diverse populations at the postsecondary level.

Critics of the college impact literature argue that findings are generalized based on research that ignores the cultural contexts of individual institutions and underrepresented students (Hurtado & Carter, 1997; Pascarella & Terenzini, 2005). However, there are recent studies that have used traditional college impact models to study diverse student populations (Cole & Espinoza, 2008; Heaney & Fisher, 2011; Museus, Nichols, & Lambert, 2008). Museus, Nichols, and Lambert (2008) used Tinto and Astin's theoretical models as a framework and showed how campus racial climates indirectly influenced student persistence among different racial groups. Cole and Espinoza (2008) used Astin's input-environment-outcome (I-E-O) model to explore factors that impacted the academic success of Latino students in STEM. By using Astin's I-E-O model, Cole and Espinoza found that both student inputs (e.g., gender, high school GPA) and college environmental factors (e.g., time studying, faculty support) were positively related to academic performance in STEM.

Heaney and Fisher (2011) also used Astin's I-E-O model as a framework for a case study that assessed the persistence of at-risk students participating in a learning community at a public university. Heaney and Fisher found that social and academic integration experiences influenced the persistence of at-risk students within learning communities. Astin's I-E-O model enables researchers to examine study participants on a holistic level through the analysis of both pre-college and college-level factors. In the current study, Astin's I-E-O college impact model was used as a framework for examining the persistence of underrepresented students in STEM.

Kelly (1996) persuasively explains the benefits of Astin's I-E-O model stating, "Although this model is a simpler conceptualization of the attrition process than depicted in the longitudinal models proposed by Spady and Tinto, it captures the intersectional essence of the process in a straightforward and meaningful manner" (p. 11). Building upon prior research, this study uses Astin's I-E-O model to investigate the influence of pre-college characteristics and college environmental factors on the persistence of undergraduate women in STEM. Over the past few decades, a debate has ensued about the underlying causes of the STEM gender gap. In the next section, relevant literature on the factors that impact women's participation in STEM fields are reviewed and critiqued.

STEM Gender Gap: Nature versus Nurture

In 2005, Lawrence Summers, the former president of Harvard University, remarked that the underrepresentation of women in science stems from innate differences between men and women (Buday, Stake, & Peterson, 2012). Summers' controversial comments reignited a heated debate about whether the underrepresentation of women in STEM is biological or environmental in nature. However, there is little evidence to

support Summers' assertions, and a large body of research-based evidence confirms that gender differences within STEM fields cannot be attributed to biological factors (Ceci et al., 2009; Eccles, 2011; Hill et al., 2010).

Ceci et al. (2009) conducted meta-analyses using over four hundred articles to uncover why there are gender disparities in mathematics-intensive fields. Although the gender gap in mathematics and science fields has decreased, computer science, mathematics, and engineering fields remain heavily dominated by males. The authors found that the biological and genetic links to gender differences in STEM are inconclusive. Ceci et al. argue that "cultural and sociodemographic differences suggest that culture may play a major, though poorly understood, role in creating proximal differences that lead to differences in STEM fields" (p. 226). Although sociocultural factors play a major role in the STEM gender gap, many psychologists would argue that innate cognitive differences are the root cause of the gap. Researchers have shown that males outperform females on spatial memory and visualization tasks (Hyde, 1996; Kimura, 2002; McConnell et al., 2011; Voyer et al., 1995). Kimura (2002) argues that sex differences in cognition are due to hormonal effects and have been observed across cultures with varying gender norms (Ceci et al., 2009; Hyde, 2014; Kimura, 2002, 2007). Hyde (2014), through meta-analyses, found significant differences in mathematics performance and spatial perception among males and females. However, it is questionable whether these cognitive differences can account for the large gender gap in disciplines such as engineering and computer science (Blickenstaff, 2005; Hill et al., 2010; Hyde, 2014; Miller & Halpern, 2014).

Wang, Eccles, and Kenny (2013) used national longitudinal data to study the influence of mathematical and verbal ability (based on SAT scores) on the choice to pursue a STEM career. The findings showed that high school students with high verbal skills who were mathematically proficient were less inclined to pursue a STEM career. In addition, there were more females in the high mathematical and verbal ability group than males. This study supports the notion that the gender gap in STEM should not be attributed to cognitive differences. Although some researchers show that spatial cognition and mathematical ability vary among the sexes, those sex differences are inconsequential and diminishing in the educational setting (Newcombe, Mathason, & Terlecki, 2002).

The American Association of University Women (AAUW) released a groundbreaking publication titled, “Why So Few?: Women in Science, Technology, Engineering, and Mathematics” that highlighted research findings that support the relevance of environmental factors in the underrepresentation of women in STEM. Hill, Corbett, and St. Rose (2010) argue, “The ratio of boys to girls among children identified as mathematically precocious has decreased dramatically in the last 30 years, far faster than it would take a genetic change to travel through the population” (p. 20). The relevant literature cites factors such as stereotype threat, implicit bias, and perceived values placed on STEM careers as influences on the gender differences in STEM (Brickhouse et al., 2000; Eccles, 2011; Kiefer & Sekaquaptewa, 2007).

Kiefer and Sekaquaptewa (2007) examined the joint roles of gender identification and gender stereotyping on mathematics-related outcomes among undergraduate women. The authors found that high gender identification and high implicit gender stereotyping

jointly contributed to women's poor mathematics performance and disinterest in pursuing a mathematics-intensive field. Kiefer and Sekaquaptewa's work supports the notion that sociocultural barriers such as implicit bias and stereotype threat contribute to the underrepresentation of women in STEM.

There are also gender disparities in terms of the perceived value of technological and engineering careers. The expectancy-value model theory suggests that achievement-related choices are based on expectations for success and the perceived value attached to a certain task. Chow, Eccles, and Salmela-Aro (2012) report, "According to the expectancy-value model of achievement-related choice... individuals' perceived values of various school subjects or activities, *subjective task values (STVs or simply task values)*, play a key role in the choices individuals make regarding education and occupation" (p. 1612). Eccles (2011) used the expectancy-value model to investigate gender differences in entry into physical science and engineering careers. Eccles reported that gender disparities could not be explained by differences in aptitude. However, there were gender differences between the perceived values placed on types of careers.

Eccles also used the expectancy-value model to study student motivation, student achievement, and gender differences in science and mathematics classrooms (Eccles, 1994, 2005). Eccles' research demonstrates that the underrepresentation of women in research and technological fields should be linked to culturally constructed values, as opposed to innate factors. The present research study builds upon prior research and explores how the secondary and postsecondary experiences of women in STEM influences college persistence. Researchers and policymakers have studied in depth the

factors that influence the persistence of college students in STEM fields, which is presented in the next section.

STEM Persistence in Higher Education

Merely 59% of first-time, bachelor's degree students who began college in 2006 attained a degree by 2012 (National Center for Education Statistics, 2014). College attrition is a complex phenomenon that has been analyzed by many researchers and policymakers (Astin, 1993; Pascarella & Terenzini, 2005). In particular, reducing STEM attrition in college has become a national priority, especially among underrepresented groups (e.g., women, minorities, first-generation students). Approximately 48% of bachelor's degree students who entered STEM fields between 2003 and 2009 left a STEM field by spring 2009 (Chen & Soldner, 2013). Further understanding of the factors that influence undergraduate students' decision to stay in STEM is vital.

In this section, a review of the literature on STEM persistence in higher education is presented. Using Astin's I-E-O model as a framework, I discuss the relevant literature on the student inputs (e.g., student demographics, pre-college preparation and achievement) and college environments (e.g., academic and social involvement and institutional characteristics) related to STEM persistence. A detailed discussion of Astin's I-E-O model is provided towards the end of the chapter.

Student Inputs

Student Demographics

There are many pre-college factors, also referred to as student inputs, which have been used to characterize college students (Astin, 1993). Pre-college factors that are prevalent in the persistence literature include student demographics and prior academic

preparation and achievement factors (Cole, Kennedy, & Ben-Avie, 2009; Reason, 2010). Student characteristics such as race/ethnicity, age, gender, parental education level, and socioeconomic status have been cited as predictors of postsecondary persistence (Anderson & Kim, 2006; Astin, 1993; Crisp, Nora, & Taggart, 2009; Gayles & Ampaw, 2014).

In the STEM persistence literature, race/ethnicity and gender have been studied to a great extent (Anderson & Kim, 2006, Eccles, 1994; Kimmel, Miller, & Eccles, 2012). Anderson and Kim (2006) used a national data set, the Beginning Postsecondary Students Longitudinal Study (BPS:96/01), to examine factors influencing the persistence of minority students in STEM. The researchers reported, “A closer look at the data reveals that African Americans and Hispanics enter higher education with the same level of interest in the STEM fields as their peers, but that they fail to persist in these majors at the same rate as their white and Asian-American classmates” (p. 1). Ong, Wright, Espinosa, and Orfield (2011) published a review of the literature on the postsecondary experiences of women of color in STEM and revealed similar findings. Ong et al. found that women of color demonstrated high interest in pursuing postsecondary STEM, but were underrepresented in STEM degree attainment. Although underrepresented minorities exhibit a lower rate of STEM degree attainment, some researchers question the overused “White male advantage” claim in STEM (Dickson, 2010; Riegle-Crumb & King, 2010).

Contrary to the prevailing literature, Riegle-Crumb and King (2010) found that White males do not have the advantage in STEM majors. The authors investigated racial/ethnic and gender disparities in STEM fields among a recent college cohort

enrolled in four-year institutions using nationally representative data. Findings showed that Black and Hispanic males were as likely to enroll in STEM fields as their White male counterparts. Riegle-Crumb and King argue that disparities between groups in STEM are often the assumption, which can lead to the reinforcement of inequities. Although Riegle-Crumb and King provide evidence for parity among certain STEM field entrants, the study was limited to students enrolled in four-year institutions. In addition, the researchers could not address issues of persistence due to the lack of degree completion data. Both factors may have masked the inequities that are prevalent in postsecondary STEM fields.

In terms of gender disparities, Riegle-Crumb and King illustrate that there continues to be a “male advantage” in STEM fields. The researchers found that across all racial/ethnic groups, females were underrepresented in STEM compared to their male peers. Much of the gender disparity was attributed to differences in physical science and engineering majors. Interestingly, African American females were more likely to declare physical science and engineering as their major than White females. Dickson (2010) also investigated gender and race differences in college major choice and found that women were less likely to declare engineering than men. And women who majored in engineering were more likely to switch fields than their male counterparts.

Although some researchers question the white male advantage, other studies show that women and underrepresented minorities have higher rates of attrition in STEM majors than White males (Long & Fox, 1995; Xie & Shauman, 2003). Carlone and Johnson (2007) argue that, “Undergraduate science majors often must negotiate a culture characterized by white, masculine values and behavioral norms, hidden within an

ideology of meritocracy” (p. 1187). In addition to racial and gender disparities in STEM, parental education and income level have been linked to STEM persistence (Chen, 2009; Gayles & Ampaw, 2014).

Parental education level and parental encouragement have been shown to impact STEM entrance and persistence, particularly women in STEM (Gayles & Ampaw, 2014; Rayman & Brett, 1995). Women who have highly educated parents or parents who work in STEM fields are more likely to persist in STEM (Astin & Sax, 1996; Shapiro & Sax, 2011; Staniec, 2004). Rayman and Brett (1995) found that parental encouragement was significantly associated with the persistence of women in STEM. Chen (2009) used a nationally representative data set and demonstrated that a higher percentage of students whose parents had some college experience or earned a high income entered STEM fields. In addition to student demographics, prior academic preparation and achievement factors have been shown to influence STEM entrance and persistence.

Prior Academic Preparation and Achievement

High school grade point average (GPA) is one of most studied predictors for college persistence (Astin, 1993; Ishler & Upcraft, 2005; Pascarella & Terenzini, 1991; Sax, 2001). Studies have shown that high school GPA is a valid predictor of academic success in college and STEM persistence (Ackerman, Kanfer, & Beier, 2013; Bonous-Hammarth, 2000). SAT/ACT admission scores have also been correlated to postsecondary success and more specifically STEM degree attainment (LeBeau et al. 2012). Chang, Sharkness, Newman, and Hurtado (2010) conducted a quantitative study on STEM persistence and found that SAT scores were significantly related to STEM persistence. More specifically, SAT/ACT mathematics scores have been shown to

predict STEM degree attainment at the undergraduate level (Astin & Astin, 1992, Astin & Sax, 1996).

In addition to high school GPA and standardized test scores, advanced placement exam scores and rigorous course taking in high school (e.g., level of mathematics, years of high school science) have also been shown to be predictors of STEM persistence (Ackerman et al., 2013; Adelman, 2006; Gayles & Ampaw, 2014; Griffith, 2010; LeBeau et al., 2012, Rayman & Brett, 1995). Adelman (2006) showed that success in climbing the high school “math ladder” (i.e., ranging from pre-algebra to calculus) was correlated to persistence at the postsecondary level. High school students who completed courses higher than algebra 2 were significantly more likely to earn a bachelor’s degree. In terms of STEM attrition, Chen and Soldner (2013) examined nationally representative data and found:

STEM attrition rates also varied by students’ precollege academic preparation...46 percent of STEM entrants with a high school GPA of less than 2.5 and 41 percent of those who did not take algebra II/trigonometry or higher math courses in high school left STEM fields by dropping out of college, compared with 14 percent of those with a high school GPA of 3.5 or higher and 12 percent of those who took calculus in high school. (p. 17)

Although relevant studies have shown that prior academic preparation relates to STEM persistence, contrasting literature challenges the significance of certain pre-college achievement factors on STEM degree completion (Chang et al, 2010; Cole & Espinoza, 2008). Chang et al. (2010) found that high school grade point average and years of high school mathematics and science were not significantly related to STEM persistence.

These findings reveal the importance of exploring both the pre-college and college-level factors associated with STEM persistence. Although prior academic preparation and achievement factors play a role in the academic success of STEM majors, examining how the college environment impacts women is vital to our understanding of STEM persistence. In addition to student inputs, the present study explores the influence of college environmental factors (e.g., academic and social involvement and institutional characteristics) on the persistence of undergraduate women in STEM.

Academic and Social Involvement

Astin's (1993) theory of involvement suggests that the amount of energy undergraduate students' invest in their college experience, both academically and socially, relates to the likelihood of persistence. Academic involvement includes "experiences such as interacting with faculty, academic administrators, and peers on academic-related tasks that ultimately lead to intellectual development and a strong connection to the institution". Social involvement is "characterized by engaging in social aspects of the environment...such experiences include involvement in campus organizations and interacting socially with peers and faculty" (Gayles & Ampaw, 2014, pp. 441-442). The weed out system in disciplines such as physics and engineering promotes individual learning and a competitive grading culture that hinders the academic and social integration of students in STEM fields (Astin & Sax, 1996; Seymour & Hewitt, 1997).

Academic Involvement

The competitive nature of STEM programs at the higher education level contributes to the attrition of STEM majors, specifically underrepresented groups.

Researchers have cited a range of reasons related to the attrition of underrepresented minorities (URM) in STEM. Campus racial climate, financial concerns, and inadequate academic preparation have been shown to influence the participation and sense of belonging of URM students in STEM fields (Adelman, 2006; Figueroa, Hughes, & Hurtado, 2013).

Garcia and Hurtado (2011) used secondary data to investigate the predictors of fourth-year persistence of Latino students in STEM. The authors found that participation in STEM-related clubs and undergraduate research were related to the persistence of Latino students. However, negative perceptions of campus racial climate hindered the persistence of Latino students in STEM. Hurtado, Cabrera, Lin, Arellano, and Espinosa (2009) also found that undergraduate research participation positively influenced URM's decision to pursue graduate or professional STEM careers. These studies support the notion that academic integration in STEM disciplines is related to academic success, particularly for underrepresented students.

Chang et al. (2010) studied STEM persistence among underrepresented minorities and found that participation in academic clubs, study groups and undergraduate research increased their chances of persistence. Gayles and Ampaw (2014) argue that faculty interaction, specifically outside of the classroom positively impacts the persistence of undergraduate women in STEM. Academic involvement connects students to an institution, which ultimately impacts student persistence and achievement.

