WHY (AND HOW) THEY DECIDE TO LEAVE: A GROUNDED THEORY ANALYSIS
OF STEM ATTRACTION AT A LARGE PUBLIC RESEARCH UNIVERSITY

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ABSTRACT

A grounded theory investigation of STEM attrition was conducted that describes and explains why undergraduates at a large Mid-Atlantic research university decided to leave their initial STEM majors to pursue non-STEM courses of study. Participants ultimately decided to leave their initial STEM majors because they were able to locate preferable non-STEM courses of study that did not present the same kinds of obstacles they had encountered in their original STEM majors. Grounded theory data analysis revealed participants initially enrolled in STEM majors with *tenuous motivation* that did not withstand the various obstacles that were present in introductory STEM coursework. Obstacles that acted as demotivating influences and prompted participants to locate alternative academic pathways include the following: (1.) disengaging curricula; (2.) competitive culture; (3.) disappointing grades; (4.) demanding time commitments; and (5.) unappealing career options. Once discouraged from continuing along their initial STEM pathways, participants then employed various strategies to discover suitable non-STEM majors that would allow them to realize their intrinsic interests and extrinsic goals. Participants were largely satisfied with their decisions to leave STEM and have achieved measures of personal satisfaction and professional success.

Keywords: STEM, attrition, grounded theory
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CHAPTER 1: BACKGROUND, PURPOSE, AND OVERVIEW OF THE STUDY

According to Goldin and Katz (2010), the twentieth century was known as the human capital century and the American century. More than any other time in history, education played a prominent role in many societies due to the direct correlation between the development of human capital and economic prosperity that emerged due to ever-changing technological forces that reshaped economic markets. The primary reason why the United States rose to a position of global and economic power during the early decades of the twentieth-century was its burgeoning educational system that provided public primary and secondary education to all its citizens, while also encouraging many secondary school graduates to pursue higher education. In fact, the United States educated a far greater percentage of its citizens than any other country during the early decades of the twentieth century (Goldin & Katz, 2010).

The United States’ educated citizenry contributed to its economic growth and prosperity during the twentieth century in a variety of ways. Perhaps most directly, the U.S.’s relatively educated workforce facilitated greater levels of labor productivity and efficiency. More indirectly, America’s educated workforce has been better able to adopt new technologies as they have emerged in industry, further generating economic growth (Goldin & Katz, 2010).

However, the United States emerged as a global superpower not only because it educated greater percentages of its citizens compared to other nations, but because it educated great percentages of its citizens in STEM academic disciplines (science, technology, engineering, and math). College graduates educated in these STEM disciplines produced the technological innovations that have created new industries and produced a wealth of high-paying employment opportunities for our nation’s educated citizenry (National Science Foundation (US), 2010). These individuals who receive specialized training in STEM disciplines have played an essential
role in the nation’s economy and ensure the future economic success of the United States (National Academy of Sciences & Institute of Medicine of The National Academies, 2005).

Although the United States’ educational system’s ability to produce such highly skilled STEM workers has traditionally been the envy of the world, recent evidence suggests that the United States is falling behind other industrialized nations in the education of STEM workers. In a recent study, only 32% of U.S. undergraduates received a B.S. degree in STEM fields, compared to 59% of Chinese and 66% of Japanese undergraduates (National Academy of Sciences & Institute of Medicine of The National Academies, 2005). In 2010, the United States ranked only 27th globally in the percentage of undergraduate students earning STEM degrees (Bok, 2013).

Furthermore, a recent government report projects a shortage of 1 million STEM workers to contribute to the American economy during the coming years (President’s Council of Advisors on Science and Technology (U.S.), & United States. Executive Office of the President. 2012). Bok (2013) writes, “These trends have led several high-level committees to conclude that the United States is at risk of producing too few scientific researchers to meet America’s future needs” (p. 228).

STEM attrition is one of the leading causes of this worker shortfall, as relatively few undergraduates who begin their college careers as STEM majors actually graduate with baccalaureate degrees in STEM disciplines. A recent study utilizing data from UCLA’s 2004 CIRP Freshman Survey and the National Student Clearinghouse indicated that only 33% of White and 42% of Asian undergraduates who initially entered STEM majors actually completed STEM baccalaureate degrees within five years of college matriculation (Hurtado et al., 2010).
Furthermore, underrepresented-minority students were found to complete such degrees at lower rates than their White and Asian peers. This study found that 22% of Latino students completed STEM degrees within five years of matriculation, whereas only 18% of African-American and 19% of Native American undergraduates were able to do the same (Hurtado et al., 2010).

These statistics are corroborated by a similar government study based on data from the 2004/09 Beginning Postsecondary Students Longitudinal Study and the 2009 Postsecondary Education Transcript study that revealed that 48% baccalaureate degree students who began their college careers as STEM majors between 2003 and 2009 failed to graduate with a STEM bachelor’s degree. These students either switched to non-STEM majors or failed to graduate altogether (Chen & Soldner, 2013). Although this same study also indicates that other non-STEM majors in fields such as the humanities, social sciences, and business experience similar or even higher attrition rates, the attrition rate for STEM majors is of particular concern to both government and higher education stakeholders due to the great importance STEM graduates play in our nation’s economy (President’s Council of Advisors on Science and Technology (U.S.), & United States. Executive Office of the President., 2012).

**Research Question**

In order to better understand why so many undergraduates decide to not complete STEM degrees after initially declaring STEM majors, I have conducted a grounded theory study of STEM attrition at a large Mid-Atlantic public research university. In describing grounded theory, Charmaz (2011) writes, “Stated simply, grounded theory methods consist of systematic, yet flexible guidelines for collecting and analyzing qualitative data to construct theories ‘grounded’
in the data themselves” (p. 2). Grounded theory takes an inductive approach to data collection and analysis and allows theory to emerge from the data. As such, grounded theory is positioned to generate a theory of STEM attrition that is rooted in the experiences and perspectives of this study’s participants and describes the impact multiple forces and factors have on the attrition process. By conducting such a study, I have described the interrelated forces that influence undergraduates’ decisions to not continue in STEM majors, as well as the processes that have guided their decisions to leave STEM disciplines. The study addresses the following research question:

What process describes and explains undergraduate students’ decisions to discontinue in STEM majors at large research universities?

Statement of the Problem

Economic importance of STEM education. In order to better understand the importance of this study and the nature of the problem being addressed, it is first necessary to understand the important role STEM graduates play in the U.S. economy and why it is necessary for American colleges and universities to graduate more highly skilled STEM workers. In commenting on the traditional vitality of the American economy, a recent government report states,

That vitality is derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living. Economic studies conducted before the information-technology revolution have shown that even then as much as 85% of measured growth in US income per capita is due to technological change. (National Academy of Sciences & Institute of Medicine of The National Academies, 2005, p. 3)

Furthermore, such “well-trained people” play an increasingly valuable role in the new
global economy and ensure American economic competitiveness in the twenty-first century (Stine & Matthews, 2009).