Sonnert and Fox (2012) conducted a multi-institutional, longitudinal study to analyze the retention of undergraduate male and female STEM students. The researchers found that the type of institution and programs available within a particular institution

had a positive impact on the grade point averages of women in STEM. Sonnert and Fox demonstrated that academic supports made available by universities influenced the academic success of undergraduate women in science.

Griffith (2010) studied the persistence of women and minorities in STEM majors at an extensive array of four-year institutions. A secondary data set was analyzed from the National Longitudinal Survey of Freshman (NLSF) to investigate the institutional factors that contribute to the persistence of women and minorities in STEM majors. Griffith uncovered that the educational experiences of women and minorities within particular institutional settings impacted persistence. According to Griffith (2010):

Colleges, universities, and others interested in increasing persistence of students in STEM field majors during college should put some focus on the institutional environment, as it seems that students are more likely to continue in a STEM major when there is more of a focus on the undergraduate student experience. (p. 28)

Griffith's study illustrated how the academic experiences of underrepresented students in STEM influenced their intent to persist.

Durham and Marshall (2012) examined engineering college students and their participation in major-related clubs. The authors found, "Students participating in the engineering clubs...enjoyed learning, had higher motivation and self-confidence, and more clear educational and career goals as a result of participating in these clubs" (p. 7). The findings highlight the importance of academic and social support structures at the postsecondary level.

In the present study, I argue that academic involvement (e.g., interactions with

faculty, involvement in study groups) and social involvement (e.g., involvement in school clubs, fine arts activities, school sports) impact the persistence of undergraduate women in STEM. I believe that social and cultural factors play a predominant role in the STEM gender gap.

Social Involvement

Social integration has been shown to promote student persistence at the postsecondary level (Astin, 1984; Gellin, 2003; Seymour & Hewitt, 1997; Tinto, 1975). Astin (1975) conducted a longitudinal study to investigate the factors that influence college student persistence. Astin found that social involvement factors such as campus residence and involvement in extracurricular activities impact student retention.

According to Astin (1999):

Living in a campus residence was positively related to retention, and this positive effect occurred in all types of institutions and among all types of students regardless of sex, race, ability, or family background...students who join social fraternities or sororities or participate in extracurricular activities of almost any type are less likely to drop out. Participation in sports, particularly intercollegiate sports, has an especially pronounced, positive effect on persistence. (p. 523)

In contrast to Astin's findings, other studies have shown that social involvement negatively impacted the persistence of college students in STEM fields (Bonous-Hammarth, 2000; Cole & Espinoza, 2008).

Cole and Espinoza (2008) studied the factors that influenced the academic success of Latino students in STEM fields. The researchers found that participation in

social events, specifically diversity functions, negatively affected college grade point average. Bonous-Hammarth (2000) also found that the retention of underrepresented minorities in science, mathematics, and engineering (SME) was negatively influenced by social integration. Bonous-Hammarth argued that minority students searched for connections outside of their SME disciplines due to marginalization, which in turn adversely impacted academic success. Although these studies revealed the negative effects of social integration, I argue that social involvement in college contributes to the persistence of undergraduate women in STEM.

Soldner, Rowan-Kenyon, Inkelas, Garvey, and Robbins (2012) studied the impact of living-learning communities on STEM persistence and found that increasing social support to STEM students was beneficial to STEM retention. Anderson and Kim (2006) used a nationally representative longitudinal data set (BPS:96/01) to study STEM persistence at the postsecondary level. Anderson and Kim found that STEM completers were “twice as likely to have to have the highest level of social integration at their institution” compared to STEM non-completers (p. 12). Relevant studies examining social involvement variables are central to understanding how the college environment influences undergraduate women’s decision to stay in STEM. In addition to academic and social involvement variables, institutional characteristics also contribute to the success of undergraduate women in STEM fields.

Institutional Characteristics

Recent studies have shown that institutional characteristics such as institutional size, selectivity, control, and Carnegie classification are associated with success in STEM fields (Chen & Soldner, 2013; Espinosa, 2011). Gayles and Ampaw (2014) conducted a

longitudinal study using a nationally representative data set (BPS:96/01) to study the influence of college environmental factors on STEM degree completion at four-year institutions. Gayles and Ampaw found that institutional characteristics such as Carnegie classification and institutional selectivity impacted degree completion of female students. Female students were more likely to attain a bachelor's degree in STEM at doctoral institutions as well as moderately selective institutions.

Espinosa (2011) conducted a quantitative study and found that undergraduate women of color in STEM who attended highly selective institutions were less likely to persist in STEM. Garcia and Hurtado (2011) also demonstrated that the climate of highly selective institutions had a negative impact on underrepresented students in STEM. Whereas other relevant studies have shown that highly selective institutions promote STEM degree completion (Chen & Soldner, 2013; Eagan, Hurtado, & Chang, 2010; Tan, 2002). For the present study, the effects of institutional characteristics (e.g., institutional selectivity, total institutional aid, and Carnegie classification) on the persistence of undergraduate women in STEM were examined using statistical analyses. In the next section, relevant research studies that examine how the college environment impacts undergraduate women in STEM are presented.

Persistence of Undergraduate Women in STEM

Although women outnumber men in terms of college enrollment, there continues to be fewer women majoring in some STEM disciplines such as engineering and computer science as shown in Figure 2.1 and Figure 2.2 (NCES, 2013; NSF, 2013). In fields such as biology and chemistry, the representation of women in STEM has increased over the past few decades. However, the current higher education literature

cites a range of reasons for the attrition of women from male-dominated STEM majors, including a lack of female role models and “chilly” atmosphere within STEM fields (Blickenstaff, 2005; Erwin & Maurutto, 1987; Sandler & Hall, 1986; Seymour & Hewitt, 1997).

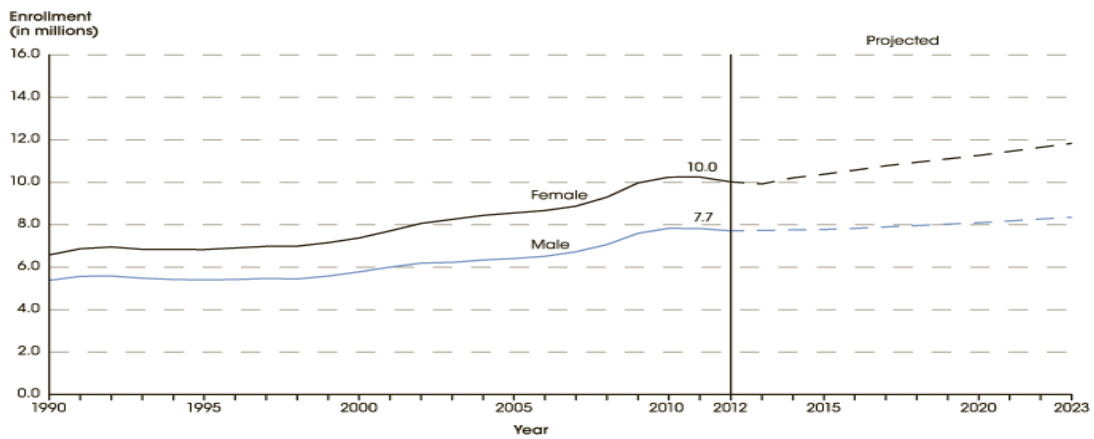
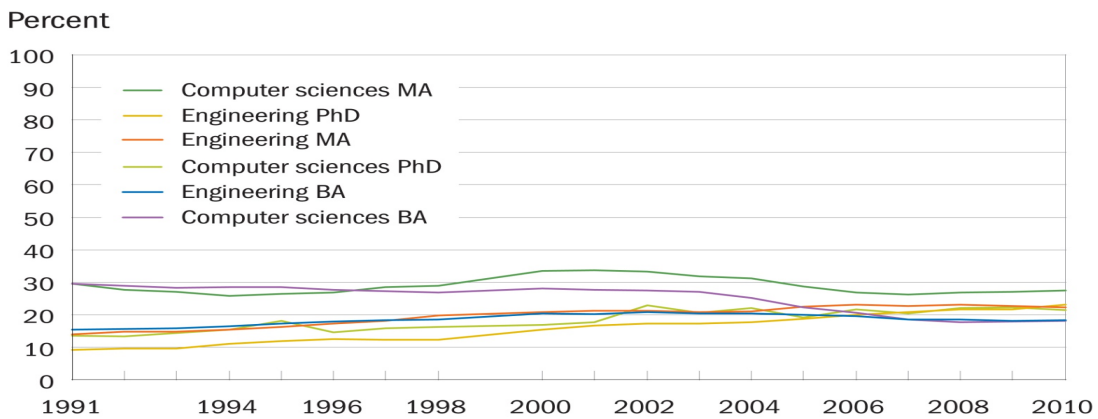


Figure 2.1. Actual and projected undergraduate enrollment in degree-granting postsecondary institutions, by sex: Fall 1990–2023. Reprinted from U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), "Fall Enrollment Survey" (IPEDS-EF:90–99); IPEDS Spring 2001 through Spring 2013, Enrollment component. See *Digest of Education Statistics 2013*. Retrieved from http://nces.ed.gov/programs/coe/indicator_cha.asp.



NOTE: Data not available for 1999.

Figure 2.2. Level of participation of women in computer science and engineering fields over a twenty-year period, from 1991 to 2010. Reprinted from National Science Foundation, National Center for Science and Engineering. Retrieved from www.nsf.gov/statistics/wmpd.

Female Role Models

Recent literature has shown that college environmental factors play a predominant role in the retention of undergraduate women in STEM (Astin & Sax, 1996; Blickenstaff, 2005). Blickenstaff (2005) reports, “A low proportion of women in a discipline probably sends a message to girls that the discipline is unattractive to women, and they should avoid it too” (p. 376). Although female role models within higher education may influence women’s interest in STEM, there is research that counters this prevailing ideology. Griffith (2010) found:

Female students in STEM fields with a higher proportion of female faculty members are less likely to persist in the major field. However, this might be capturing the influence of junior versus senior faculty members, as many of the female faculty members are likely to have a lower rank than their male colleagues. (p. 27)

Griffith argues that junior faculty members may not have as much influence in retaining female students as senior faculty. In this same study, Griffith found that female undergraduate students were more likely to persist in STEM majors at institutions that have a higher percentage of STEM female graduate students. This finding supports the importance of female role models within STEM fields in higher education institutions and ties into Bandura’s concept of self-efficacy through vicarious experience (Bandura, 1977, 2001).

STEM female graduate students may provide vicarious experiences to female undergraduate students, which can influence self-efficacy beliefs. Bandura (1977) argued that, “Many expectations are derived from vicarious experience. Seeing others perform

threatening activities without adverse consequences can generate expectations in observers that they too will improve if they intensify and persist in their efforts” (p. 197). Higher self-efficacy contributes to students’ willingness to persist in challenging environments (Hsieh, Sullivan, & Guerra, 2007). Female role models can influence undergraduate women in STEM to become fully integrated and involved in their college experience (Astin, 1984; Tinto 1993). In addition to a lack of female role models, the isolating and competitive culture of undergraduate STEM departments contributes to the attrition of women in STEM.

Culture of Postsecondary STEM Fields

Peer interactions have been shown to influence the college experience and academic growth of postsecondary students (Gellin, 2003; Whitt, Edison, Pascarella, Nora, & Terenzini, 1999). Astin and Astin (1992) found that the percentage of peers majoring in STEM influences student interest in STEM. Underrepresented students may feel isolated and lack a sense of belonging in STEM fields (Margolis & Fisher 2002; Shapiro & Sax, 2011). Margolis and Fisher (2002) studied computer science undergraduate students at a highly selective university, Carnegie Mellon University. Through interviews, the researchers discovered that female computer science students felt alienated and did not fit the ‘male model’ of doing computer science. Margolis and Fisher argue, “A critical part of attracting more girls and women in computer science is providing multiple ways to ‘be in’ computer science” (p. 72). Women who are competent in a perceived male role such as a computer scientist run the risk of being humiliated or shamed by their peers. This lack of social support hinders the ability of women to become fully integrated as accepted members of their STEM major (Tinto,

1993). In addition to women feeling isolated due to the unique nature of STEM fields, societal pressures may push potentially capable students away from pursuing STEM.

Female students who major in science, technology, engineering, and mathematics fields may face discrimination because they are in opposition to society's accepted gendered roles. Although more women are entering STEM fields, there are still unconscious biases against women in science. In the AAUW "Why So Few Report?", Hill et al. (2010) found:

More than a half million people from around the world have taken the gender-science test, and more than 70 percent of test takers more readily associated "male" with science and "female" with arts than the reverse...these findings indicate a strong implicit association of male with science and female with arts and a high level of gender stereotyping at the unconscious level among both women and men of all races and ethnicities.
(p. 76)

Due to implicit gender attitudes, undergraduate women may feel pressure to switch out of male dominated STEM fields to fit into the college environment. Recent research studies illustrate that the departure of women from research and technological fields can be attributed to a STEM culture that is unwelcoming to women (Carlone & Jonson, 2007; Dasgupta & Stout, 2014; Hill et al., 2010).

Dasgupta and Stout (2014) examined the barriers females face at various junctures along the STEM pipeline. The authors purposefully considered the different stages of human development (childhood to adulthood) when offering solutions to decreasing gender disparities in STEM. In respect to higher education, Dasgupta and

Stout contend, “Once women make it to college, they are bombarded with subtle (and not so subtle) messages that signal they do not belong in STEM career tracks, especially physical sciences, computer science, engineering, and mathematics” (p. 24). The study offered evidence-based solutions to changing the social environment within STEM departments, which included offering peer and mentor networking opportunities and developing a climate that provided a sense of belonging to undergraduate women in STEM. Although many persistence studies illustrate that women are underrepresented in STEM fields at the undergraduate level, there is literature that counters this notion.

Recent studies have examined women’s departure from STEM at the undergraduate, graduate, and career levels (George-Jackson, 2011; Xu, 2008). George-Jackson (2011) conducted a quantitative study using secondary longitudinal data to examine the departure of women from STEM fields at the postsecondary level. The study findings showed that a gender gap in terms of entry into STEM majors continues to persist. However, when examining STEM attrition, the researcher found that the number of men and women leaving STEM fields were comparable. George Jackson argued, “In essence, what may be perceived as a “loss” to the STEM fields in terms of student departures does not differ greatly between men and women...The findings challenge notions of women’s lower levels of participation in the STEM fields” (pp. 160, 165). Although the results of this study were convincing, the author broadened the definition of STEM fields to include health, biology, and psychology where women are highly represented. Further research is needed to fully understand why women are switching from high-profile STEM fields such as physics, computer science, and engineering to

other STEM fields. It may be the isolating culture of high-profile STEM majors (e.g., engineering) that plays a role in women's decision to leave these fields.

In a review of the literature on undergraduate and graduate women of color in STEM, Ong et al. (2011) presented the barriers women of color face in STEM fields. The researchers argue that the STEM climate and culture of STEM departments contributes to the attrition of women of color. The authors also highlight the gaps in the literature and report, "among the gaps in literature on women of color in STEM is the lack of national quantitative longitudinal studies" (p. 199). My research study, which utilized a nationally representative, longitudinal data set, has implications for higher education STEM programs for underrepresented students. Using Astin's I-E-O model as the guiding theoretical framework, the current study examined which student inputs and college environmental factors best predict the persistence of undergraduate women in STEM. The theoretical framework that framed this study is discussed in detail in the next section.

Theoretical Framework

The theoretical framework for this study is based on Alexander Astin's (1977, 1993) Input-Environment-Output (I-E-O) model. Astin's I-E-O model was originally developed as a framework for assessment and evaluation in higher education. This framework takes into account the effects of both student inputs and college environments on student outcomes as shown in Figure 2.3. In Astin's (1993) I-E-O model, inputs are defined as student characteristics at time of entry into college (e.g., demographic information, financial status, educational background). Environments refer to factors in which students are exposed to during their college experience (e.g., peer interactions,

faculty interactions, co-curricular involvement, mentoring experiences). Outputs refer to factors that are observed after exposure to the college environment (e.g., grade point average, student retention, civic engagement, and intellectual growth).