More specifically, how do STEM graduates contribute to the economic competitiveness of the United States? Economic competitiveness can be defined as the “…ability of a firm to compete for market share against imports from abroad or to compete with foreign firms in overseas export markets” (Stine & Matthews, 2009, p. 1). Such ability is made possible by the technological advancements created by high-skilled STEM workers “…because they contribute to the creation of new goods, services, jobs, and capital, or increased productivity” (Stine & Matthews, 2009, p. 1). Langdon et al. (2011) writes, “The greatest advancements in our society from medicine to mechanics have come from the minds of those interested in or studied in the areas of STEM. Although still relatively small in number, the STEM workforce has an outsized impact on a nation’s competitiveness, economic growth, and overall standard of living” (p. 6).

Due in large measure to the important role STEM workers play in the twenty-first century economy, employment opportunities in STEM occupations are expected to grow at a faster rate than employment opportunities in other sectors. Between 2008 and 2018, STEM employment opportunities are projected to increase by 17%, while job growth in other sectors of the economy are only projected to increase by 9.8% (Langdon et al., 2011). This projected growth in STEM employment opportunities is not only correlated with the general economic importance of STEM workers, but is also due to the demographic and technological shifts that will shape our economy in the coming decades.

Furthermore, government projections state that the age 55 and older demographic group represents the fastest growing demographic sector in the United States, thereby creating a
growing need for healthcare worker to care for the needs of the elderly. As such, “A substantial portion of the 30 fastest growing occupations are directly related to healthcare” (Lacey & Wright, 2009, p. 90). Similarly, the recent technological advances that defined the new knowledge economy of the twenty-first century have created a need for more highly-skilled workers, such as network systems and data communication analysts, to attend to the various expanding technologies that have been and will be created in coming decades (Lacey and Wright, 2009).

Shortage of STEM graduates. In light of these employment projections and the general importance of STEM workers to the economic competitiveness of the United States, some have begun to question whether or not American colleges and universities are producing enough STEM graduates. For example, a recent government report states that there is currently a severe shortage of STEM graduates in the United States and projects that the situation could become even worse in the coming years. In fact, if American higher education continues to produce STEM graduates at its current rate over the next decade, there will be a shortage of approximately 1 million STEM workers in our economy. This shortage will threaten U.S. economic competitiveness as well as our nation’s “…historical preeminence in science and technology” (President’s Council of Advisors on Science and Technology (U.S.), & United States. Executive Office of the President. 2012, p. i).

This potential STEM worker shortfall is further exacerbated by the twin realities of relatively high STEM attrition rates among underrepresented minority undergraduates and the changing demographic landscape in the United States. Many empirical investigations have illustrated that underrepresented minority groups are typically less likely to persist in STEM
majors than their white and Asian peers. For example, Hurtado et al. (2010) revealed that while 33% and 42% of White and Asian-American undergraduates who initially entered STEM majors completed STEM baccalaureate degrees within five years of matriculation, the STEM completion rate among Latino, Black, and Native American undergraduates is actually far lower. When these troubling rates of relatively high STEM attrition are combined with the fact that United States is currently experiencing rapid demographic shifts that are increasing the diversity of its population, the need to better understand the underlying causes of STEM attrition takes on even greater significance (Andersen & Ward, 2014).

It is important to note that not all scholars concur with this projected STEM worker shortfall. For example, Teitelbaum (2003) notes that the U.S. government has predicted several such STEM worker shortfalls since the 1950’s, yet no shortfalls have apparently materialized. In addition, other scholars argue that current labor market analyses contradict the government’s assertion of a STEM worker shortage. More specifically, Anft (2013) states that wages for STEM occupations have remained largely stagnant, which would contradict the presence of a looming worker shortage, and Lowell and Salzman (2007) write that “the pool of S&E-qualified secondary and postsecondary graduates is several times larger than the number of annual openings” (p. 2). These assertions are further supported by research that indicates a relatively high unemployment rate for STEM graduates (Teitelbaum, 2003). These findings would seem to argue against a current and future STEM worker shortage.

However, the government’s assertion of a looming STEM worker shortage is supported by Carnevale et al.’s (2011) comprehensive labor market analysis. Carnevale et al. (2011) criticize the labor market analyses that have refuted the notion of a looming STEM worker
shortage on methodological grounds, stating that such analyses do not take into account the fact that many STEM graduates work in non-traditional STEM occupations that value STEM core competencies. Carnevale et al. (2010) write,

We conclude that our education system is not producing enough STEM-capable students to keep up with demand both in traditional STEM occupations and other sectors across the economy that demand similar competencies. The demand for STEM competencies outside STEM occupations is strong and growing… In other words, even when the numbers indicate that we are producing enough STEM graduates for STEM occupations, we do face STEM scarcity in some occupations because STEM-capable workers divert from STEM into non-STEM occupations, particularly Managerial and Professional and Healthcare Professional occupations. (p. 10)

Carnevale et al. (2010) concludes by stating, "The market for STEM competencies far exceeds the 5 percent of science, technology, and engineering occupations. As a result, the demand for STEM competencies throughout the economy diverts STEM workers into nontraditional STEM occupations—making what seems like plenty, not enough to go around" (p. 41).

**STEM attrition.** A key factor in closing this projected STEM worker shortage is the ability of colleges and universities to reduce STEM attrition and improve undergraduate persistence in STEM majors. Improving the STEM retention rate to just 50% would produce an additional 750,000 STEM graduates and practically close the projected STEM worker shortage (President’s Council of Advisors on Science and Technology (U.S.), & United States. Executive Office of the President. 2012). Therefore, research that can illustrate the reasons why so many undergraduates decide to leave STEM majors is needed more than ever to help colleges and universities reduce STEM attrition and graduate the additional STEM graduates that are needed to ensure American economic competitiveness in the twenty-first century.
Research that addresses this important area of inquiry is even more crucial when one considers the fact that many talented undergraduates who have the ability to complete STEM degree willingly elect to leave STEM majors after initially declaring such majors upon entering college. Seymour and Hewitt’s (1997) landmark study of STEM attrition revealed that many talented undergraduates actively decide to leave their initial STEM majors on their own accord and are not forced out of these majors by poor performance. In fact, this study found that many undergraduates who left STEM actually had higher STEM grades than their classmates who decided to stay enrolled in STEM majors. This interesting finding begs the question to be asked: Why do these talented and academically able students decide to leave STEM if they are initially interested in pursuing these fields of study? It is this question that this study looks to address.

**Purpose of the Study**

In order to address the study’s research questions, I carried out a grounded theory study of STEM attrition at a large Mid-Atlantic research university. Consistent with typical grounded theory research design, 20 interviews of undergraduates were conducted that serve as the primary method of data collection (Creswell, 2013). Interviews were transcribed and then coded, utilizing traditional grounded theory methods of coding and data analysis. All participants were undergraduates who began their undergraduate careers as STEM majors but decided to switch their majors to other non-STEM disciplines. In order to ensure that I interviewed participants who willfully elected to leave their initial STEM majors, I chose to interview participants who maintained above a 2.0 GPA in core STEM courses, the minimum GPA that is required of College of Science majors at the university where the study was conducted. By engaging in such
methods of data collection and analysis, I have produced a grounded theory that describes both the stated reasons and processes behind undergraduates’ decisions to leave STEM majors in favor of pursuing other non-STEM disciplines.

**Significance of the Study**

According to Maxwell (2013), qualitative investigations such as this study often pursue both intellectual and practical goals. *Intellectual goals* represent research objectives that attempt to contribute to the theoretical knowledge of a subject and perhaps fill a current literature gap that has yet to be addressed by the scholarly community (Maxwell, 2013). This study’s primary intellectual goal is to contribute to the literature on STEM attrition by directly questioning undergraduates who have decided to switch their majors from STEM to non-STEM disciplines, thereby describing the process behind STEM attrition from the perspective and accounts of students who experienced this phenomena first-hand.

The value of collecting and analyzing data drawn from such persons cannot be overlooked. In describing the value of qualitative research in deciphering undergraduate trajectories such as attrition and retention, Harper (2007) writes, "College students are arguably best positioned to offer personalized data and perspectives that help shed light on the magnitude of how they were affected by something in their learning environment, participation in a program or activity, or interactions with faculty and student affairs educators" (p. 58).

Although there has been much academic research in this area, the majority of studies has been quantitative in nature and therefore does not take into the unique perspectives of the participants themselves. Quantitative studies also tend to establish statistical relationships
between one or more variables and STEM attrition, but fail to develop a coherent theoretical understanding of the reasons and processes that affect undergraduates’ decisions to leave STEM majors. This grounded theory investigation of STEM attrition addresses both of these shortcomings in the extant literature.

In addition, this study accomplishes several practical goals. Maxwell (2013) describes practical goals as objectives that are “...focused on accomplishing something—meeting some need, changing some situation, or achieving some objective” (p. 28). This study’s first practical goal is to help reduce STEM attrition on a local level by facilitating a deeper understanding of this phenomenon at the Mid-Atlantic research university where data will be collected. Like many similar universities nationally, the university in question is suffering from a problem of high STEM attrition. Between the entering classes of Fall 2011 and 2012, approximately 16% of undergraduates who had begun their college careers as STEM majors in the university’s College of Science had decided to leave the College and pursue non-STEM courses of study by the Fall of 2014. In addition, another 15% of these students who had enrolled in the university’s College of Science during this same time frame had dropped out of the university altogether by Fall of 2014. The study’s contextual nature sheds light on this local problem and helps university faculty and administrators develop appropriate practices aimed at attracting more students to persist STEM majors.

Furthermore, I hope this study’s findings can contribute to a larger conversation about the causes of STEM attrition nationally and help various STEM and higher education stakeholders better understand the reasons and processes behind this phenomenon. This knowledge can then
be used by stakeholders to develop and implement practices aimed at encouraging more undergraduates to remain committed to their STEM majors.

**Organization of the Dissertation**

Chapter Two of this dissertation contains a review of the theoretical and empirical literature relevant to this study. This review will place this study in a broad intellectual context; an argument will then be made regarding the need for the completion of this study and how this study will contribute to the theoretical literature on the phenomenon of STEM retention. Chapter Three contains a methodological overview of the study and explains how the study was conceptualized, designed, and carried out. Chapter Four describes the results of the study and the emergent grounded theory that explains the reasons and processes behind undergraduates’ decisions to leave STEM majors. Finally, Chapter Five will include a brief summary of the study’s results and a discussion of the implications of this study’s findings that can inform both the academic literature on this field of study and administrative practices aimed at curbing STEM attrition.
CHAPTER 2: REVIEW OF THE LITERATURE

This study looks to illustrate the major reasons and processes that influence undergraduates’ decisions to leave STEM disciplines and major in other non-STEM fields. Before describing the study’s methodology in greater detail, it is first necessary to offer a review of the existing academic literature on STEM attrition. Although grounded theory investigations are methodologically inductive, literature reviews play key roles in these studies by illustrating topics that have not been fully explored by extant literature and that could benefit from grounded theory explorations (Corbin & Strauss, 2008).

As such, this review of the literature reveals that much of the empirical literature on STEM attrition establishes statistical relationships between STEM attrition and one or more variables. The variables that have been found to influence STEM attrition occur both before and during undergraduates’ collegiate experiences, and can be divided into several major categories: (1.) pre-college academic preparation; (2.) achievement motivation; (3.) demographic characteristics; (4.) instructional methods utilized in collegiate classrooms; and (5.) co-curricular programming.

This chapter will begin by describing the extant STEM attrition literature and explain why the current literature base does not adequately explain the reasons and processes behind STEM attrition. The chapter will then explain how this study’s grounded theory design will address this gap in the extant literature by creating a multidimensional conceptual model of STEM attrition.
Pre-College Academic Preparation

Many quantitative investigations have found correlations between undergraduates’ pre-college academic preparation and the likelihood that they will persist or leave STEM majors. Multiple studies have demonstrated that undergraduates who have stronger records of pre-college academic preparation are often more likely to persist in STEM majors. For example, Ackerman et al.’s (2013) quantitative analyses of student data of 1999-2009 Georgia Tech undergraduates found that completion of AP exams in high school was positively correlated with STEM academic performance and persistence in college. Undergraduates who had completed more AP exams were found to be more likely to persist in STEM majors. In addition, undergraduates who had completed more STEM-related AP exams in high school were also more likely to persist in STEM majors than those students who had passed fewer such exams. Kokkelenberg and Sinha (2010) conducted a similar analysis of data from Binghamton University and also found that AP exam completion was correlated with STEM persistence.

High school GPA and standardized test scores have also been found to be correlated with STEM persistence. For example, Espinosa (2011) discovered that high school GPA was a significant predictor of STEM persistence for women of color. In addition, Whalen and Shelley’s (2010) recent study of STEM persistence at a Midwestern university revealed that low ACT scores negatively predicted STEM persistence.

Achievement Motivation

In addition to pre-college academic preparation, there is some evidence that various degrees of achievement motivation influence STEM attrition and persistence. According to Elliot
and Church (1997), “achievement motivation refers to striving to be competent in effortful activities” (as cited in Schunk, 2011, p. 358). Achievement motivation is a broad conceptual term that encompasses several different constructs that have been positively associated with STEM persistence.

The motivational construct of self-efficacy has been most prominently examined in relation to STEM persistence (Lent et al., 2008; McLaughlin et al., 2008; Sawtelle et al., 2012). Self-efficacy can be defined as an individual’s conviction that he or she possesses the necessary ability to achieve a desired outcome (Bandura, 1977). From the perspective of social cognitive theory, such convictions arise from an individual’s interpretation of past experiences within a given domain. For example, if an individual has experienced successful outcomes within a given domain and attributes those successes to his or her personal agency, then said individual will theoretically possess high levels of self-efficacy and is likely to predict future successes in that domain (Bandura, 1989). Such belief patterns are important because they influence motivation and the degree of effort that one will expend to achieve a challenging objective (Bandura, 1989). As such, self-efficacy has been linked to STEM persistence.