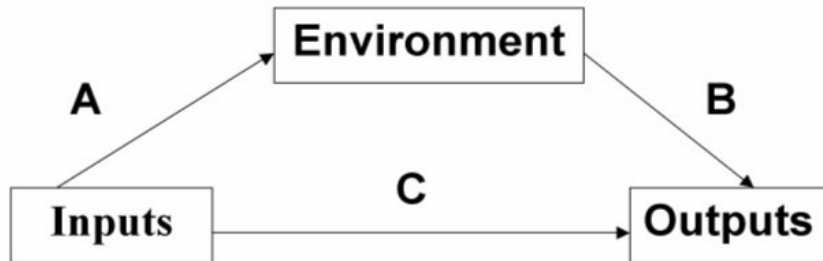


Figure 2.3. Alexander Astin’s Input-Environment-Output (I-E-O) Model. Source: *Assessment for Excellence* (p. 18), by Alexander W. Astin, 1993, Phoenix: The Oryx Press. Copyright 1993 by The Oryx Press.

Astin’s I-E-O model enables researchers to assess student outcomes, while considering pre-college and college level experiences. Astin and Sax (1998) utilized the I-E-O model in a longitudinal study to investigate undergraduate students’ participation in community service programs. Through hierarchical regression analysis, the authors controlled for the effects of student input characteristics and found that service participation impacts the cognitive development of undergraduates. Astin and Sax argue, “The I-E-O model was designed to address the basic methodological problem with all nonexperimental studies in the social science, namely the nonrandom assignment of people (inputs) to programs (environments)” (p. 252). Astin and Sax used national survey data from the Cooperative Institutional Research Program (CIRP), located at UCLA’s Higher Education Research Institute. Astin is the founding director of CIRP, and has published numerous studies using the I-E-O model as the guiding framework (Astin & Astin, 1992; Renn & Reason, 2012).

The I-E-O model has been used extensively to assess postsecondary issues such as student persistence, academic performance, and degree completion in relation to underrepresented students (Campbell and Blakey 1996; Heaney & Fisher, 2011; Kelly, 1996; Knight 1994; Whalen & Shelly, 2010). Campbell and Blakey (1996) conducted a longitudinal study to investigate the impact of early remediation on the persistence of underprepared students at a Midwestern community college. The authors applied Astin's I-E-O model to assess the effectiveness of an intervention on student persistence and academic performance. The findings showed that both student inputs (age, gender, ethnicity) and environmental variables (cumulative GPA, number of remedial courses) were predictors of persistence.

Knight (1994) used Astin's I-E-O model in an exploratory analysis that examined predictors of time to degree attainment at a Southeastern university. Knight found that both inputs (age and gender) and environmental variables were predictors of time to degree attainment. Although Campbell and Blakey and Knight effectively used Astin's I-E-O model to study persistence, these studies were limited in scope due to the use of single institution data. In the present study, I utilized multi-institutional, longitudinal data to examine persistence among undergraduate women in STEM.

Astin emphasizes the importance of using longitudinal data sets for institutional effectiveness assessments. According to Astin and Astin (1992):

The proper application of the I-E-O model requires longitudinal data, where the three components of the model are separated in time: student inputs are assessed prior to exposure to the environment, and the

characteristics of the environment are assessed prior to the assessment of outcomes. (p. 60)

Kelly (1996) used the I-E-O model to study long-term persistence at the United States Coast Guard Academy. The author investigated the influence of input variables and academic and social integration on long-term persistence. Through multivariate statistical analyses, Kelly found that academic performance and social involvement measures were significant indicators of persistence. Astin's I-E-O model will enable me to study how student inputs and college environmental factors influence the long-term persistence of undergraduate women in STEM fields. Relevant research has shown that the I-E-O model can be instrumental in studying the impact of both student inputs and environmental variables on long-term college persistence (Campbell & Blakey, 1996).

Astin and Lee (2003) conducted a cross-sectional analysis of college students to illustrate the risks associated with cross-sectional research. The study showed that much of the variation among entering college students could be attributed to pre-college factors, rather than institutional environments. Astin and Lee's study highlighted the value of considering students inputs when assessing institutional effectiveness. Astin and Antonio (2012) contend:

The basic purpose of the I-E-O design is to allow us to measure relevant input characteristics of each student and then correct or adjust for the effects of these input differences in order to get a less biased estimate of the comparative effects of different environments on outputs. (p. 21)

Astin and Astin (1992) used the I-E-O model to examine student background and college environment factors that affect student interest in STEM majors and careers. The authors

conducted a longitudinal study that analyzed survey data from approximately 27,000 freshman entering four-year colleges. Astin and Astin found that the strongest predictor of student interest in STEM was academic competency, specifically in mathematics. The authors demonstrated the importance of considering both the pre-college and college experiences of undergraduate students when researching STEM issues.

Astin's I-E-O model can be applied to a wide range of research interests such as web-based education evaluation and the academic success of underrepresented students. Thurmond, Wambach, Connors, and Frey (2002) investigated the influence of college environmental variables on the satisfaction level of nursing students enrolled in web-based education courses. Thurmond et al. conducted secondary data analysis framed by Astin's I-E-O model and found that student satisfaction was due to aspects of the web-based environment.

Whalen and Shelly (2010) used Astin's I-E-O model to compare the academic success of underrepresented and traditional students in STEM majors. Whalen and Shelly found that underrepresented groups were less likely to persist in STEM majors than traditional students. Although the findings were compelling, the study was limited to a single research institution. Whalen and Shelly argue "whether results would be substantially different in institutions of higher education with more diverse student bodies is not known, but the lower success achieved by underrepresented STEM students is an effect that we expect would persist at many other institutions" (p. 55). In the current study, Astin's I-E-O framework was applied to a nationally representative, longitudinal data set to investigate the effects of pre-college characteristics and experiences and college environmental factors (e.g., academic and social involvement and institutional

characteristics) on the persistence of undergraduate women in STEM over a six-year period as shown in Figure 2.4.

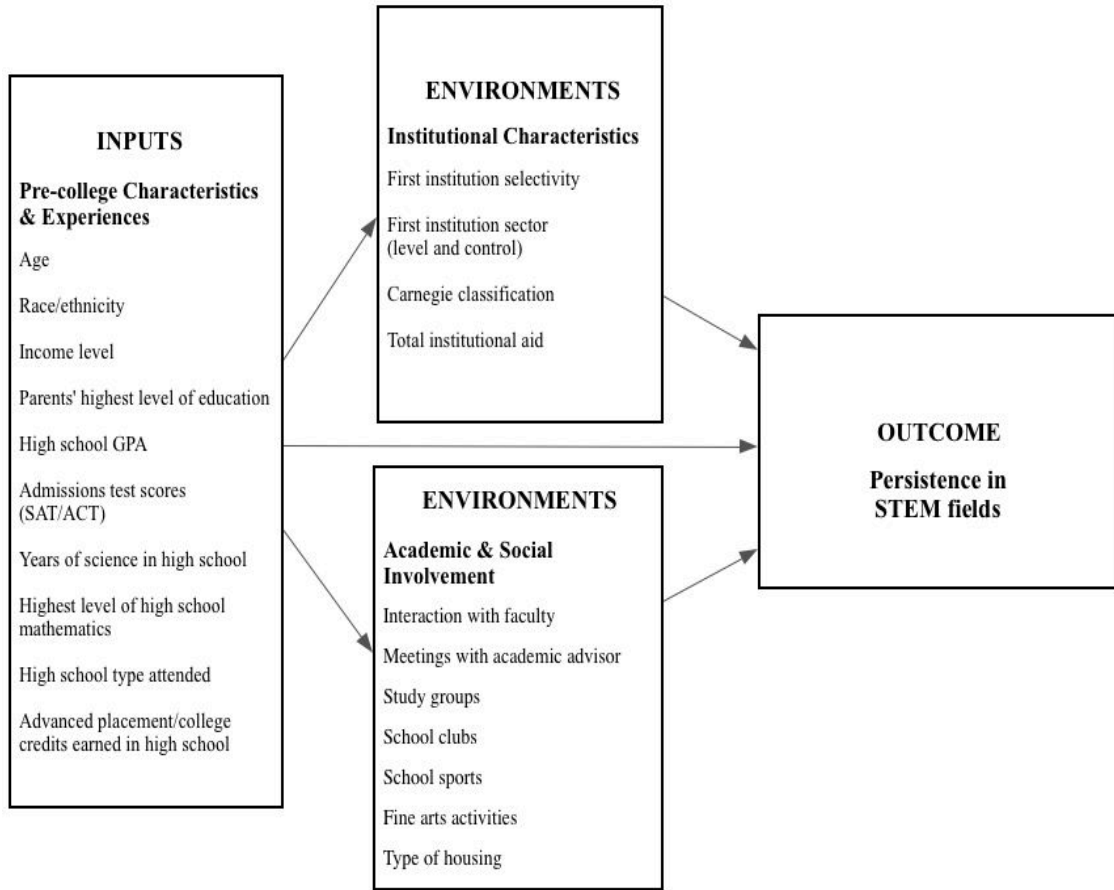


Figure 2.4. Theoretical framework for persistence in STEM fields using Astin’s I-E-O model.

For the present study, pre-college characteristics and experiences represented the student inputs (I) (e.g., age, race/ethnicity, high school grade point average), academic and social involvement and institutional characteristics represented the college environments (E) (e.g., Carnegie classification, study groups, school clubs), and persistence in STEM fields signified the outcome (O). This research study has potential

policy implications for initiatives to improve the persistence and postsecondary success of undergraduate women in STEM fields.

Summary

In this chapter, a review of the literature on STEM persistence at the postsecondary level was presented. In particular, research studies that offered insight into the factors that influence undergraduate women's persistence in STEM were discussed. After reviewing the literature, it is evident that marginalized groups exhibit a high interest in majoring in STEM. However, despite this high interest, critical pre-college and college level factors contribute to the attrition of underrepresented groups in STEM fields.

The pre-college level characteristics that influence STEM persistence include student demographics and prior academic preparation and achievement factors. Factors such as race/ethnicity, high school GPA, college admissions test scores, rigorous course taking in high school, and parental education level have all been shown to influence postsecondary STEM persistence. College level factors relevant to STEM degree attainment include academic and social involvement in college such as faculty and peer interactions, female role models, participation in school clubs, and campus residence. The relevant literature clearly shows that the isolating and "chilly" atmosphere of many postsecondary STEM fields contributes to undergraduate women's decision to turn away from STEM.

In order to further understand the student inputs and college environmental factors associated with STEM persistence, this study utilized Astin's I-E-O model. Relevant studies have used Astin's I-E-O model to explore the STEM attrition problem among

underrepresented students (Campbell & Blakey 1996; Heaney & Fisher, 2011; Whalen & Shelly, 2010). In addition, relevant studies demonstrate that Astin's I-E-O framework is a useful tool for exploring long-term college persistence. For the present study, Astin's I-E-O framework was utilized to explore which student inputs and college environmental factors best predict the persistence of undergraduate women in STEM over six years. The next chapter summarizes the methods and data analysis performed in this study.

CHAPTER 3

METHODOLOGY

This chapter provides an overview of the methods and data analysis procedures used in this study. First, a description of the data source, the Beginning Postsecondary Students Longitudinal Study (BPS:04/09), and rationale for choosing this particular dataset are addressed. The data collection methods, characterization of the target population for BPS:04/09, and a description of the selected subsample are then presented. The next section summarizes the preliminary analysis and data preparation needed to conduct the main data analysis. Then a short description of each variable used in this study is provided. The final section includes an in-depth discussion of the data analysis procedures and the potential limitations of this study.

Data Source

The data source for this study was the Beginning Postsecondary Students Longitudinal Study (BPS:04/09), sponsored by the National Center for Education Statistics (NCES) of the U.S. Department of Education. The Beginning Postsecondary Students Longitudinal Study surveys a nationally representative sample of students who are enrolled in postsecondary education for the first time (i.e., first-time beginners, or FTBs). BPS collects data that “tracks students’ paths through postsecondary education and helps answer questions of policy interest, such as why students leave school, how financial aid influences persistence and completion, and what percentages of students complete various degree programs” (NCES, 2014, para. 1).

BPS:04/09 is the third and latest data set released after the first two BPS cohorts,

BPS:90/94 and BPS:96/01. The BPS:04/09 longitudinal study provides relevant data on factors that influence postsecondary student persistence and degree completion within a six-year period. For the present study, the restricted-use data files for the base year (2003-2004) and follow-up data collections (2005-2006 and 2008-2009) were utilized to examine factors that relate to the persistence of female undergraduates in STEM fields. BPS:04/09 was selected as the secondary data source for this study due to the longitudinal nature of the data set and the inclusion of traditional and nontraditional students during the survey process. The wide range of students and institutions included in BPS:04/09 enabled me to address research questions that have far-reaching policy implications.

The BPS:04/09 study was conducted in three waves, including a base year survey (2003-2004) and two follow-up surveys (2006 and 2009). The BPS:04/09 base year sample was a subsample selected from the National Postsecondary Student Aid Study (NPSAS:04). NPSAS provides pertinent information about how postsecondary students and their families pay for higher education. NPSAS:04 utilized a complex two-stage sampling design. Eligible institutions were selected during the first stage and eligible students were selected within the institution sample during the second stage. The institution sample for NPSAS:04 was constructed using the Integrated Postsecondary Education Data System (IPEDS). Eligible postsecondary institutions consisted of any institution in the United States or Puerto Rico permitted to distribute Title IV federal student aid (Wine, Janson, Wheelless, & Hunt-White, 2011).

Multiple sources of data were collected in order to construct the BPS:04 study cohort from within the selected institutions. The types of data included were the

NPSAS:04 interview data, institutional records collected through computer-assisted data entry (CADE), and Free Application for Federal Student Aid (FAFSA) data from the U.S. Department of Education's Central Processing System (CPS). The BPS:04/09 study respondents were surveyed three times throughout the study (NPSAS:04, BPS:04/06, BPS:04/09). A single web-based instrument was administered in the following three ways: self-administered interviews, computer-assisted telephone interviews (CATI), and computer-assisted personal interviews (CAPI) (Wine et al., 2011). The first follow-up (BPS:04/06) and second follow-up (BPS:04/09) interview questions were comparable, which contributed to the longitudinal nature of the study. Survey questions were separated into the following four sections: enrollment history, enrollment characteristics, employment, and background. In addition to survey data, postsecondary transcripts were also collected for the BPS04/09 study respondents, which were not incorporated into the current study.

Study Population

The BPS:04/09 target population included first-time beginning students who were enrolled in eligible postsecondary institutions during the 2003-2004 academic year. The base year student sample (BPS:04) consisted of a subset of students who participated in the NPSAS:04 study during the 2003-2004 academic year. Eligible students participated in follow-up interviews during their third year (2005-2006) and sixth year (2008-2009) after initial entry into a postsecondary institution. NPSAS:04 consisted of an eligible sample of 101,010 postsecondary students from 1,630 institutions. The subset of NPSAS:04 respondents that made up the final BPS:04/09 respondent sample included approximately 16,680 eligible students from 1,360 institutions (82% response rate) (Wine

et al., 2011).

BPS:04/09 study respondents were “defined as any sample member who was determined to be eligible for the study, was still alive at the time of the BPS:04/09 data collection, and had the requisite valid data from any source to allow construction of his or her enrollment history” (Wine et al., 2011, p. iii). Postsecondary students who qualified for the BPS:04/09 study included those who were enrolled in either an academic program, a vocational program, or one course that counted towards a degree and were not simultaneously enrolled in a high school completion program.

Subsample

The purpose of the present study was to examine the student inputs and college environmental factors that predict the persistence of undergraduate women in STEM fields. Therefore, the subsample was restricted to postsecondary female students enrolled in a beginning bachelor’s degree program in 2003-2004. Since the focus of this study was persistence, the subsample included female bachelor’s degree students who participated in all three waves of the BPS:04/09 study (NSPAS:04, BPS:04/06, and BPS:04/09). More specifically, the subsample was comprised of female students (under 24 years of age) who were enrolled in either a STEM or non-STEM bachelor’s degree program. The sample was restricted by age due to the nature of the variables used in this study. Many of the variables chosen for this investigation only applied to respondents who were under the age of twenty-four.

The analysis weight used in this study, referred to as the longitudinal or panel weight (WTB000), applies to students who were study respondents in each wave of BPS:04/09 (NPSAS:04, BPS04/06, and BPS:04/09). The longitudinal weight, WTB000,

was chosen for this study as a means of studying persistence over a six-year time span. Due to the complex nature of this dataset, the use of the panel weight “also adjusted for multiplicity at the institution and student levels, unknown student eligibility, nonresponse, and poststratification” (Cominole, Wheelless, Dudley, Franklin, & Wine, 2007, p. 67). In order to preserve the sample size, normalized weights were used and calculated by dividing the raw panel weight (WTB000) by its mean (Hahs-Vaughn, 2005). The subsample for this study included a weighted sample size of 3,155. The subsample was further divided into female bachelor’s degree students who declared either a STEM major or non-STEM major in 2003-2004. The weighted total of female non-STEM majors included 2,714 respondents and the weighted total of female STEM majors included 441 respondents. Female STEM majors were further divided into STEM persisters and STEM non-persisters. A visual representation depicting the weighted subsample breakdown for each research question is shown below in Figure 3.1.

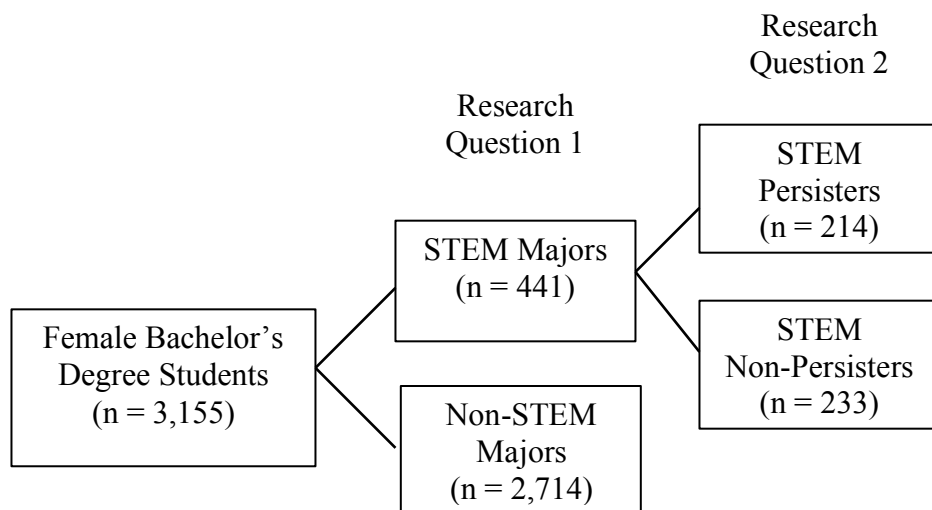


Figure 3.1. Weighted subsample breakdown for central research questions.

Variables in the Analysis

This section characterizes the independent and dependent variables used in this study. The variables are separated into three sections based on Astin's I-E-O model. The first section characterizes the independent variables that are classified as inputs (I). Student inputs included the characteristics of the student subsample at time of entry into college (2003-2004) (e.g., student demographics and prior academic preparation). The second section describes the independent variables that were categorized as the environments (E). College environments included factors in which students were exposed to during their college experience (e.g., institutional characteristics and academic and social involvement). The third section characterizes the dependent variable, which was classified as the output (O). Student outputs refer to factors that are observed after exposure to particular students inputs and college environments (e.g., persistence, grade point average) (Astin, 1993). Persistence in STEM was the only student output examined in this study.

Inputs (I)

The student input variables represented the pre-college characteristics and experiences of undergraduate women who entered a postsecondary institution in 2003-2004. Student inputs were separated into two categories, student demographics and prior academic preparation and achievement. The student demographics variables included age, race/ethnicity, income level, and parents' education level. Some of the pre-college academic preparation and achievement variables included college admissions test scores, high school GPA, and high school course taking patterns. The description of each student input variable is presented below.

Student Demographics

Age. Age (AGE) was defined as student's age first year enrolled as of December 31, 2003. Age was constructed as a categorical variable for descriptive statistics and divided into the following two categories: 18 years old or younger and 19 to 23 years of age. For logistic regression analyses, the age variable was constructed as a continuous variable.

Race/ethnicity. Race/ethnicity (RACE) included students who reported one of the following categories: White, Black or African American, Hispanic or Latino, Asian, and Other (included American Indian or Alaska Native, Native Hawaiian/other Pacific Islander, other, more than one race).

TRIO program eligibility criteria. TRIO program eligibility was based on a combination of the parents' educational level and family income (TRIO) of the respondents during the 2003-2004 academic year. The variable was divided into the following four categories: low income and first generation, low income and not first generation, first generation and not low income, and not low income and not first generation (low income: \$25,000 or below and first generation: neither parent has a bachelor's degree or higher).

Income Level. Total income (INCGRP2) for parents of dependent students or independent students in 2002 was derived from either financial aid application records, self-reported, or stochastic imputation. The income level was separated into the following four categories for descriptive statistics: low, low middle, high middle, and high. For logistic regression analyses, total income (CINCOME) was constructed as a continuous variable.

Highest level of father's education. Father's educational level (PDADED) of the respondents during the 2003-2004 academic year was constructed as a categorical variable and divided into the following three recoded categories: high school or less, some college, and bachelor's degree or higher.

Highest level of mother's education. Mother's educational level (PMOMED) of the respondents during the 2003-2004 academic year was constructed as a categorical variable and divided into the following three recoded categories: high school or less, some college, and bachelor's degree or higher.

Prior Academic Preparation and Achievement

High School Grade Point Average (GPA). High school grade point average (HCGPAREP) was derived from student's self-reported GPA on a standardized test questionnaire (College Board/ACT) and represents a student input. High school GPA is a categorical variable and was recoded into the following categories: Less than GPA 2.5 (D- to B-), GPA 2.5-2.9 (B- to B), GPA 3.0-3.4 (B to A), GPA 3.5-4 (A- to A). For the logistic regression analyses, the high school GPA variable was constructed as a continuous variable.

Highest level of high school mathematics. Highest level of high school mathematics (HCMATH) was derived from College Board, ACT, or student interviews for students under 24 years of age. The following mathematics courses were compared and examined as a pre-college characteristic: Algebra 2, Trigonometry/Algebra 2, Pre-calculus, Calculus, and None of these.

Years of science in high school. The number of years of science in high school (HCYSSCIE) was derived from College Board and ACT for students under 24 years of

age. The number of years of high school science were recoded into the following categories: Less than two years, two years to two and a half years, three years to three and a half years, and four or more years.

Years of mathematics in high school. The number of years of mathematics in high school (HCYSMATH) was derived from College Board and ACT for students under 24 years of age. The number of years of high school mathematics were separated into the following categories: Less than three years, three years to three and a half years, and four or more years.

High school type attended. High school type (HSTYPE) reflects the type of high school the respondent attended and was recoded into the following categories: public, private, and other. The other category includes students who attended a foreign high school or did not receive a high school diploma.

Earned AP credits in high school. Signified whether respondent (under the age of 24) received advanced placement credits while in high school (CRDAP04). Respondent replied yes or no during student interview.

Earned any college credits in high school. Signified whether respondent (under the age of 24) received any college credits while in high school (CRDHS04). Respondent replied yes or no during student interview.

Earned college credits at a college while in high school. Signified whether respondent (under the age of 24) received college credits for courses at a college/university while in high school (CRDCL04). Respondent replied yes or no during student interview.

Admissions test scores (ACT or SAT). Respondents admissions test scores (TESATDER) were constructed from ACT composite scores or SAT 1 verbal and math scores for students under 24 years of age. The admissions test scores were divided into the following ranges for the descriptive statistics: Lowest (400-840), Low middle (850-990), High middle (1000-1130), and Highest (1140-1600). For logistic regression analyses, admissions test scores were constructed as a continuous variable.

Highest postsecondary degree ever expected. Signified the highest degree that the responded ever expected to complete during the 2003-2004 academic year (HIGHLVEX) and included the following categories: bachelor's degree/post-BA or post-master certificate, master's degree, doctoral degree, and first-professional degree.

Environments (E)

The college environmental variables represented the environments in which undergraduate women were exposed to during their college experience. The environmental variables are separated into two categories, academic and social involvement and institutional characteristics. The academic and social involvement variables included interactions with faculty and peers through meetings, clubs, and extracurricular activities. The institutional characteristics variables included institutional selectivity and sector, total institutional aid, and Carnegie classification. A description of each college environmental variable is presented below.

Academic and Social Involvement

Faculty informal meeting. Students reported how often they interacted informally or socially with faculty outside of classrooms and the office in 2003-2004 (FREQ04A)

and when last enrolled as of 2006 (FREQ06A). Responses were divided into the following three categories: never, sometimes, and often.

Faculty interaction outside classroom. Students reported how often they talked with faculty about academics outside of classroom (including email) in 2003-2004 (FREQ04B) and when last enrolled as of 2006 (FREQ06B). Responses were divided into the following three categories: never, sometimes, and often.

Meet academic advisor. Students reported how often they met with academic advisor about academic matters in 2003-2004 (FREQ04C) and when last enrolled as of 2006 (FREQ06C). Responses were divided into the following three categories: never, sometimes, and often.

Study groups. Students reported how often they attended study groups outside of the classroom in 2003-2004 (FREQ04G) and when last enrolled as of 2006 (FREQ06G). Responses were separated into the following three categories: never, sometimes, and often.

Fine arts activities. Students reported how often they attended music, choir, drama, or other fine arts activities in 2003-2004 (FREQ04D) and when last enrolled as of 2006 (FREQ06D). Responses included the following three categories: never, sometimes, and often.

School clubs. Students reported how often they participated in school clubs in 2003-2004 (FREQ04E) and when last enrolled as of 2006 (FREQ06E). Responses were divided into the following three categories: never, sometimes, and often.

School sports. Students reported how often they participated in school sports (varsity, intramural, or club) in 2003-2004 (FREQ04F) and when last enrolled as of 2006

(FREQ06F). Responses were divided into the following three categories: never, sometimes, and often.

Type of housing. Respondents reported housing status during the 2003-2004 academic year (LOCALRES). The following categories were included in the study: on-campus, off campus, attended more than one institution, and living with parents.

Institutional Characteristics

Institution Selectivity. The selectivity of the first institution (2003-2004) attended was measured and developed for IPEDS using standard criteria (SELECTV2). The selectivity of the first institution was separated into the following categories: not public or private not-for-profit four-year, very selective, moderately selective, and minimally selective/open admission.

Institution Sector. The level and control of the first institution (2003-2004) (FSECTOR) were divided into the following categories: Public 4-year and Private 4-year (includes for-profit and not-for-profit 4-year).

Carnegie classification. Carnegie classification of institutions in 2003-2004 (CC2005C) included the following categories: Research & Doctoral, Master's, Baccalaureate, and Other. The other category combined the following classifications: not degree granting, associate's, and special focus and other.

Total institutional aid. Respondents reported the total amount of institutional aid received during the 2003-2004 academic year (INSTAMT). Institutional aid total equals sum of institutional grants and fellowships, institutional loans, institution-sponsored work-study, and graduate student assistantships. For descriptive statistics, the total amount of aid was divided into the following categories: \$0, \$1-2,399, \$2,400-4,999,

\$5,000-10,399, and \$10,400 or more. For logistic regression analyses, the total institutional aid variable was constructed as a continuous variable.

Output (O)

The output variable examined in this study was STEM persistence at the postsecondary level. More specifically, STEM persistence was defined as undergraduate women who entered a STEM field in 2003-2004 and either attained a bachelor's degree in a STEM field by 2009 or remained enrolled in a STEM field by 2009. The outcome variable was measured using data collected during the third wave of the BPS:04/09 study. An explanation of the output variable is presented below.

Persistence

STEM Persistence. Represents female students' enrollment or degree attainment in a STEM field through 2009 (STEMPERSISTERS). The measure included the following two categories: STEM persisters and STEM non-persisters. STEM persisters included female students who entered a STEM field in 2003-2004 and either (a) attained a bachelor's degree in a STEM field by 2009; or (b) remained enrolled in a STEM field by 2009. STEM non-persisters included entering female STEM majors who either (a) left postsecondary education by 2009; (b) changed to a non-STEM field and left postsecondary education by 2009; (c) changed to a non-STEM field and attained a degree (includes certificate, associate's degree, and bachelor's degree) in a non-STEM field by 2009; or (d) changed to a non-STEM field and remained enrolled in a non-STEM field by 2009.

Data Analysis

Descriptive and multivariate statistics were used to characterize the analytic sample and address the central research questions. The data set was first filtered to include only female students enrolled in a bachelor's degree program and under the age of 24. The sample was further separated into female students who declared a STEM major and female students who declared a non-STEM major in 2003-2004. Through the use of percentage distributions and sample sizes, female bachelor's degree students who entered STEM fields and non-STEM fields were described, based on pre-college characteristics and college environmental factors.

The first research question was modeled using inferential statistics through chi-square tests. Female bachelor's degree students who majored in STEM fields and female bachelor's degree students who majored in non-STEM fields were compared using chi-square analyses. The Pearson's chi-square test was chosen because this test can be used to uncover whether there is a significant relationship between two categorical variables (Field, 2009). Cross-tabulation tables were constructed for each independent variable. Then the Pearson's chi-square test was used to determine whether there were significant differences between female bachelor's degree students who entered STEM and non-STEM fields in 2003-2004, based on student inputs and college environmental factors. A $p\text{-level} < .05$ signified statistical significance for the weighted variables used in the chi-square analyses.

Logistic regression models were used to address the second research question. Logistic regression was the appropriate technique for this study due to the nominal and dichotomous nature of the outcome variable, persistence in STEM. For the second

research question, the focus was specifically on female bachelor's degree students who entered STEM fields. Therefore, before running the regression models, the analytic sample was filtered to include only female bachelor's degree students who declared a STEM major in 2003-2004 ($n = 447$). The subsample was further divided into STEM persisters ($n = 214$) and STEM non-persisters ($n = 233$). STEM persisters included female students who entered a STEM field in 2003-2004 and either attained a bachelor's degree in a STEM field by 2009 or remained enrolled in a STEM field by 2009. STEM non-persisters included entering female STEM majors who either left postsecondary education by 2009, changed to a non-STEM field and left postsecondary education by 2009, or attained a degree (or remained enrolled) in a non-STEM field by 2009.

After the analytic subsample was formulated, predictors were grouped into models and then tested based on Astin's I-E-O model. The independent variables were entered simultaneously into each regression model based on theory and temporal order of impact (Astin & Antonio, 2012; Inkelas, 2004; Saenz, Ngai, Hurtado, 2007). The models were added into the regression equation based on proximity to the dependent variable as recommended by Astin's I-E-O model. A total of thirty-three predictors, which included student inputs (I) and college environmental (E) variables (academic and social involvement and institutional characteristics), were entered into the logistic regression models. Through an iterative process, the thirty-three independent variables were narrowed down to include only the significant predictors of STEM persistence.

The first model contained the student input variables, which included the pre-college characteristics and experiences. As recommended by Astin and Astin (1992), the student inputs included the following variables: student demographics (e.g., race, age,

family income) and high school preparation and achievement (e.g., college admissions test scores, years of high school science). The student input variables were entered simultaneously into the logistic regression equation.

The second and third models encompassed the college environmental measures. Astin and Astin (1992) advised separating environmental variables into the following categories: within-institution variables (at time of entry and subsequent to matriculation) and between-institution measures. Between-institutions variables are measures that characterize an entire institution, while within-institution measures may differ between students within a particular institution. Astin and Antonio (2012) recommended entering the most proximate environmental variables first and the most distal environmental variables last because “by controlling first for these within-institution environmental experiences, we can determine whether the type of college contributes anything else to the student’s outcome performance” (p. 327).