For example, Lent et al.’s (2008) survey of 209 undergraduates enrolled in an introductory engineering course found that high self-efficacy beliefs positively predicted STEM outcome expectations, interest, and persistence goals. Sawtelle et al. (2012) also found a positive relationship between levels of self-efficacy and academic performance and conceptual understanding in introductory Physics classes. This study also discovered a positive relationship between women’s levels of vicarious self-efficacy and academic success. However, both of these studies have their flaws. The Lent et al. (2008) study only evaluated self-efficacy in
relation to STEM persistence goals and Sawtelle et al. (2012) defined physics retention as simply passing an introductory physics course. Therefore, neither study operationalized STEM retention and are not able to clearly uncover the relationship between self-efficacy and STEM retention. Furthermore, McLaughlin et al. (2008) did not find a relationship between self-efficacy and undergraduates’ decisions to persist in STEM majors. Although this study found self-efficacy to be positively associated with nursing academic achievement, it did not find a relationship between self-efficacy and persistence towards a nursing degree.

A similar motivational construct, *professional role confidence*, has also been found to be a significant predictor of STEM persistence of female undergraduates. According to Cech et al. (2011), “*professional role confidence* refers to individuals’ confidence in their ability to fulfill the expected roles, competencies, and identify features of a successful member of their profession” (p. 642). This study’s regression analyses revealed that, on average, women in STEM disciplines have less *professional role confidence* than their male peers and that this discrepancy may help explain why women are less likely to persist in STEM majors.

Several other motivational constructs have been studied in relation to STEM persistence and degree completion. For example, several studies have found early interest in science to be a positive predictor of STEM baccalaureate degree completion. Analyses of the NELS:88 longitudinal data set found that undergraduates who completed STEM baccalaureate degrees were more likely to have reported having high interest in pursuing science-related careers during Middle School than undergraduates who did not earn such degrees (Tai et al., 2006; Maltese and Tai, 2011). Kokkelenberg and Sinha’s (2010)’s analysis of student-level data from Binghamton
University also revealed that “long-term interest in STEM” is one of the significant predictors of STEM persistence to graduation.

Expectancy-value theory has also been applied by several studies to the issue of STEM persistence. *Expectancy-value theory* states that individuals are more likely to be motivated to achieve a particular goal if they expect their efforts to achieve the goal to be successful and if they value the achievement of said goal (Schunk, 2011). For instance, Burtner’s (2005) longitudinal study demonstrated a correlation between factors associated with expectancy-value theory and Engineering persistence. This study’s discriminant analysis found that “…confidence in college-level math and science ability, and the belief that an engineering degree enhances career security were significant predictors of persistence” (Burtner, 2005, p. 337). In addition, Andersen and Ward’s (2014) recent study of the relationship between various motivational constructs and the STEM persistence plans of high-ability high school students found that “…ninth-grade, high-ability students who have a higher attainment value for science are more likely to plan to persist in STEM” than those students who possess a lower science attainment value.

Similarly, Sullins et al.’s (1995) study of 181 undergraduates taking an introductory biology course found that undergraduates who more highly valued the subject of biology and expected future success in the field were more likely to be Biology majors. However, this study does not specifically relate expectancy-value theory to the problem of STEM attrition because it only applied the construct to the prediction of Biology majors at one point in time.
Demographic Characteristics

Empirical research has illustrated a correlation between several demographic characteristics and STEM persistence. For example, many studies have found that women persist less frequently in STEM majors than do men. Astin and Astin’s (1992) landmark study of STEM persistence analyzed longitudinal data of over 27,000 college students and found that women exhibit lower STEM persistence rates than do men. More recent studies have come to the same conclusion regarding the relationship between gender and STEM persistence (Barr et al., 2008; Whalen & Shelley, 2010).

Similarly, much empirical literature exists that describes the inverse relationship between underrepresented minority group status and STEM persistence (Barr et al., 2008; Hurtado et al., 2010; National Academy of Sciences (US), National Academy of Engineering (US), and Institute of Medicine (US) Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline, 2011; Whalen and Shelley, 2010). Recent data analyses reveal that minority undergraduates are much less likely to persist in STEM majors than their white and Asian peers.

For instance, Hurtado et al.’s (2010) analysis of data from UCLA’s 2004 CIRP Freshman Survey and the 2008-09 National Student Clearinghouse revealed that “Approximately 33% and 42% of White and Asian American STEM majors, respectively, completed their bachelor’s degree in STEM within five years of college entry. In contrast, five-year STEM completion rates for Latino, Black, and Native American students were 22.1%, 18.4%, and 18.8%, respectively.” In addition, underrepresented minorities are severely underrepresented in STEM disciplines compared to their overall percentage of the U.S. population. In 2006, URM’s represented 28.5%
of the U.S. population but only 9.1% of STEM graduates. These statistics are particularly troubling because URM’s aspire to major in STEM disciplines at the rate as their white and Asian-American peers, yet persist in far fewer numbers than non-URM students (National Academy of Sciences (US), National Academy of Engineering (US), and Institute of Medicine (US) Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline, 2011).

This problem of the underrepresentation of minority students in STEM disciplines due to their relatively low STEM persistence rates must be addressed if the United States is to reduce the current STEM worker shortage and maintain its status as an economic superpower.

Andersen and Ward (2014) state,

> Future scientists, mathematicians and engineers should come from the talent pool consisting of all students who have high ability or demonstrate superior performance in mathematics and science. Demographic trends in the United States indicate that population diversity is rapidly increasing. Understanding the variables that facilitate STEM persistence for talented Black and Hispanic students is important, not only to provide equitable outcomes for these students compared to the outcomes attained by their White and Asian peers but also to ensure the viability of the U.S. STEM workforce. (p. 217)

While such empirical investigations highlight the disparities among disparate demographic groups regarding STEM attrition, they are unable to shed light on the reasons and processes behind women and underrepresented minorities’ decisions to leave STEM majors in greater percentages than their male and white peers. Qualitative investigations such as this study can contribute to this knowledge base and help higher education stakeholders better understand the challenges facing these students in their efforts to complete STEM degrees.
Instructional Methods

Research indicates that STEM attrition is not only correlated with undergraduates’ academic preparation, achievement motivation, and demographic characteristics, but with the classes and instructional practices that students are exposed to once they arrive in college. Despite mounting evidence of the value in utilizing such active and collaborative instructional methods, a recent survey of higher education faculty revealed that 63% of STEM faculty utilize lecturing “extensively” in their classes. Furthermore, this study also revealed that STEM faculty lecture more than faculty in any other academic discipline (Berrett, 2012). Perhaps as a result of this reliance on traditional instructional methods, many talented STEM undergraduates decide to ultimately leave STEM majors due to their dissatisfaction with the STEM curricula (Tobias, 1990; Alberts, 2005; Mervis, 2010).

Tobias (1990) found that student dissatisfaction with undergraduate STEM courses may be a significant cause of attrition. In her qualitative study, participants criticized STEM introductory courses for their lack of engaging intellectual content and student community. The author recommends that in order to reduce STEM attrition, educators must become serious about improving the quality of STEM educational offerings and face the serious challenges posed by the large class sizes, poor pedagogy, and unwelcoming climates that often characterize STEM introductory classes.

Similarly, Seymour and Hewitt’s (1997) landmark study of STEM attrition supports the notion that many undergraduates decide to leave STEM majors due to the quality of educational offerings in STEM disciplines. In fact, widespread dissatisfaction with the quality of undergraduate STEM offerings was often identified by students as one of their chief reasons for
leaving their STEM majors. In describing the results of their qualitative analysis, Seymour and Hewitt (1997) write,

> All of the four most highly-ranked factors contributing to switching decisions reflect some aspect of teaching, or rate the quality of learning experiences offered by S.M.E. faculty as poor, compared with those offered by former high school science teachers, and/or faculty in non-S.M.E. decisions. The significance of these factors does not end here. In one way or another, concerns about S.M.E. faculty teaching, advising, assessment practices and curriculum design, pervade all but seven of the 23 issues represented in our 'iceberg' tables. (p. 23)

More recently, a study by the National Academies states that a significant impediment to retaining greater numbers of undergraduate STEM majors are the large introductory classes that students often encounter when they first enroll in STEM majors. Efforts to retain more STEM undergraduates must begin with transforming these classes and improving the educational experiences students encounter when they first enroll in STEM majors (Mervis, 2010).

In addition, there is also mounting empirical evidence that supports this position and discovers correlations between the use of active and collaborative instructional methods in the classroom and STEM learning and persistence (Hake, 1998; Lyon and Lagowski, 2008; Paulson, 1999; Springer, 1999). Prince (2004) defines active learning instructional methods “…as any instructional method that engages students in the learning process” (p.223), whereas collaborative learning instructional methods involve small groups of students working together to achieve common goals. These methods have been demonstrated effective in improving STEM learning and persistence in higher education.

For example, Springer’s (1999) meta-analysis of 39 studies conducted between 1980 and 1999 found that the use of collaborative learning instructional methods positively impacted STEM undergraduate achievement and persistence. Springer (1999) writes,
The main effect of small-group learning on achievement, persistence, and attitudes among undergraduates in SMET was significant and positive...Based on 49 independent samples, from 37 studies encompassing 116 separate findings, students who learned in small groups demonstrated greater achievement (d = 0.51) than students who were exposed to instruction without cooperative or collaborative grouping. Similarly, based on 10 independent samples and findings from 9 studies, students who worked in small groups persisted through SMET courses or programs to a greater extent (d = 0.46) than students who did not work cooperatively or collaboratively. (p. 7)

Springer’s (1999) findings are supported by Paulson (1999). Comparing the grades and persistence of students taking organic chemistry classes taught by utilizing active and collaborative instructional methods with the grades and persistence of students taking organic chemistry classes taught by using a more traditional lecture format, Paulson (1999) found that the students in the classes taught by using the active and collaborative instructional methods had higher grades and double the retention rate (75% to 38%) of students in the more traditional lecture classes.

Additionally, other studies have found strong statistical correlations between the use of active and collaborative instructional methods and undergraduate academic performance in STEM courses. For example, one large-scale study involving over 6,000 students taking 62 different introductory physics classes between 1992 and 1996 found that students taking classes utilizing active and collaborative instructional methods performed two standard deviations better on the Force Concept Inventory, a measure of scientific problem-solving abilities, than students who took traditional lecture classes (Hake, 1998). While this study did not specifically address the issue of STEM attrition, it still has much to contribute to the discussion on this topic. When students learn more, they tend to be more satisfied with their academic work and therefore achieve a sense of academic integration that can help promote student persistence and retention.
Furthermore, the use of active and collaborative instructional methods often fosters social relationships between students themselves and between students and faculty members. These relationships can promote social integration which also helps to promote student persistence and retention (Braxton & Milem, 2000). Therefore, Hake’s (1998) findings further support the importance of using active and collaborative instructional methods in STEM classrooms as methods that might contribute to STEM persistence.

In addition, there is also evidence that more advanced uses of active and collaborative instructional methods, such as flipped classrooms, can improve undergraduates’ learning and satisfaction with STEM educational offerings. *Flipped classrooms* are a specific curricular intervention aimed at improving large introductory classes in which undergraduates are expected to review lecture notes and content videos before coming to class, so that class time can be spent discussing conceptual questions and engaging in problem-solving activities with their peers (McGivney-Burelle & Xue, 2013).

Mazur (2009) notes that his utilization of the flipped classroom model in Harvard University’s undergraduate Physics courses has resulted in widespread gains in student learning over his previous use of the traditional lecture model. There is also evidence that the use of flipped classrooms improves STEM learning in other higher education contexts, as well. Love et al. (2013) illustrates that students in an undergraduate Algebra course demonstrated greater content understanding and satisfaction with their academic experiences when taught by the flipped classroom model, when compared to their peers in a traditional lecture section of the same course. Similarly, McGivney-Burelle and Xue (2013) found benefits to using the flipped classroom model in undergraduate Calculus classes. The authors write,
Overall, there was enough evidence to indicate that our flipping pedagogy in calculus was effective and worth the significant investment of faculty time and effort. Students in the flipped section of the course preferred this type of pedagogy, particularly the availability of videos and the use of class time to solve problems, and fared better on homework and tests. We look forward to developing more flipped units for our calculus courses and to conducting further research on the impact of this type of pedagogy on student perceptions of and performance in mathematics. Furthermore, we believe flipping pedagogy has the potential to work well across a range of mathematics, as well as other STEM courses, and are encouraged by the growing national interest in this type of pedagogy which will certainly lead to new insights, strategies, and tools. (p. 485)

Co-Curricular Programming

Supplemental instruction. Undergraduate participation in various co-curricular programs has also been illustrated to strengthen STEM academic performance and persistence. For instance, empirical evidence has demonstrated that Supplemental Instruction, a co-curricular peer-tutoring program that began in the 1970’s, is particularly effective at helping students excel academically in STEM disciplines and increasing persistence rates (Lundeberg, 1990; Shaya et al., 1993; Peterfreund et al., 2007; Terrion and Daoust, 2011). Supplemental Instruction (SI) was developed in 1973 at the University of Missouri-Kansas City to help undergraduates pass “high risk” classes in which 30% or more of the class enrollments received “D’s” or “F’s”. A key component of SI is that its services are offered to all students enrolled in “high risk” classes, thereby reducing the stigma associated with receiving peer tutoring. SI tutoring sessions are held outside of regular class time (usually once or twice per week) and are led by older undergraduates who have previously excelled in the “high risk” class in question. Tutoring sessions are taught utilizing collaborative learning instructional methods that foster high-levels of student interaction (Arendale, 1994).
Numerous empirical studies indicate the effectiveness of SI in facilitating academic performance and persistence in STEM disciplines. Lundeberg (1990) collected data on 148 undergraduates taking General Organic and Biology Chemistry classes over a two-year period. Her data analysis revealed that undergraduates participating in supplemental instruction had a 2.80 mean grade point average, compared to a 2.26 grade point average for students who did not participate in supplemental instruction. Furthermore, no students who participated in SI withdrew from these courses.