The second model included the student input variables and within-institution variables (e.g., type of housing and academic and social involvement measures). The third model contained the student input variables, within-institution variables, and between-institution variables (e.g., Carnegie classification, total institutional aid, institution sector, and institution selectivity). Predictor variables were analyzed through logistic regression models. As each set of variables was added into the models, the odds ratios were reported. Odds ratios were used to examine the effects of the predictors on the likelihood that STEM persistence would occur among female bachelor’s degree students. Odds ratios greater than or less than one indicated the association of the independent variables with the dependent variable, persistence in STEM. A p-level < .05

signified statistical significance for the predictors entered into the logistic regression models.

Data Preparation and Preliminary Analysis

Before conducting statistical analyses, the BPS:04/09 population sample was first filtered to obtain the study subsample. The study subsample included female (GENDER=2) bachelor's degree students (UGDEG=3) under the age of 24 (AGEGROUP=1-3). The study subsample was further divided into two groups, STEM majors and non-STEM majors (See Chapter 1 for definitions of STEM and non-STEM fields). The STEM and non-STEM field categories were derived from the variable, MAJ04A, and coded into a new variable (MAJ04condensedNONSTEMvsSTEM). The variable, MAJ04A, was chosen because it included the respondent's major from the first year enrolled (2003-2004) with categories comparable to majors declared in 2006 and 2009. Once the subsample was constructed, the independent and dependent variables were examined and cleaned for analysis.

Before conducting descriptive and inferential statistical analyses, collinearity testing was performed to ensure validity of the predictor variables. The variance inflation factors (VIF), tolerances, and condition indices were examined to determine whether predictors were correlated. Variables were removed if the VIF values were greater than 5 or the tolerance levels were higher than 0.1 as suggested in the literature (Field, 2009). In addition to collinearity testing, several variables were recoded to ensure proper analysis. For the cross-tabulations, variables with cells that contained an expected count of less than five cases were recoded to increase the expected count. For the logistic regressions, the dependent variable, STEM persistence, was recoded into a dichotomous variable.

The independent and dependent variables were also examined for missing values. A total of three variables contained missing values that represented less than 5% of the subsample population, which included high school grade point average, first institution selectivity, and total institutional aid. For the descriptive and inferential statistics, frequencies and cross-tabulations were run with and without the missing cases. Little to no difference was detected between models that included and excluded the missing cases. Therefore, missing cases were excluded before running frequencies and cross-tabulations for the three abovementioned variables. Missing cases were also excluded from the logistic regression models. The potential limitations of this study are discussed in the next section.

Limitations

Limitations were considered when conducting this research study. Due to the use of secondary data, there were limitations in the range of variables available for studying STEM persistence. BPS:04/09 was not specifically designed to address STEM issues in their entirety. Chen and Soldner (2013) studied STEM attrition using the BPS:04/09 data set and reported:

BPS:04/09 is a general purpose survey on postsecondary education, its questions and survey elements were not tailored to include all variables relevant to research on STEM attrition. Some data identified in the literature as potentially important to STEM attrition (e.g., characteristics of STEM faculty and noncognitive factors such as motivation, interest, confidence, and beliefs) were not collected. (p. 8)

As described above, this study does not address potentially valuable student-level factors linked to STEM persistence such as self-efficacy, motivation, and academic and social involvement factors specific to STEM (e.g., STEM-related clubs, interactions with STEM faculty and peers). In addition, the institutional characteristics variables available in the BPS:04/09 data set were restricted to the first year of college (2003-2004 academic year), limiting the scope of my analysis. Since institutional characteristics variables were only available from the first year of college, information regarding the influence of transfer institutions on persistence was not addressed in this study. Lastly, the academic and social involvement variables collected in the BPS:04/09 data set were based on self-reported data, which introduced elements of bias into the study.

Although there were a limited number of variables related to STEM in the BPS:04/09 study, the data set did include key student-level and institutional-level factors associated with postsecondary STEM persistence. The BPS:04/09 study, which followed a nationally representative sample of postsecondary students over six years, enabled me to explore critical predictors of STEM persistence for undergraduate women.

CHAPTER 4

RESULTS

This chapter examines pre-college characteristics and college environmental factors that predict persistence in STEM among female bachelor's degree students. In the first section, the study population is characterized using descriptive and inferential statistics, addressing the first research question. Findings revealed significant differences between undergraduate women majoring in STEM and non-STEM fields, including student demographics, prior academic achievement, high school course-taking patterns, and student involvement in college such as participation in study groups and school clubs. The next section addresses the second research question, which is guided by Astin's I-E-O model. Logistic regression models are analyzed to examine the relationships between student inputs (I) and college environments (E) and the output (O) variable, persistence in STEM. The regression models demonstrated several key predictors of STEM persistence such as age of enrollment, race/ethnicity, earned college credits in high school, and involvement in study groups.

Recall the research questions that guided this study are as follows:

Research Question 1: Are there significant differences between female bachelor's degree students who enter STEM fields and those who enter non-STEM fields, based on pre-college characteristics and experiences, academic and social involvement factors, and institutional characteristics?

Research Question 2: Which pre-college characteristics and experiences, academic and social involvement factors, and institutional characteristics best predict the

persistence of female bachelor's degree students in STEM fields?

Characteristics of Undergraduate Women in STEM and Non-STEM Fields

Descriptive and inferential statistics were used to characterize and compare undergraduate women who entered STEM and non-STEM fields during the 2003-2004 academic year. Percentage distributions and sample sizes of the measures used in this study were separated into the following four categories: student demographics, prior academic preparation and achievement, academic and social involvement, and institutional characteristics. Cross-tabulations and Pearson's chi-square tests were conducted for each independent variable to determine whether there were significant differences between female students who majored in STEM and non-STEM fields. Each of the pre-college student input variables (student demographic variables and prior academic preparation and achievement) and college environmental variables (academic and social involvement and institutional characteristics) were analyzed as shown in Tables 4.1 through 4.5.

Student Demographics

Student demographics of the analytic sample were examined through weighted frequency distributions. Then characteristics of female bachelor's degree students who entered STEM and non-STEM fields were compared using chi-square analyses as shown below in Table 4.1. Prior research has shown that factors such as age, financial support from parents, race/ethnicity, and parents' education level influence entry into STEM fields at the postsecondary level (Chen, 2009; Gayles & Ampaw, 2014; Wang, 2013). In the current study, the majority of female STEM and non-STEM majors were 18 years old or younger, 68.5% and 67.3% and White, 58.0% and 69.8%, respectively.

Table 4.1

Weighted Distribution of 2003-2004 Female Bachelor's Degree Students who Majored in STEM and Non-STEM fields, Based on Student Demographics.

Student Demographics	Non-STEM Majors		STEM Majors		X ² (df)
	<i>n</i>	%	<i>n</i>	%	
Age					0.23 (1)
18 or younger	1,828	67.3	302	68.5	
19 to 23	887	32.7	139	31.5	
Total	2,715	100	441	100	
Race/Ethnicity					
White	1,896	69.8	256	58.0	24.28 (1)**
Black or African American	282	10.4	70	16.0	11.63 (1)**
Hispanic or Latino	268	9.9	60	13.6	5.67 (1)*
Asian	122	4.5	38	8.7	13.48 (1)**
Other	147	5.4	16	3.7	2.44 (1)
Total	2,715	100	440	100	
TRIO program eligibility criteria					7.80 (3)
Low income & first generation	344	12.7	49	11.2	
Low income & not first generation	128	4.7	18	4.0	
First generation & not low income	947	34.9	132	29.9	
Not low income & not first generation	1,295	47.7	242	54.9	
Total	2,714	100	441	100	
Income level					3.02 (3)
Low	581	21.4	79	17.9	
Low middle	705	26.0	118	26.7	
High middle	659	24.3	109	24.7	
High	769	28.3	135	30.7	
Total	2,714	100	441	100	
Father's education level					16.93 (2)**
High school or less	1,033	38.1	123	28.0	
Some college	599	22.1	108	24.5	
Bachelor's degree or higher	1,083	39.9	209	47.5	
Total	2,715	100	440	100	
Mother's education level					8.00 (2)*
High school or less	919	33.8	146	33.1	
Some college	777	28.6	102	23.1	
Bachelor's degree or higher	1,019	37.5	193	43.8	
Total	2,715	100	441	100	

Note: Weighted using the NCES-provided panel weight (WTB000).

* $p < .05$, ** $p < .01$

A noteworthy pattern emerged in the student demographics data. Minority female students were more highly represented in STEM fields than non-STEM fields. The weighted distribution of minority female STEM majors was 16.0% African American, 13.6% Hispanic, and 8.7% Asian. Whereas, 10.4% of female non-STEM majors were African American, 9.9% Hispanic, and 4.5% Asian. These key findings are important to the field and may be due to cultural differences in gender-STEM stereotypes.

Relevant research studies have shown that African American female undergraduates are more likely to show interest in entering STEM fields than White female undergraduates (Hanson, 2009; O'Brien, Blodorn, Adams, Garcia, & Hammer, 2015; Riegle-Crumb & King, 2010). O'Brien et al. (2015) found that African American women in college exhibited weaker implicit associations between STEM and gender and were more likely to enter STEM fields than White women. In terms of motivation, Hanson (2009) found that family and community influences play a major role in African American women's interest and success in postsecondary STEM fields. Recent research studies have also shown that Hispanic students are just as likely to major in STEM fields as White students and Asian/Pacific Islander students are more likely to major in STEM than White students (Anderson & Kim, 2006; Chen, 2009; National Science Foundation, 2013). The findings from the present study support and contribute to the current STEM literature.

In terms of race/ethnicity, the chi-square analyses showed significant differences between female bachelor's degree students who majored in STEM and non-STEM fields. A significantly lower percentage of White female students majored in STEM fields compared to non-STEM fields, $\chi^2(1, N = 3,155) = 24.28, p < .01$. Whereas, a

significantly higher proportion of African American females majored in STEM compared to non-STEM, $\chi^2 (1, N = 3,155) = 11.63, p < .01$. In addition, a significantly higher percentage of Hispanic females enrolled in STEM majors compared to non-STEM majors, $\chi^2 (1, N = 3,155) = 5.67, p < .05$. Lastly, a significantly higher proportion of Asian female students entered STEM fields compared to non-STEM fields, $\chi^2 (1, N = 3,155) = 13.48, p < .01$.

Ong et al. (2011) conducted a review of the literature on the postsecondary experiences of women of color in STEM and reported, "...despite great interest by women of color to pursue STEM baccalaureate degrees, this group nonetheless remains underrepresented in degree completion (p.181). Ong et al. challenge the belief that women of color are "just not interested" in STEM and attribute non-persistence to the structural and social elements of the undergraduate experience. When examining the experiences of women in STEM, it is important to also consider the cultural differences between groups of women (Hanson, 2006). The significant racial/ethnic differences in STEM entry found in this study also challenges the myth that women of color are less interested in STEM and may have potential policy implications.

Relevant literature has shown that parental education level influences entry into STEM among undergraduate women (Chen, 2009; Gayles & Ampaw, 2014). When comparing father's education level, a higher percentage of female STEM majors (47.5%) reported the bachelor's degree or higher category than non-STEM majors (39.9%). Whereas, the high school or less group was higher among female non-STEM majors (38.1%) compared to STEM majors (28%). Chi-square tests revealed a significant association between type of major and father's education level, $\chi^2 (2, N = 3,155) = 16.93,$

$p < .01$.

When comparing mother's education level, a higher percentage of female STEM majors (43.8%) reported the bachelor's degree or higher category than non-STEM majors (37.5%), although to a lesser extent than father's education level. Chi-square tests showed a significant association between type of major and mother's education level, $\chi^2(2, N = 3,155) = 8.00, p < .05$. Lastly, there were no significant differences between income level/first-generation status and type of major. In the next section, differences in prior academic preparation and achievement between undergraduate women who majored in STEM and non-STEM fields are analyzed.

Prior Academic Preparation and Achievement

Relevant research studies have shown that pre-college academic preparation and achievement factors such as high school grade point average, college admissions test scores, math and science proficiency, and advanced course-taking in high school influence entry into postsecondary STEM fields (Astin & Astin, 1992; Astin & Sax, 1996; Seymour & Hewitt, 1997; Wang, 2013; Xie & Shauman, 2003). Weighted frequency distributions and chi-square analyses revealed significant differences between female STEM and non-STEM majors for nearly all pre-college academic preparation and achievement variables as shown in Table 4.2.

High school grade point averages, college admissions test scores, and high school mathematics and science course-taking patterns were significantly associated with type of major. The sample size for the high school grade point average variable ($N = 3048$) was lower due to the exclusion of students who did not receive a high school diploma. Nonetheless, there were significant differences in high school grade point averages.

Table 4.2

Weighted Distribution of 2003-2004 Female Bachelor's Degree Students who Majored in STEM and Non-STEM fields, Based on Prior Academic Preparation and Achievement.

Prior Academic Preparation and Achievement	Non-STEM Majors		STEM Majors		X ² (df)
	n	%	n	%	
High school GPA					56.35 (3)**
Less than 2.5	125	4.6	28	6.3	
2.5-2.9	239	8.8	15	3.4	
3.0-3.4	941	34.7	96	21.8	
3.5-4.0	1,316	48.5	288	65.4	
Total	2,621	97	427	97	
Highest level of high school math					141.99 (4)**
Algebra 2	597	22.0	37	8.4	
Trigonometry/Algebra 2	608	22.4	68	15.4	
Pre-Calculus	790	29.1	125	28.4	
Calculus	566	20.9	199	45.2	
None of these	153	5.6	12	2.7	
Total	2,714	100	441	100	
Years of high school science					53.92 (3)**
Less than two years	83	3.1	8	1.9	
Two to two and a half	248	9.1	30	6.8	
Three to three and a half	1,141	42.0	118	26.9	
Four or more years	1,242	45.8	284	64.5	
Total	2,714	100	440	100	
Type of high school					5.02 (2)
Public	2,260	83.3	385	87.4	
Private	360	13.2	42	9.5	
Other	95	3.5	14	3.1	
Total	2,715	100	441	100	
Advanced placement credits accepted					29.37 (1)**
No	1,999	73.7	269	61.1	
Yes	715	26.3	171	38.9	
Total	2,714	100	440	100	
Earned college credits in high school					1.94 (1)
No	1,971	72.6	306	69.4	
Yes	744	27.4	135	30.6	
Total	2,715	100	441	100	
Admissions test scores (ACT or SAT)					72.61 (3)**
Lowest (400-840)	467	17.2	75	17.1	
Low middle (850-990)	755	27.8	60	13.7	
High middle (1000-1130)	768	28.3	109	24.7	
Highest (1140-1600)	724	26.7	196	44.5	
Total	2,714	100	440	100	
Highest degree ever expected					134.17 (3)**
Bachelor's degree/Postsecondary certificate	655	24.1	65	14.7	
Master's degree	1,343	49.5	140	31.7	
Doctoral degree	489	18.0	154	34.8	
First-professional degree	226	8.3	82	18.7	
Total	2,713	100	441	100	

Note: Weighted using the NCES-provided panel weight (WTB000).

* $p < .05$, ** $p < .01$

When comparing high school grade point averages, female STEM majors (64.5%) were significantly more likely to have earned a high school GPA of 3.5 to 4.0 than non-STEM majors (45.8%), $\chi^2(3, N = 3,048) = 56.35, p < .01$. When examining college admissions test scores, a higher percentage of female STEM majors (44.5%) earned high college admissions test scores (1140-1600) than non-STEM majors (26.7%), $\chi^2(3, N = 3,155) = 72.61, p < .01$. Lastly, findings showed that a significantly higher proportion of female STEM majors (34.8%) had expectations of earning a doctoral degree than non-STEM majors (18%), $\chi^2(3, N = 3,155) = 134.17, p < .01$.

Prior research has shown that mathematics and science exposure and performance in high school is related to postsecondary achievement, and more specifically related to success in college STEM fields (Adelman, 2006; Anderson & Kim, 2006; Astin & Astin, 1992; Gayles & Ampaw, 2014). In terms of high school course-taking patterns, the data showed that female STEM majors completed a more rigorous high school course load than non-STEM majors. A higher proportion of female STEM majors (45.2%) took calculus as their highest level of high school mathematics than non-STEM majors (20.9%). Whereas, a higher percentage of female non-STEM majors (22.0%) reported algebra 2 as their highest mathematics course in high school compared to STEM majors (8.4%). Chi-square analysis revealed a significant association between type of major and highest level of high school mathematics, $\chi^2(4, N = 3,155) = 141.99, p < .01$.