Similar results were also produced by a much larger study conducted by Hensen and Shelley (2003). Collecting data from over 7,000 students enrolled in entry-level STEM courses during the 1999-2000 academic year, they discovered that SI participants, on average, earned higher final course grades and had fewer course withdrawals than students who did not participate in SI. These statistics are even more impressive considering that the study controlled for the prior academic achievement of the two groups. SI participants outperformed non-participants in the STEM courses despite having lower ACT scores, on average (Hensen and Shelley, 2003).

Peterfreund et al. (2007) provides the strongest evidence that SI positively impacts STEM persistence over a series of undergraduate courses. Analyzing student data from 22 STEM courses over a six-year period at San Francisco State University, they concluded that SI participation not only positively affected academic performance but progression through a sequence of STEM classes. That is, students who participated in SI were more likely to earn higher grades and persist through a series of STEM courses than students who did not participate. Peterfreund et al. (2007) state, “Students who take an accompanying SI class at the
beginning of their sequence of chemistry or biology courses also take the subsequent courses in that discipline required by many majors at a much higher rate than those who do not take SI…” (p. 494). This analysis is also noteworthy because it controlled for students’ prior academic performance; SI participants, on average, had lower SAT scores and high school GPA’s than non-participants (Peterfreund, Rath, Xenos, & Bayliss, 2007).

Furthermore, a related study over the same period at San Francisco State University revealed that supplemental instruction is particularly effective at improving minority students’ academic performance and retention in STEM courses. Between 1999 and 2005, minority students who participated in supplemental instruction had higher final grades and persistence rates than minority students who did not participate in SI. Perhaps most telling, minority students were more likely to graduate with a bachelor’s degree in a STEM discipline when they participated in supplemental instruction (Rath et al., 2007). This article is particularly noteworthy due to the changing demographics of the United States and American colleges and universities. As greater percentages of minorities make up the U.S. population and populate American campuses, higher education institutions will need to take steps to encourage minority students to major in STEM disciplines if they are serious about increasing the overall numbers of American college students who graduate with such degrees. This is especially true considering minority students currently earn STEM degrees at far lower rates than their white peers (Stine & Matthews, 2009).

Gateway science workshop. Northwestern University’s Gateway Science Workshop (GSW) is another co-curricular peer tutoring program that has been found to improve STEM learning and persistence. Similar to Supplemental Instruction (SI), the Gateway Science
Workshop’s peer tutoring sessions are voluntary, take place outside of regular class hours, and are associated with specific STEM courses. The tutoring sessions consist of small groups (5-7 students) of undergraduates meeting weekly for 2 hours with a more experienced undergraduate peer mentor, who leads the group in collaborative problem-solving activities. The peer mentors receive extensive training in research-based instructional practices that have been demonstrated to improve student learning (Light & Micari, 2013).

Empirical evidence suggests its effectiveness in achieving several important outcomes. Students participating in the Gateway Science Workshop achieve higher grades in associated STEM courses, and are more likely to persist through Northwestern’s sequence of STEM courses, than students who do not participate in the program. Furthermore, survey results revealed that participating students reported high levels of satisfaction with their participation in the program (Light & Micari, 2013).

**Targeted intervention programs.** There is also some evidence that targeted STEM intervention programs, those co-curricular programs designed to reduce STEM attrition among certain targeted student populations, have been successful in reducing STEM attrition and increasing student persistence in STEM majors. Perhaps the most common of these programs are the various minority intervention programs that have been charged with helping URMs complete STEM baccalaureate degrees. For example, it has been demonstrated that minority undergraduates who participate in the Howard Hughes Medical Institute Professors program, an intervention program that provides students with mentoring support, research opportunities, and financial support, are more likely to complete STEM baccalaureate degrees than minority students who do not participate (Wilson et al., 2012). Participation in the RISE program, another
minority intervention program that provides students with mentorship and research opportunities, has been found to positively influence undergraduates’ desire to pursue STEM research careers (Wesley Schultz et al., 2011).

**Summary of the Literature**

This review of the empirical literature on STEM attrition reveals that undergraduates’ decisions to persist or not persist in STEM majors is correlated with a variety of variables. Inherent demographic characteristics, pre-college academic preparation, elements of achievement motivation and various dimensions of the college curricula and co-curricular environments have all been demonstrated to impact STEM persistence. In particular, undergraduates who enter college less academically prepared, are members of underrepresented minority groups or are women, and are exposed to more traditional modes of content delivery such as lecturing are less likely to remain in STEM majors. Participation in certain co-curricular programs such as Supplemental Instruction (SI) and targeted intervention programs have been shown to increase motivation and reduce STEM attrition. Therefore, STEM persistence decisions are likely influenced by a variety of variables that occur both before and during the collegiate experience.

However, it should be noted that the extant research on this subject is predominately quantitative in nature. While quantitative research is certainly a useful tool in understanding questions of variance, it is not the best research method for understanding the “why” and “how” of STEM attrition, or for understanding how different factors relate to one another within cases
or contexts (Maxwell, 2013). A recent qualitative investigation into engineering attrition explains the currently situation of STEM attrition research thusly,

Significant research has been done on the reasons why undergraduates leave engineering…however, the vast majority of the literature has been quantitative in nature and does not focus on the voices of students who leave engineering. We are missing a deeper understanding of the reasons and justifications students give for leaving engineering that can be gained through qualitative inquiry.” (Meyer & Marx, 2014, p. 529)

As a result of these scholarly limitations, Lang (2008) notes that relatively few studies have examined why undergraduates leave STEM majors to pursue non-STEM majors, and Griffith (2010) argues that extant scholarship on STEM attrition still has not identified the specific factors that influence undergraduates’ decisions to either persist or leave STEM majors.

Therefore, scholars have begun to call for a wider array of research methods to be used in studying STEM attrition. For instance, Tobias (1990) has called for the utilization of research methods that directly query STEM undergraduates who leave STEM majors about their persistence decisions in order to better understand why so many undergraduates decide to leave STEM disciplines to major in non-STEM fields. This knowledge can then be used colleges and universities to craft effective strategies for encouraging more undergraduates to persist in their STEM studies (Tobias, 1990). Chen and Soldner (2013) have emphasized the need to utilize research methods capable of examining multiple causal influences concurrently. They write, “The review of past research suggests that students’ decisions to leave STEM fields are likely to arise from a multitude of factors, underscoring the need to examine models of STEM attrition that include multiple factors simultaneously” (Chen & Soldner, 2013). As such, a grounded
theory of STEM attrition is positioned to contribute to the extant scholarly literature and helps fill the current literature gap.

Why does this literature gap exist? One reason is that many qualitative studies have focused more on persistence, that is, why certain undergraduates have chosen to remain committed to their STEM studies rather than pursue other majors. The knowledge gleaned from such studies can then be utilized in efforts to retain more undergraduate STEM majors. In addition, these studies also tend to have a limited demographic focus and concentrate on the STEM persistence of either minority or female students, since these groups of students have traditionally been underrepresented in STEM majors and leave STEM majors in greater percentages than their white and male peers. This phenomenon of STEM attrition literature focusing on the STEM persistence decisions of minority and female students is noted by Seymour and Hewitt (1997) who write,

Prior to 1990, there was no body of work that had explored the range of factors contributing to attrition among both male and female undergraduates, different racial or ethnic groups, and different S.M.E. majors. Theories of attrition based on research tended to be limited in scope. Studies focused on particular groups (often women), were offered as by-products of research into other issues... (p. 8)

For example, Charleston (2012) explored the factors that influence African-Americans’ decisions to pursue computer science degrees. This grounded theory study interviewed 37 “persisters” at various stages of the STEM pipeline—undergraduates, graduate students, and professors, in order to produce a grounded theory of minority students’ Computer Science persistence. Various variables related to pre-college academic preparation and collegiate experiences, including “early advanced engagement with computers and computing” and
“computing-related cohort building,” were found to positively influence minority persistence in Computer Science degrees.

Similarly, Ellington (2006) utilized a case study methodology to examine the factors that have contributed to African-Americans’ decisions to persist in Math majors; this study also discovered that both pre-college and college experiences (e.g. advanced science/math coursework in elementary/high school; peer support; teacher encouragement; financial aid; perception of faculty/peer support during college; social consciousness/spirituality during college years) contributed to the STEM persistence decisions of minority students.

Furthermore, Justin-Johnson (2004) utilized a phenomenological approach and interviewed recent STEM graduates to investigate the STEM “persistence experiences” of African-American women at PWI’s who decided to remain committed to their STEM majors and ultimately graduated with STEM baccalaureate degrees. Participants generally described the environments of PWI’s as non-supportive to the STEM persistence of minority students. However, successful minority persisters who were able to complete STEM baccalaureate degrees were found to utilize various support mechanisms that supported their persistence.

All three of these studies focused their attention on “successful” STEM students who have completed STEM degrees and made it through the STEM pipeline. In addition, one case study (Perna et al., 2009) examined “why” and “how” one HBCU has achieved great success in facilitating the STEM persistence of minority women. The results of this study demonstrated that various institutional characteristics, such as small class sizes, supportive environments, and the availability of academic support services and undergraduate research opportunities, contributed to this institution’s ability to facilitate the STEM persistence of women of color.
This body of research has been successful in identifying the salient characteristics of certain groups of STEM “persisters,” as well as institutional characteristics that are essential in helping students persist in STEM majors. However, more research is needed to identify the specific reasons and processes why undergraduate choose to leave STEM disciplines to pursue other courses of study. More specifically, certain students who leave STEM majors might possess the same characteristics as their peers who persist in the same fields of study. Why might that be the case?

Similar to the research that has examined STEM persistence, the research that has qualitatively explored STEM attrition is often limited in methodological and demographic scope. For example, several works have examined the reasons behind undergraduate attrition in nursing majors (Wells, 2007; Cook, 2010). Wells (2007) found that undergraduates leave Nursing majors due to four specific factors: disillusionment with the Nursing program, perceived lack of academic support, disillusionment with campus life, and external stressors such as family problems. Alternatively, Cook (2010) attributed Nursing attrition to diminishing “psychic strength.” A more recent study, Meyer and Marx (2014), investigated engineering attrition and discovered that students’ decisions to leave engineering were impacted by both individual and institutional factors.

In addition, other works have explored STEM attrition from the perspective of underrepresented minority groups (Johnson, 2001; Varma, 2002). Johnson (2001) found that a fundamental conflict of values between women of color and STEM academic departments contributed to undergraduate attrition, while Varma (2002) demonstrated the tensions between
academic and familial responsibilities to be a root cause of attrition of women studying computer science and computer engineering in a minority-serving institution.

These studies, while valuable for their contribution to knowledge on STEM attrition, only speak to the attrition experiences of limited student populations and do not capture the lived realities of different student populations pursuing STEM degrees in a variety of undergraduate disciplines.

The one extant qualitative work that does not suffer from such a limited methodological or demographic focus, Seymour and Hewitt’s (1997) classic *Talking About Leaving: Why Undergraduates Leave the Sciences*, conducted an investigation into why undergraduates so often fail to persist in STEM majors. This study identified 23 factors, mostly related to undergraduates’ dissatisfaction with their educational experiences in STEM coursework, that contribute to STEM attrition. Although these are important findings, the study did not produce a grounded theory that can illustrate how a coherent theoretical process over time contributes to STEM attrition. Such a process can demonstrate how various concepts fit into a conceptual model that explains the targeted process of STEM attrition. Furthermore, *Talking About Leaving* is nearly 20 years old and might not adequately address the reasons and processes behind STEM attrition of a new generation of college students.

Therefore, this proposed qualitative study of STEM attrition fills the current literature gap and contribute to the extant literature on this topic in three ways. First, unlike many qualitative investigations of STEM persistence that often highlight the persistence stories of successful STEM undergraduates, this study explores the reasons and processes behind undergraduates’ decisions to leave STEM majors. As Cook (2010) notes in her grounded theory
investigation of nursing attrition, understanding the root causes of attrition is the first step in developing retention programs aimed at reducing attrition.

Second, this study utilizes a wider scope than many previous domain- and demographically-specific qualitative studies of this topical area and interview undergraduates from a wide variety of demographic backgrounds, thereby describing the phenomenon of STEM attrition from a diversity of undergraduate perspectives.

And finally, this study not only examines individual factors that influence STEM attrition, but also the process behind STEM attrition. It addresses the following sub-questions: What are the concrete temporal steps that precede these attrition decisions? For example, do students seek advice from their advisors or faculty before leaving STEM majors? Do they consult their parents? If they are having academic difficulty in their STEM-related courses, do they seek outside assistance? This study sheds light on such process-related questions related to STEM departure

In this way, this study produces a grounded theory of STEM attrition that outlines the reasons and processes behind the STEM attrition decisions of a wide variety of undergraduates that can inform both scholarly theory and administrative practices aimed at curbing attrition and promoting persistence in STEM disciplines, and therefore fulfill this investigation’s intellectual and practical objectives.
CHAPTER 3: RESEARCH METHODS

Overview of Study

The goal of this study is to produce a grounded theory of STEM attrition that explains the process and related reasons behind undergraduates’ decisions to leave STEM majors. In order to accomplish this objective, I interviewed undergraduates at a Mid-Atlantic research university who had previously declared a STEM major during their freshman year but since switched to another non-STEM field of study. By utilizing research methods consistent with grounded theory traditions of inquiry, the study addresses the following research question:

What process describes and explains undergraduate students’ decisions to discontinue in STEM majors at large research universities?

In this chapter, I will explain the research methods I utilized to address these research questions, beginning with a short summary of the nature of qualitative research and grounded theory, and continuing on to describe the study’s methodology, participant selection, data collection and analysis, validity, and limitations.