Chi-square tests also demonstrated that undergraduate women in STEM (64.5%) were significantly more likely to have completed four or more years of high school science than non-STEM majors (45.8%), $\chi^2(3, N = 3,155) = 53.92, p < .01$. And a higher percentage of female STEM majors (38.9%) earned advanced placement credits in

high school than non-STEM majors (26.3%), $\chi^2 (1, N = 3,155) = 29.37, p < .01$. The differences in college entrance exam scores, high school grade point averages, and rigorous course-taking patterns between female STEM and non-STEM majors, as shown in Table 4.2, contributes to the current STEM literature (Chen, 2009; Crisp, Nora, & Taggart, 2009; Maltese & Tai, 2011). The pre-college preparation findings demonstrated that women who entered STEM fields were more academically prepared and had higher expectations of earning an advanced postsecondary degree than women who entered non-STEM fields.

Academic and Social Involvement

Astin's (1993) theory of involvement suggests that the amount of energy undergraduate students' invest in their college experience, both academically and socially, relates to the likelihood of persistence. For the present study, the academic and social involvement variables were examined at two time points (2003-2004 and 2006) to assess student involvement over time. The weighted frequencies and chi-square analyses of the academic and social involvement variables are shown below in Tables 4.3 through 4.4.

During the 2003-2004 academic year, chi-square analyses revealed four significant differences between female STEM and non-STEM majors, including one academic and three social involvement variables. In terms of academic involvement, there was no association between type of major and interactions with faculty. However, a significantly higher percentage of STEM majors (24.1%) interacted with peers through study groups than non-STEM majors (15.1%), $\chi^2 (2, N = 3,155) = 26.15, p < .01$.

Table 4.3

Weighted Distribution of 2003-2004 Female Bachelor's Degree Students who Majored in STEM and Non-STEM fields, Based on Academic and Social Involvement in 2003-2004.

Academic and Social Involvement	Non-STEM Majors		STEM Majors		X ² (df)
	n	%	n	%	
Academic Involvement (2003-2004)					
Faculty informal meeting					
Never	1,427	52.6	219	49.7	1.88 (2)
Sometimes	1,048	38.6	185	42.1	
Often	239	8.8	36	8.2	
Total	2,714	100	440	100	
Faculty talk outside class					
Never	342	12.6	60	13.5	0.46 (2)
Sometimes	1,837	67.7	298	67.7	
Often	535	19.7	83	18.8	
Total	2,714	100	441	100	
Meet academic advisor					
Never	382	14.1	58	13.2	2.76 (2)
Sometimes	1,650	60.8	286	64.8	
Often	682	25.1	97	21.9	
Total	2,714	100	441	100	
Study groups					
Never	738	27.2	89	20.2	26.15 (2)**
Sometimes	1,567	57.7	245	55.6	
Often	409	15.1	106	24.1	
Total	2,714	100	440	100	
Social Involvement (2003-2004)					
Fine arts activities					
Never	1,182	43.6	178	40.5	6.35 (2)*
Sometimes	1,090	40.2	204	46.2	
Often	442	16.3	59	13.3	
Total	2,714	100	441	100	
School clubs					
Never	1,395	51.4	196	44.5	7.41 (2)*
Sometimes	854	31.5	156	35.4	
Often	466	17.2	89	20.1	
Total	2,715	100	441	100	
School sports					
Never	1,881	69.3	275	62.5	9.56 (2)**
Sometimes	445	16.4	80	18.2	
Often	389	14.3	85	19.4	
Total	2,715	100	440	100	
Housing (2003-2004)					
On campus	1,732	63.8	283	64.2	4.78 (2)
Off campus	277	10.2	58	13.1	
Living with parents	568	20.9	81	18.4	
Attended more than one institution	138	5.1	19	4.3	
Total	2,715	100	441	100	

Note: Weighted using the NCES-provided panel weight (WTB000).

* $p < .05$, ** $p < .01$

In terms of social involvement, a significantly higher proportion of female non-STEM majors (51.4%) reported never engaging in school clubs compared to STEM majors (44.5%), $\chi^2(2, N = 3,155) = 7.41, p < .05$. In addition, a significantly higher proportion of female STEM majors (46.2%) participated in fine arts activities compared to STEM majors (40.2%), $\chi^2(2, N = 3,155) = 6.35, p < .05$. Lastly, a significantly higher percentage of female STEM majors (19.4%) participated in school sports than non-STEM majors (14.3%), $\chi^2(2, N = 3,155) = 9.56, p < .01$. These findings showed that female STEM majors engaged with peers more than non-STEM majors, both academically and socially, during their freshman year of college.

The percentage distributions and chi-square analyses for academic and social involvement reported in 2006 are shown below in Table 4.4. The variables included the students' reported academic and social involvement from when they were last enrolled at an institution. The sample sizes for the academic and social involvement variables in 2006 were lower ($N = 3047$) than the sample sizes in 2003-2004 ($N = 3155$) due to the exclusion of students who were last enrolled in school prior to July 2004.

Chi-square analyses revealed two significant differences in academic and social involvement between female STEM and non-STEM majors in 2006. In terms of academic involvement, again there was no association between type of major and interactions with faculty. However, a significantly higher percentage of STEM majors (25.6%) interacted with peers through study groups than non-STEM majors (16.1%), $\chi^2(2, N = 3,047) = 21.74, p < .01$. In terms of social involvement, a significantly higher proportion of female non-STEM majors (39.7%) reported never engaging in school clubs compared to STEM majors (29.8%), $\chi^2(2, N = 3,047) = 22.20, p < .01$.

Table 4.4

Weighted Distribution of 2003-2004 Female Bachelor's Degree Students who Majored in STEM and Non-STEM fields, Based on Academic and Social Involvement in 2006.

Academic and Social Involvement	Non-STEM Majors		STEM Majors		X ² (df)
	n	%	n	%	
Academic Involvement (2006)					
Faculty informal meeting					0.25 (2)
Never	1,243	45.8	201	45.7	
Sometimes	1,054	38.8	180	41.0	
Often	316	11.6	53	12.0	
Total	2,613	96	434	99	
Faculty talk outside class					4.92 (2)
Never	217	8.0	25	5.7	
Sometimes	1,370	50.5	248	56.3	
Often	1,025	37.8	162	36.7	
Total	2,612	96	435	99	
Meet academic advisor					4.12 (2)
Never	253	9.3	42	9.6	
Sometimes	1,608	59.2	288	65.2	
Often	751	27.7	105	23.8	
Total	2,612	96	435	99	
Study groups					21.74 (2)**
Never	619	22.8	86	19.5	
Sometimes	1,555	57.3	236	53.6	
Often	438	16.1	113	25.6	
Total	2,612	96	435	99	
Social Involvement (2006)					
Fine arts activities					3.78 (2)
Never	1,105	40.7	171	38.8	
Sometimes	1,115	41.1	207	46.9	
Often	392	14.5	57	13.0	
Total	2,612	96	435	99	
School clubs					22.20 (2)**
Never	1,077	39.7	131	29.8	
Sometimes	880	32.4	159	36.1	
Often	655	24.1	145	32.8	
Total	2,612	96	435	99	
School sports					0.91 (2)
Never	1,706	62.9	274	62.2	
Sometimes	535	19.7	96	21.8	
Often	371	13.7	65	14.7	
Total	2,612	96	435	99	

Note: Weighted using the NCES-provided panel weight (WTB000).

* $p < .05$, ** $p < .01$

By assessing academic and social involvement levels in 2003-2004 and 2006, I was able to examine whether differences between female STEM and non-STEM majors changed over time. Findings revealed differences between female STEM and non-STEM majors decreased over time when examining academic and social involvement factors.

Institutional Characteristics

The weighted frequencies and chi-square analyses of the institutional characteristics are shown below in Table 4.5. When comparing female STEM and non-STEM majors, significant differences were observed for three of the four institutional characteristics variables. In 2003-2004, the percentage distributions showed that a higher proportion of female STEM majors (34.9%) attended very selective institutions compared to non-STEM majors (21.4%). Whereas, 59.6% of non-STEM majors attended moderately selective institutions compared to 47.7% of STEM majors. The sample size for the first institution selectivity variable was lower ($N = 3,137$) due to the exclusion of missing cases. Chi-square analyses showed a significant association between type of major and first institution selectivity, $\chi^2(3, N = 3,137) = 40.14, p < .01$. There is conflicting literature on whether the selectivity of an institution promotes or hinders the persistence of underrepresented students in STEM (Chang, Sharkness, Newman, & Hurtado, 2010; Eagan, Hurtado, & Chang, 2010).

When examining Carnegie classification the percentage distributions showed that a higher percentage of female STEM majors (48.9%) enrolled in research and doctoral institutions compared to non-STEM majors (40.0%). Whereas, a higher percentage of female non-STEM majors (42.2%) enrolled in master's colleges and universities compared to STEM majors (29.6%).

Table 4.5

Weighted Distribution of 2003-2004 Female Bachelor's Degree Students who Majored in STEM and non-STEM fields, Based on Institutional Characteristics.

Institutional Characteristics	Non-STEM Majors		STEM Majors		X ² (df)
	<i>n</i>	%	<i>n</i>	%	
First Institution Selectivity					40.14 (3)**
Very selective	581	21.4	154	34.9	
Moderately selective	1,619	59.6	210	47.7	
Minimally selective/open admission	418	15.4	60	13.6	
Not public or private nfp 4-year	82	3.0	13	2.9	
Total	2,700	99	437	99	
First institution sector (level & control)					0.30 (1)
Public 4-year	1,801	66.3	286	65.0	
Private 4-year	914	33.7	154	35.0	
Total	2,715	100	440	100	
Carnegie: Basic classification					28.33 (3)**
Research & Doctoral	1,085	40.0	215	48.9	
Master's	1,145	42.2	130	29.6	
Baccalaureate	364	13.4	79	17.9	
Other	120	4.4	16	3.7	
Total	2,714	100	440	100	
Total institutional aid 2003-2004					28.00 (4)**
\$0	1,398	51.5	216	48.9	
\$1-2,399	505	18.6	64	14.5	
\$2,400-4,999	264	9.7	30	6.8	
\$5,000-10,399	354	13.0	75	16.9	
\$10,400 or more	193	7.1	57	12.9	
Total	2,714	100	442	100	

Note: Weighted using the NCES-provided panel weight (WTB000).

* $p < .05$, ** $p < .01$

The chi-square analyses also demonstrated a significant association between type of major and Carnegie classification, $\chi^2(3, N = 3,155) = 28.33, p < .01$. In terms of total institutional aid, a higher percentage of female STEM majors (12.9%) received \$10,400 or more of total institutional aid than non-STEM majors (7.1%). The chi-square analyses revealed a significant association between type of major and total institutional aid, $\chi^2(4, N = 3,155) = 28.00, p < .01$. In the next section, I discuss which pre-college characteristics and experiences, academic and social involvement factors, and institutional characteristics best predict STEM persistence of female bachelor's degree students.

Predicting Undergraduate Women's Persistence in STEM

In the previous section, I explored the differences between female bachelor's degree students who entered STEM fields and non-STEM fields. In this section, I address the second research question and examine predictors of persistence of undergraduate women in STEM over a six-year time period. I focus specifically on female bachelor's degree students who declared a STEM major in 2003-2004 ($N = 447$). The sample was further divided into STEM persisters ($n = 214$) and STEM non-persisters ($n = 233$). STEM persisters was operationalized as female students who entered a STEM field in 2003-2004 and either attained a bachelor's degree in a STEM field by 2009 or remained enrolled in a STEM field by 2009. After the subsample was constructed, weighted logistic regression models were analyzed to determine the impact of student inputs and college environments on the odds of persistence of undergraduate women in STEM.

The independent variables were entered simultaneously into each regression model based on Astin's I-E-O framework and temporal order of impact (Astin & Antonio, 2012; Inkelas, 2004; Saenz, Ngai, & Hurtado, 2007). A total of thirty-three predictors, which encompassed student demographics, prior academic preparation and achievement, academic and social involvement, and institutional characteristics, were entered into the logistic regression models. Through an iterative process, the thirty-three independent variables were narrowed down to thirteen significant predictors of STEM persistence. In the final models of analysis, there were six student input (I) variables and seven college environmental (E) variables (academic and social involvement and institutional characteristics) that were analyzed as shown below in Table 4.6.

Student Inputs

Model 1, which included only the student input variables, correctly classified 65.6% of STEM persisters and 68.4% of STEM non-persisters, an overall correct classification of 67.1%. The logistic regression results revealed six significant student input predictors of STEM persistence. The percent of variance explained by the model ranged from a Cox and Snell R^2 of 19.1% to a Nagelkerke R^2 of 25.5%. Based solely on pre-college characteristics and experiences, Model 1 revealed a 41% decrease in the odds of STEM persistence for every one-unit (one year) increase in age ($OR = 0.585, p < .01$). This finding demonstrates that delayed entry into college negatively impacts persistence of undergraduate women in STEM. In respect to race/ethnicity, the odds of persisting in STEM increased by a factor of 3 for Asian female students compared to White female students ($OR = 3.03, p < .05$).

Table 4.6

Odds Ratios of Student Inputs and College Environments on Six-Year Persistence of Female STEM Majors.

Variable	Model 1	Model 2	Model 3
Student Inputs			
Age	0.585**	0.609*	0.595*
Race/Ethnicity (reference group: White)			
Black or African American	0.595	0.633	0.644
Hispanic or Latino	1.203	2.257*	2.424*
Asian	3.030*	3.848**	3.976**
Other	1.022	1.233	1.200
Highest level of high school mathematics (reference group: Calculus)			
None of these	0.742	1.292	1.221
Algebra 2	0.899	0.737	0.780
Trigonometry/Algebra 2	0.435*	0.404*	0.416*
Pre-Calculus	0.665	0.789	0.828
Earned college credits in high school (reference group: No)			
Yes	2.046**	2.376**	2.426**
Admissions test scores (ACT or SAT)			
	1.002**	1.002**	1.002**
Highest degree ever expected (reference group: First-professional degree)			
Bachelor's degree/Post-BA or post-master certificate	0.422*	0.396*	0.426*
Master's degree	0.496*	0.417*	0.435*
Doctoral degree	0.758	0.519	0.529
Academic and Social Involvement			
Study groups (2003-2004) (reference group: Never)			
Sometimes		2.040*	1.949
Often		4.266**	3.977**
School clubs (2003-2004) (reference group: Never)			
Sometimes		0.971	0.940
Often		0.454*	0.456*
Housing (2003-2004) (reference group: On campus)			
Off campus		0.363*	0.349*
Living with parents		1.261	1.280
Attended more than one institution		0.274*	0.227*
Faculty informal meeting (2006) (reference group: Never)			
Sometimes		2.137**	2.014**
Often		1.963	1.850
Fine arts activities (2006) (reference group: Never)			
Sometimes		1.931*	1.909*
Often		1.424	1.392
School sports (2006) (reference group: Never)			
Sometimes		2.172*	2.294**
Often		2.550**	2.417*
Institutional Characteristics			
Total institutional aid (2003-2004)			1.000*

Note: Weighted using the NCES-provided panel weight (WTB000).

* $p < .05$, ** $p < .01$

In terms of prior academic preparation and achievement, the highest level of high school mathematics, earning college credits in high school, and college admissions test scores were significant predictors of STEM persistence. The pre-college preparation and achievement findings align and contribute to the current STEM literature (Chang, Sharkness, Newman, & Hurtado, 2010). There was approximately a 57% decrease in the odds of STEM persistence for female students who took trigonometry/algebra 2 as their highest level of high school mathematics compared to female students who completed calculus ($OR = 0.435, p < 0.05$). In addition, the odds of persisting in STEM increased by a factor of 2 for students who earned college credits in high school ($OR = 2.046, p < 0.01$). In terms of SAT/ACT scores, there was only a 0.2% increase in the odds of persistence for every one-unit increase in admissions test scores among female STEM students ($OR = 1.002, p < .01$). Lastly, the odds of persistence decreased for undergraduate women in STEM who had expectations of earning a bachelor's degree and master's degree compared to a first-professional degree ($OR = 0.422, p < .05$; $OR = 0.496, p < .05$).

When examining only the pre-college characteristics and experiences of female bachelor's degree students in STEM fields, there were several critical predictors of STEM persistence. However, this study is framed by Astin's I-E-O model, which stresses the importance of considering college environmental influences when assessing student success. Therefore, the second regression model was conducted to examine the influence of student inputs and academic and social involvement variables on the six-year persistence of female STEM majors.

Academic and Social Involvement

Model 2, which included the student inputs along with academic and social involvement variables, correctly classified 76% of STEM persisters and 74.9% of STEM non-persisters, an overall correct classification of 75.4%. When considering both the student inputs and academic and social involvement variables, Model 2 showed to be a fairly robust model. The percent of variance explained by the second model improved compared to the first model, ranging from a Cox and Snell R^2 of 29.8% to a Nagelkerke R^2 of 39.8%. In the second model, age upon college entry continued to be a significant predictor of persistence with a 39% decrease in the odds of STEM persistence for every one-unit increase in age ($OR = 0.609, p < 0.05$). However, the significant race/ethnicity predictors changed when adding in college environmental variables. The odds of persisting in STEM increased by a factor of about 2 for Hispanic female students compared to White female students ($OR = 2.257, p < 0.05$). In the second model, the odds of persisting in STEM once again increased for Asian female students compared to White female students ($OR = 3.848, p < 0.01$).

When examining prior academic preparation and achievement predictors, minimal changes in significance between Model 1 and Model 2 were observed. Once again, the odds of persisting in STEM increased for students who earned college credits in high school ($OR = 2.376, p < .01$) and STEM persistence odds decreased by 60% for students with trigonometry/algebra 2 as their highest level of high school mathematics compared to calculus ($OR = 0.404, p < 0.05$). In addition, a one-unit increase in admissions test scores increased the odds of persistence by only 0.2% among female STEM students ($OR = 1.002, p < .01$).

In terms of academic and social involvement, three variables were significant predictors of STEM persistence during the first academic year (2003-2004). The odds of STEM persistence increased by a factor of 4 for female STEM majors who reported engaging in study groups than students who never participated in study groups ($OR = 4.266, p < .01$). Living off campus or attending more than one institution were negative predictors of STEM persistence compared to students who lived on campus in 2003-2004 ($OR = 0.363, p < .05$; $OR = 0.274, p < .05$). These findings align with Astin's student development theory, which suggests that student involvement (e.g., spending time on campus, investing energy to studies, interacting with faculty) is related to college success and persistence (Astin, 1999). Interestingly, there was a 55% decrease in the odds of STEM persistence for female students who reported participating in school clubs compared to students who never participated in school clubs ($OR = 0.454, p < .05$).

By the end of the third academic year (2005-2006), three academic and social involvement variables were significant predictors of STEM persistence as shown in Model 2. However, significant predictors of persistence by the end of the third academic year (2006) were different from the first academic year (2003-2004). The odds of STEM persistence increased by a factor of 2 for female STEM majors who interacted with faculty informally ($OR = 2.137, p < .01$). In addition, the odds of STEM persistence increased by a factor of 2 for female STEM majors who attended fine arts activities (e.g., music, choir, drama performances) ($OR = 1.931, p < .05$). Lastly, the odds of STEM persistence increased by a factor of 2.6 for female STEM majors who participated in school sports (e.g., varsity, club, intramural) than students who never participated in school sports ($OR = 2.550, p < .01$). In the next section, I discuss the third regression

model, which was conducted to examine the influence of student inputs, academic and social involvement, and institutional characteristics variables on the persistence of undergraduate women in STEM.

Institutional Characteristics

Model 3, which included student inputs, academic and social involvement variables, and institutional characteristics variables, correctly classified 75.6% of STEM persisters and 75.8% of STEM non-persisters, an overall correct classification of 75.7%. The percent of variance explained by the third model improved ranging from a Cox and Snell R^2 of 30.6% to a Nagelkerke R^2 of 40.8% and showed to be a fairly robust model. After entering all of the pre-college and college environmental variables, age upon college entry continued to be a significant predictor of STEM persistence ($OR = .595, p < .05$). In the third model, the odds of STEM persistence once again increased for Asian and Hispanic female students compared to White female students ($OR = 3.976, p < .01$; $OR = 2.424, p < .05$). STEM persistence odds decreased by 58% for female students with trigonometry/algebra 2 as their highest level of high school mathematics compared to calculus ($OR = 0.416, p < 0.05$). The odds of STEM persistence increased by a factor of 2.4 for female students who earned college credits in high school ($OR = 2.426, p < .01$). Like Model 2, Model 3 showed that a one-unit increase in admissions test scores increased the odds of persistence by 0.2% for female STEM majors ($OR = 1.002, p < .01$).

For the academic and social involvement variables, all of the variables that were significant in Model 2 were significant predictors of STEM persistence in Model 3. In 2003-2004, the odds of persisting in STEM increased by a factor of 4 for female STEM

majors who reported engaging in study groups often compared to students who never participated in study groups ($OR = 3.977, p < .01$). There was a 54% decrease in the odds of STEM persistence for students who participated in school clubs compared to students who never participated in school clubs ($OR = 0.456, p < .05$). Once again, living off campus (65% decrease) or attending more than one institution (77% decrease) were negative predictors of STEM persistence compared to students who lived on campus in 2003-2004 ($OR = 0.349, p < .05$; $OR = 0.227, p < .05$).

In 2006, the odds of persistence increased by a factor of 2 for female STEM majors who interacted with faculty informally than students who never interacted with faculty informally ($OR = 2.014, p < .01$). The odds of persistence also increased by a factor of 2 for female STEM majors who attended fine arts activities (e.g., music, choir, drama performances) compared to students who never attended a fine arts activity ($OR = 1.909, p < .05$). The odds of STEM persistence increased by a factor of 2.4 for female STEM majors who participated in school sports compared to students who never participated in school sports ($OR = 2.417, p < .05$). Lastly, when analyzing institutional characteristics variables, total institutional aid was a significant predictor of STEM persistence ($OR = 1.000, p < .05$). Overall, the findings from Model 3 reiterated the importance of examining student inputs and college environmental factors when studying predictors of STEM persistence.

Summary

This chapter presents findings on the analysis of pre-college and college level predictors of undergraduate women's persistence in STEM. Descriptive statistics were used to characterize the subsample and compare female bachelor's degree students who

entered STEM and non-STEM fields during the 2003-2004 academic year. Inferential statistics, through Pearson's chi square analyses, revealed significant differences between undergraduate women who declared STEM and non-STEM majors. In terms of student demographics, the majority of undergraduate women in STEM were White and 18 years old or younger. However, minority female students were more highly represented in STEM fields than non-STEM fields.

When analyzing prior academic achievement and preparation factors, a higher proportion of undergraduate women in STEM earned high admissions test scores, maintained a high school grade point average of 3.5 to 4.0, and completed a rigorous mathematics course in high school. These patterns highlighted the differences between undergraduate women who majored in STEM and non-STEM fields in terms of pre-college level factors.

In terms of college level factors, a higher percentage of female STEM majors reported engaging in study groups, school clubs, fine arts activities, and school sports compared to non-STEM majors. In addition, a higher percentage of female STEM majors enrolled in research and doctoral institutions and very selective institutions compared to non-STEM majors. After analyzing the characteristics of the study population, logistic regressions were performed to determine which student inputs and college environmental factors best predicted the persistence of undergraduate women in STEM.

The logistic regression models resulted in numerous significant relationships between the predictor variables (student inputs and college environments) and the output variable, STEM persistence. Models 2 and 3, which factored in student inputs and college environmental factors of undergraduate women in STEM, were better fitting

models for predicting persistence than Model 1 (students inputs only). In the third model, the findings revealed thirteen significant predictors of STEM persistence of female STEM majors. In terms of student demographics, the significant predictors included age and race/ethnicity. The findings showed that younger female students as well as Asian students were at increased odds of persisting in STEM. Contrary to prior research, the results showed that Hispanic female students were more likely to persist in STEM than White female students.

In terms of prior academic preparation and achievement, undergraduate women who entered college with high college entrance exam scores, completed a high level of high school mathematics, earned college credits in high school, and had first-professional degree expectations were more likely to persist in STEM.

For the college environmental variables, female STEM majors who were more academically and socially involved in school were at increased odds of persisting in STEM over a six-year period. Contrary to prior research, participation in school clubs was a negative predictor of STEM persistence. The remaining academic and social involvement variables positively influenced STEM persistence which included informal interactions with faculty and participation in study groups, fine arts activities, and school sports. In addition, female STEM majors who lived off campus or attended more than one institution were less likely to persist in STEM than students who lived on campus. The academic and social involvement findings align with Astin's theory of student involvement. The practical significance of the findings from this study have potential policy and practice implications for the recruitment and retention of undergraduate women in STEM, which will be discussed in Chapter 5.

CHAPTER 5

DISCUSSION

Women are underrepresented in postsecondary STEM fields, particularly in majors such as physics, engineering, and computer science (Hill et al., 2010). The underrepresentation of women in STEM is a part of a larger gender inequality problem in the United States. By addressing gender inequities in STEM, we are helping to narrow our nation's gender pay gap and women's leadership gap. National education policies have directed efforts towards the recruitment and retention of females in STEM using the simplistic 'leaky pipeline' approach (Blickenstaff, 2005). The 'leaky pipeline' metaphor refers to the loss of women at each stage along the STEM education pathway. This model suggests that increasing the number of women in the pipeline would in turn increase the number of women in the STEM workforce. However, this linear depiction of women entering and exiting STEM does not accurately reflect the complexities of the problem. To effectively address the inequities prevalent in higher education STEM fields, it is crucial to consider students' experiences prior to and during college enrollment.

In this study, I examined the pre-college and college level factors that influence the persistence of undergraduate women over a six-year period. In addition, I explored the characteristics of undergraduate women who declared a STEM major in 2003-2004, using a nationally representative data set. This study used Astin's I-E-O model to examine student inputs (prior to college) and college environmental factors that impacted the persistence of female bachelor's degree students in STEM. In this chapter, I analyze

the practical significance of the key findings in relation to relevant literature, discuss implications for policy and practice, and provide recommendations for future research.

Research Question 1: Characteristics of Undergraduate Women in STEM

For the first research question, I examined differences in student inputs and college environmental factors between female bachelor's degree students who entered STEM fields and non-STEM fields in 2003-2004. Findings revealed significant differences between undergraduate women who majored in STEM and non-STEM fields and provided a depiction of the women interested in pursuing postsecondary STEM degrees. Female students who entered STEM fields were more academically prepared for college (e.g., college admissions test scores, high school GPA, level of high school mathematics) than female students who entered non-STEM fields. In addition, women in STEM had higher expectations of earning an advanced postsecondary degree than female non-STEM majors. These results align with prior literature, which show that rigorous academic preparation and career aspirations are tied to entry into and persistence in postsecondary STEM fields (Astin & Astin, 1992; Chen & Soldner, 2013; Maltese & Tai, 2011; Seymour & Hewitt, 1997).

Relevant literature has also shown that parental education level influences entry and academic success for undergraduate women in STEM (Astin & Sax, 1998; Chen, 2009; Seymour & Hewitt, 1997). More specifically, past studies have shown that father's education level influences women's choice to pursue a STEM field (Gayles & Ampaw, 2014; Rinn, Miner, & Taylor, 2013). In this study, parental education level was significantly associated with type of major. When comparing father's education level, a higher percentage of female STEM majors reported their father earning a bachelor's

degree or higher degree compared to female non-STEM majors. Although having a highly educated father positively influences entry into STEM, some studies have shown this can negatively impact women's mathematics self-confidence (Sax, 1994). High confidence in mathematical abilities has been linked to academic success and persistence in postsecondary STEM fields. Therefore, it is important for STEM departments, especially mathematics-intensive fields such as engineering and physics to evaluate undergraduate students' mathematics self-confidence and offer support when needed (Sax, 2008; Sax, Kanny, Riggers-Piehl, Whang, & Paulson, 2015).

A prominent discussion in the STEM literature is how to improve the participation of underrepresented minorities in STEM fields (Hanson, 2009; O'Brien et al., 2015). Serendipitously, enlightening findings of this study revealed that a higher proportion of female minority students entered STEM fields than non-STEM fields in 2003-2004. Expectedly, a higher rate of Asian female students entered STEM fields than non-STEM fields, a pattern that has been shown in the literature (Chen, 2009). However, the significantly higher percentage of African American and Hispanic undergraduate women pursuing STEM fields was a notable finding. Several research studies have reported similarities between racial/ethnic groups in terms of postsecondary STEM interest, however these works lacked information on gender differences (Anderson and Kim, 2006; Chen, 2009). Other studies have shown that African American female undergraduates were more likely to exhibit interest and enter postsecondary STEM fields than White female undergraduates (Riegle-Crumb and King, 2010). O'Brien et al. (2015) demonstrated that African American women were more likely to declare a STEM major and exhibited weaker gender-STEM stereotypes than White women. Riegle-Crumb and

King (2010) also demonstrated that African American female students were more likely to enter physical science or engineering fields than White female students, in comparison to White males.

Although an increasing proportion of African American and Hispanic women are entering postsecondary STEM fields, there continues to be gaps in retention and STEM degree attainment for underrepresented minority students (Cole & Espinoza, 2008; Crisp, Nora, & Taggart, 2015; Garcia & Hurtado, 2011). Underrepresented minorities make up almost 30 percent of the United States population, however less than 10 percent work in science and engineering fields (National Research Council, 2011). The racial/ethnic differences in STEM entry found in this study suggest that female minority students are interested in pursuing postsecondary STEM fields. However, these women are turning away from STEM due to numerous cited factors such as a lack of sense of belonging, financial concerns, and unsupportive campus climate (Carlone & Johnson, 2007; Gayles & Ampaw, 2014; Hill et al., 2010).

In order to improve the retention of underrepresented female minority students in STEM, it is crucial that reform efforts take place at the postsecondary level. In terms of postsecondary institutional characteristics, there were significant differences between female STEM and non-STEM majors. In 2003-2004, a higher proportion of female STEM majors attended highly selective institutions as well as research and doctoral institutions compared to female non-STEM majors. In addition, female STEM majors received more institutional aid than non-STEM majors. Prior studies have shown that African American and Hispanic students as well as low-income students are exceedingly underrepresented in very selective colleges (Griffith, 2010; Reardon, Baker, & Klasik,

2012). Therefore, underrepresented female minorities may feel isolated and unable to become academically and socially involved in these highly selective institutions.

Astin's theory of involvement suggests that energy invested in the academic and social aspects of higher education relates to the persistence and academic success of college students (Astin, 1999). In this study, women in STEM fields were more academically and socially involved (e.g., study groups, school clubs, fine arts, school sports) in college than female non-STEM majors. However, whether this increased academic and social involvement positively or negatively predicted STEM persistence of undergraduate women was explored in the second research question. In the next section, I analyze the pre-college characteristics and experiences, academic and social involvement factors, and institutional characteristics that predict persistence of undergraduate women in STEM.

Research Question 2: Persistence of Undergraduate Women in STEM

For the second research question, I investigated factors that influence STEM persistence of undergraduate women using a longitudinal data set. Logistic regression models were used, based on Astin's I-E-O framework, to uncover student inputs and college environmental factors related to long-term persistence of female bachelor's degree students in STEM. Three logistic regression models were analyzed in this study. The first model included solely the student input variables and the second and third models included student inputs as well college environmental variables. The final logistic regression model revealed thirteen significant predictors of persistence of undergraduate women in STEM fields. Using Astin's I-E-O model to study predictors of STEM persistence enabled me to support and contribute to the current STEM literature.

The findings of the second research question are separated into three sections: student inputs, academic and social involvement, and institutional characteristics.

Student Inputs

When studying undergraduate persistence, it is important for researchers, educators, and policymakers to consider students' experiences prior to entering college. Student inputs (pre-college characteristics and experiences) have been shown to influence the academic success and persistence of female STEM students (Astin & Astin, 1992; Gayles & Ampaw, 2014). In this study, there were several significant input predictors of STEM persistence that were practically meaningful, which included age, race/ethnicity, highest level of high school mathematics, earning credits from college while in high school, and highest postsecondary degree expectations.

Findings showed that age at the time of college enrollment was a predictor of STEM persistence for female bachelor's degree students. The odds of persisting in STEM significantly decreased as the age at time of entry increased for female STEM students. Age is a relevant factor in postsecondary STEM persistence. Anderson and Kim (2006) showed that nearly 100 percent of students who received a bachelor's degree in STEM in 2001 were younger than 19 at time of entry into college. Prior research studies have also shown that delayed college enrollment can negatively influence degree attainment (Adelman, 2006; Maltese & Tai, 2011). Some reasons for delayed enrollment include financial concerns, lack of academic preparedness, and family responsibilities (NRC, 2011). The results of this study show that older, nontraditional students who may have taken alternative paths into college need support navigating STEM fields. Underrepresented minorities have been shown to be more likely to delay college

enrollment, which may play a role in STEM attrition among underrepresented groups. In this study, racial/ethnic differences were also shown to be predictors of female STEM persistence.

Consistent with previous research, the odds of STEM persistence increased considerably for Asian female students compared to White female students (Astin & Astin, 1992; Maltese & Tai, 2011). Relevant studies have shown that Asian students are highly represented and demonstrate high rates of persistence in STEM fields (Anderson & Kim, 2006; Lord et al, 2009). Contrary to prior literature, an unexpected finding showed that Hispanic female students were at increased odds of persisting in STEM fields compared to White female students. Hispanics are a growing minority group in the United States, which is leading to a rise in college enrollment numbers and potential source of talent for our STEM workforce (Crisp, Nora, & Taggart, 2009). Although this study does not specifically look at factors that influence Hispanic female students, it is evident that these women are persisting in STEM over a six-year period.

When examining the first logistic regression model (student inputs), Hispanic females were not at an increased likelihood of persisting in STEM as compared to White females. However, after factoring in college environmental measures, odds of persisting in STEM increased by a factor of two for Hispanic female students compared to White female students. Recent literature studies have shown that campus climate and student involvement in college influence the academic success and persistence of Hispanic students (Crisp & Nora, 2012; Crisp, Taggart, & Nora, 2015; Garcia & Hurtado, 2011). In this study, female Hispanic students may have been positively influenced by college environmental factors such as participation in study groups or interactions with faculty.

On the other hand, this study was limited to first-time beginning female bachelor's degree students enrolled in four-year institutions. The literature shows that approximately 60 percent of Hispanic students who attained a STEM bachelor's degree attended a community college during their college career (Crisp & Nora, 2012). Therefore, this select group of Hispanic female students may not truly represent the population of underrepresented Hispanic students in postsecondary STEM fields.

In this study, African American women made up the largest percentage of the female minority student population entering STEM fields. However, these women are turning away from STEM after being exposed to the college environment (Carlone & Johnson, 2007; Hanson, 2006; Ong et al., 2011; Riegle-Crumb and King, 2010). As discussed earlier, African American women are less influenced by gender-STEM stereotypes and in turn choose to enter STEM fields (O'Brien et al., 2015). However, racial microaggressions that occur inside and outside of the classroom may contribute to feelings of isolation and invisibility that disrupt the developing science identities of African American women (Carlone & Johnson, 2007). This study confirms the importance of incorporating inclusive practices in STEM departments that focus on community culture versus competitive culture.

In this study, female bachelor's degree students who were more likely to persist in STEM entered college with high college entrance exam scores, completed a high level of high school mathematics, earned college credits in high school, and had first-professional degree expectations. Prior research studies have demonstrated that prior academic preparation is related to postsecondary STEM persistence (Chen, 2009; Crisp, Nora, and Taggart, 2009; Maltese and Tai, 2011). In this study, odds of persisting in STEM

decreased for students who completed trigonometry/algebra 2 as their highest level of high school mathematics compared to calculus. This finding supports the current literature, which shows that mathematics achievement and mathematics self-confidence prior to college are related to bachelor's degree attainment and postsecondary STEM persistence (Adelman, 2006; Astin & Astin, 1992; Bonous-Hammarth, 2000; Chen & Soldner, 2013; Ware & Lee, 1988).

Chen and Soldner (2013) found that less than 15 percent of STEM majors who completed calculus in high school left STEM fields. Whereas an alarming 40 percent of STEM majors who did not complete a trigonometry/algebra 2 course or higher in high school turned away from STEM. These figures demonstrate the importance of access to a quality secondary mathematics education. Other studies have shown that undergraduate women, in particular, have lower perceptions of their mathematical abilities than male students (Astin 1993; Sax, 1994). Therefore, if female STEM students lack mathematical self-confidence and are not receiving adequate mathematics preparation in high school, they may feel overwhelmed when entering mathematics-intensive science courses and turn away from STEM. In addition to mathematics achievement in high school, this study demonstrated that college admissions test scores to a limited extent and earning college credits in high school positively influenced undergraduate women's STEM persistence.

In this study, higher college admissions test scores increased the odds of persistence for undergraduate women in STEM by only 0.2%. Past studies have shown that college admissions test scores and more specifically SAT/ACT math scores were correlated to STEM persistence for undergraduate women (Astin & Astin, 1992; LeBeau

et al., 2012; Chang et al., 2010; Griffith, 2010). However, the findings of this study illustrated that college admissions test scores may be less relevant than adequate mathematics preparation and earning college credits in high school. Female students in pursuit of STEM degrees can prepare academically for rigorous postsecondary STEM fields by enrolling in college level coursework in high school.

This study demonstrated that the odds of STEM persistence increased dramatically for female students who reported earning college credits at a college while in high school than their counterparts. There are limited studies available on the effectiveness of dual enrollment programs in postsecondary persistence. One of the first national studies on dual enrollment patterns was conducted only ten years ago by NCES (Waits, Setzer, & Lewis, 2005). More recent NCES reports showed that 82% of public high schools had students enrolled in dual enrollment programs. However, 60% of postsecondary institutions required a minimum high school GPA for participation in the dual enrollment program. And only 4% of postsecondary institutions offered dual enrollment programs targeted towards high school students at risk of educational failure (Marken, Gray, and Lewis, 2013; Thomas, Marken, Gray, Lewis, & Ralph, 2013).

Proponents for expanding access to college-level courses in high school argue that these programs help prepare students for college coursework and bridge the gap between high schools and universities (An, 2013; Marken, Gray, & Lewis, 2013). Karp, Calcagno, Hughes, Jeong, and Bailey (2007) showed that dual enrollment programs were particularly advantageous for low-achieving and low-income students and positively influenced postsecondary persistence. This current study expands upon the dual

enrollment literature and showed that earning college credits in high school positively impacted the persistence of undergraduate women in STEM.

This study also showed that female students who entered college with expectations of earning a first-professional postsecondary degree were more likely to persist in STEM than students whose highest expectations were a bachelor's degree or master's degree. Past studies have shown that career aspirations of students in STEM are related to persistence (Maltese and Tai, 2011; Tai, Liu, Maltese, & Fan, 2006). Overall, prior academic preparation and achievement factors play an important role in predicting STEM persistence. In addition to pre-college factors, this study examined college environmental factors that influenced undergraduate women's decision to persist in STEM fields as discussed in the next two sections.

Academic and Social Involvement

In this study, academic and social involvement factors were examined after the first and third years of college (2003-2004 and 2006) to assess female student involvement over time. Overall, the findings showed that female STEM majors who were academically and socially involved in college were more likely to persist in STEM. Relevant studies have shown that student involvement during the first year of college influenced academic success and long-term persistence (Ishler and Upcraft, 2005). During the first year of college (2003-2004), female STEM majors were at increased odds of persistence if they participated in study groups and lived on campus.

Undergraduate women in STEM who engaged in study groups were more likely to persist in STEM than those who never participated in study groups. Consistent with prior research, these findings demonstrate that peer support and peer interactions on an

academic level can positively influence STEM persistence, especially for underrepresented groups (Tsui, 2007). In addition to studying with peers, female STEM majors who lived on campus were more likely to persist than female STEM majors who lived off campus or attended more than one institution. Past studies have shown that students who lived on campus were more connected to the institution and invested more energy into their studies, which in turn positively impacted persistence (Astin, 1999; Reason, 2010). Academic and social supports can positively impact women in STEM fields, however findings of this study unexpectedly revealed that participation in school clubs was a negative predictor of STEM persistence.

Prior works have shown that students who engaged in school clubs may have felt isolated among peers in their fields, particularly true for underrepresented groups (Bonous-Hammarth, 2000). Therefore, spending time in school clubs might be an indicator that female STEM non-persisters were finding ways to fit in somewhere outside of their STEM majors. Unfortunately, BPS:04/09 lacks data on participation in STEM-related clubs, which may have presented a different picture of the influence of clubs on STEM persistence.

In terms of academic and social involvement during the third year of college, female STEM majors who interacted with faculty informally, attended fine arts activities (e.g., music, choir, drama performances), and participated in school sports were approximately two times more likely to persist in STEM. Consistent with prior research, this study shows that interactions with faculty influence the persistence of women in STEM (Astin, 1999; Gayles & Ampaw, 2014). Participation in sports has also been linked to college student persistence (Pascarella & Terenzini, 2005). However, this study

expands upon the current literature by showing the impact of participation in school sports on women in STEM. Astin's (1993) theory of involvement suggests that the amount of energy undergraduate students' invest in their college experience, both academically and socially, relates to the likelihood of persistence. Female STEM majors who were academically and socially involved in school over time were more likely to persist in STEM. Further research is necessary to examine the enrollment and working patterns of female students who turned away from STEM. Female STEM non-persisters may have been unable to become fully integrated into the campus culture due to part-time attendance or work responsibilities, which negatively impacted persistence. Higher education institutions need to provide academic and social supports for women in STEM in order to promote academic success and long-term persistence.

Institutional Characteristics

When analyzing institutional characteristics variables, total institutional aid was the only significant predictor of STEM persistence. Little is known about the influence of total institutional aid on women's persistence in STEM. However, college persistence literature shows that financial aid impacts retention rates (Reason, 2010). Astin and Cross (1979) demonstrated that different types of financial aid have varying effects on persistence. Student loans have been shown to have a negative impact on the persistence of underrepresented students. In this study, as total institutional aid increased, the odds of STEM persistence increased to a limited extent for undergraduate women.

An increased amount of total institutional aid may have enabled female students to focus on their studies as opposed to working, and ultimately persist in STEM. Students' financial concerns can negatively impact persistence in college, particularly for low-

income students and underrepresented minorities. Higher education institutions need to assess whether the financial support provided to students promotes student involvement, which in turn impacts persistence in STEM fields.

Implications for Policy and Practice

After examining critical predictors of STEM persistence, implications for practice and policy plans emerged for improving gender inequities in higher education STEM fields. Stakeholders in both secondary and postsecondary levels of education should consider policy and practice initiatives for women in STEM. The results of this longitudinal study showed that pre-college and college level factors influenced the persistence of female bachelor's degree students in STEM. Wang (2013) investigated factors related to entrance into postsecondary STEM fields and argued, "A decision to pursue a STEM major is a longitudinal process that builds during secondary education and carries into postsecondary studies. A full picture of this process is best realized through incorporating the effects of these two levels of education..." (p. 1083). In order to improve the entrance into and persistence of women in STEM, it is imperative that changes take place in the secondary and postsecondary education sectors.

Bridging the gaps in communication between secondary and postsecondary institutions is key to reforming STEM education. Through the expansion and improvement of academic bridge programs and dual enrollment programs, underrepresented female students can gain opportunities to enter into and persist in postsecondary STEM fields. It is crucial that collaboration efforts between secondary and postsecondary institutions progress in order to help support underrepresented students in STEM.

The results of this study showed that pre-college preparation factors such as exposure to advanced level mathematics and college level courses were predictors of undergraduate women's persistence in STEM. Secondary level educators, administrators, and parents need to encourage and support young women who show interest in pursuing STEM fields. This encouragement and support means ensuring female high school students have access to the academic preparation and role models needed to build confidence and succeed in postsecondary STEM fields. Nonprofit organizations such as the American Association of University Women (AAUW) and Girls Who Code are excellent models for implementing community programs and clubs that inspire young girls to pursue STEM (Hill et al., 2010; Saujani, 2016). These organizations educate young women, provide real world connections to STEM, and expose girls to role models in STEM fields.

Imbalances in access to an adequate mathematics and science education at the secondary level continue to be an issue for underrepresented students in STEM (Crisp and Nora, 2012; Wang, 2013). Therefore, it is important that programs are also available at the higher education level to support entering female STEM students. In particular STEM departments, especially mathematically intensive fields such as engineering and physics need to evaluate students' mathematical readiness and self-confidence and offer support when needed.

On the other hand, many young women who are academically prepared for the sciences continue to turn away due to an unwelcoming college environment. This study showed that academic and social involvement in college positively influenced undergraduate women's persistence in STEM. Female students, who lived on campus,

engaged in study groups, interacted with faculty, and participated in fine arts and sports activities were more likely to persist in STEM. The results of this study demonstrate the important role universities play in the success of their female science students. It is imperative that college campuses and STEM departments promote inclusive practices that enhance the learning and academic success of underrepresented students in STEM. STEM departments can focus on promoting a community culture versus the traditional competitive culture by setting up mentoring programs that include faculty members in the process. Institutional interventions have been shown to improve the persistence and academic development of college students (e.g., seminars, learning communities, service-learning). Learning communities and seminars that enhance faculty and peer interactions could potentially help female students persist in STEM fields (Ischler & Upcraft, 2005; Astin & Sax, 1998).

Recommendations for Future Research

In effort to further our understanding of the factors that influence persistence of postsecondary women in STEM fields, there are several key recommendations for future research. In higher education, the STEM gender gap is wider and more problematic in mathematically intensive fields such as engineering, physics, and computer science. In this study, STEM fields were aggregated and included majors that varied in female representation. Therefore, research is needed that compares predictors of undergraduate women's persistence across different STEM fields. Disaggregating STEM majors may provide more insight into where retention efforts need to be placed. In addition to comparing individual STEM majors, future studies could further explore the college experiences that impact the persistence of women in STEM.

This study used quantitative, longitudinal data to examine differences between undergraduate women in terms of entrance into and persistence in STEM fields. For future research, more qualitative studies are needed to further understand why some women turn away from STEM once exposed to the college environment. Qualitative studies that focus on sociocultural factors, both inside and outside of the classroom, would provide a deeper look into how STEM culture influences the retention of undergraduate women.

In particular, this study showed that minority female students were more highly represented in STEM fields than non-STEM fields. Although underrepresented minority females are entering postsecondary STEM fields, many of these women choose to leave STEM after exposure to the college environment. Qualitative research that explores the experiences of minority female STEM majors may offer more insight into factors that impact STEM persistence. Qualitative studies that examine how academic and social involvement experiences (e.g., faculty and peer interactions, study groups, school clubs, school sports) influence underrepresented minority women's motivation, self-confidence, and persistence in STEM are crucial to further understanding the STEM gender gap.

This study focused specifically on first-time beginning female students who were enrolled in STEM bachelor's degree programs. Community colleges now play a major role in the STEM pipeline, particularly for underrepresented students. This study included a select sample of female bachelor's degree students who attended four-year institutions. Therefore, research is recommended that examine the influence of community colleges on the persistence of women in STEM. Further research that broadens the scope of analysis by including more non-traditional students (e.g.,

community college students, associate's degree students, and transfer students) would further unpack gender disparities in postsecondary STEM fields.

Another recommendation for future research includes using data from the most recent Beginning Postsecondary Students Longitudinal Study cohort (BPS:12/17) to study STEM persistence, which will become available in the next few years. Building upon this current study, it would be advantageous to explore whether the characteristics and persistence patterns of undergraduate women in STEM have changed over time. Solutions to the gender gap issue in STEM are complex and will take a concerted effort by secondary and postsecondary stakeholders. In order to improve women's representation and success in postsecondary STEM fields, it is crucial that researchers and policymakers consider both pre-college and college level factors when implementing institutional interventions.

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