Qualitative Research

In order to address the research question posed by this study, I have chosen to utilize qualitative research methods. Qualitative research seeks to discover and understand “the meaning individuals or groups ascribe to a social or human problem” (Creswell, 2013, p. 44) through the collection of data in natural settings. Ultimate meaning and “truth” lies in the minds of the research participants, who describe to the researcher their own personal interpretations of the problem being addressed by the research study. Unlike quantitative research which nominally
seeks a more “objective” reality through the utilization of statistical methods and the purported elimination of bias through large numbers and random selection, qualitative research embraces and seeks to better understand the perspectives of individuals who have something to say about the subject matter at hand. In order to accomplish this objective, the qualitative researcher uses various data collection methods, such as interviewing and direct observations, in a naturalistic setting to better understand the perspectives of the research participants within their own unique contexts (Creswell, 2013).

In addition, qualitative research tends to focus on particular types of research questions that are often unsuitable for quantitative analysis. For example, “…quantitative researchers tend to be interested in whether and to what extent variance in x causes variance in y,” whereas “…qualitative researchers, on the other hand, tend to ask how x plays a role in causing y, what the process is that connects x and y” (Maxwell, 2013, p. 31). Furthermore, qualitative research allows for a more detailed investigation of the research problem being explored than is usually possible with quantitative methods. Creswell (2013) writes, "We conduct qualitative research because a problem or issue needs to be explored…We also conduct qualitative research because we need a complex, detailed understanding of the issue" (p. 48).

These features of qualitative research that allow for the deep exploration of “how” and “why” research questions make qualitative research methods the ideal tools for investigating this study’s research questions. By utilizing qualitative research methods, this study will probe the reasons (the “why”) and processes (the “how”) behind undergraduates’ decisions to leave STEM majors and ultimately produce a grounded theory of STEM attrition that will move beyond the surface level explanations of this phenomena often produced by quantitative research.
**Grounded Theory**

More specifically, this study not only answers this study’s research questions by using qualitative research methods, but produces a grounded theory of STEM attrition. Grounded theory is a particular analytic technique that is rooted in symbolic interactionism and the belief that individual psychology and motivation are impacted by the social meanings individuals derive from intersubjectivity. Individuals’ self-concepts and personal motivations are ever evolving as they develop meaning based on their interactions with the outside world (Charmaz, 2014). Furthermore, grounded theory assumes an ontological reality in which the world is inherently complex but “discoverable.” In describing the ontological perspective behind grounded theory, Corbin and Strauss (2008) write, “The world is very complex. There are no single explanations for things. Rather, events are the result of multiple factors coming together and interacting in complex and often unanticipated ways” (p. 8). Phenomena such as STEM attrition are caused by multiple factors that must be examined in order to better understand how they impact the phenomenon under investigation, as well as how they influence each other (Corbin & Strauss, 2008).

Grounded theory presumes that such “multiple factors” that influence events such as STEM attrition can be known by the event’s participants. Knowledge about events is tied to the experiences of participants who construct such knowledge through a process of self-reflection (Corbin & Strauss, 2008). This process of self-reflection can be facilitated by grounded theory researchers who, through the interviewing process, can assist participants in the retelling of their experiences and perspectives on the reasons and processes underlying the phenomenon under investigation. By interviewing multiple participants who experienced a phenomenon first-hand,
grounded theorists gather conceptual data that can then be analyzed and developed into a theoretical framework that explains the phenomenon in question (Corbin & Strauss, 2008).

This process of theory building presumes knowledge can be constructed by both participants and researchers alike. Event participants, through self-reflection, create knowledge in light of their own personal biases and experiences, whereas researchers then analyze and interpret participants’ experiences, thereby constructing theory (Corbin & Strauss, 2008).

In order to produce such theories, grounded theory uses research methods such as interviewing to gather data that can highlight the various phenomena and processes under investigation (Charmaz, 2011). Therefore, in this research study, I will aim to not simply describe the various reasons and processes behind undergraduates’ decisions to leave STEM disciplines, but collect and analyze data through an interpretive process to produce a coherent theory of STEM attrition that can inform and guide both future research and administrative practice in the hopes of helping reduce STEM attrition.

Furthermore, this process of theory building is inductive in nature and rooted in the perspectives of the participants being interviewed for this study who have personally experienced STEM attrition (Creswell, 2013). As such, the generated theory holds the potential to offer fresh insights into STEM attrition that have not been discovered by previous empirical research and therefore contribute to the scholarly and administrative conversation on a much-debated local and national issue.
Site and Participant Selection

Site selection. In order to conduct a grounded theory study of STEM attrition and answer the research questions described above, I interviewed 20 undergraduates who began their college careers as STEM majors but have decided to major in non-STEM disciplines (Creswell, 2013). The study was conducted at Mid-Atlantic research university¹ that is also experiencing a problem of relatively high STEM attrition. Informal conversations with College of Science faculty and the Associate Dean reveal that this university’s College of Science is indeed struggling with the problem of STEM attrition and has gathered quantitative data to study the issue. Between the entering classes of Fall 2011 and 2012, approximately 16% of undergraduates who had begun their college careers as STEM majors in the university’s College of Science in Fall of 2012 had decided to leave the College and pursue non-STEM courses of study by the Fall of 2014. Many of these undergraduates who enter the College of Science as STEM majors decide to major in other non-STEM disciplines, such as the liberal arts, business, education, and communications. In addition, another 15% of these students who had enrolled in the university’s College of Science in the Fall of 2011 or 2012 had dropped out of the university altogether by Fall of 2014.

Although the STEM attrition numbers at this Mid-Atlantic research university are not as high as the national STEM attrition numbers, administrators at this university are still concerned with this issue and are eager to learn more about why so many of their students who begin their college careers as STEM majors in the College of Science ultimately decide to leave and pursue non-STEM majors. While the College of Science keeps such quantitative statistics, no in-depth

¹ I will refer to this Mid-Atlantic research university where the study was conducted as State University throughout the remainder of this document.
qualitative research that interviews undergraduates who have decided to leave the College of Science to major in non-STEM disciplines has been conducted to date that examines the process behind these decisions. Therefore, the grounded theory produced by this study, in addition to contributing to the theoretical literature on the issue of STEM attrition, will also help this institution’s College of Science better develop policies to help reduce STEM attrition on its campus. As such, the Associate Dean of the College of Science agrees with my assessment that my project will provide a much-needed fresh theoretical perspective into this important issue.

**Participant selection.** Consistent with traditional qualitative and grounded theory research methods, participants for this study were selected on the basis of purposeful sampling. As Conrad (1978) notes, participants in grounded theory studies “…should be selected on the basis of their theoretical relevance” (p. 104). By studying participants who possess such “theoretical relevance,” qualitative researchers are able to talk with individuals who have something important to say about the phenomenon under investigation and thereby more deeply investigate a topic than might normally be possible by using quantitative methods that rely on large-scale random sampling (Patton, 1990). Therefore, participants were recruited who have experienced STEM attrition at the participating institution and who can shed light on the reasons and processes behind their decisions to leave STEM majors to pursue non-STEM courses of study.

I decided to interview participants who have actively elected to leave their initial STEM pre-majors, rather than students who might have been forced to leave the College of Science due to poor academic performance. As noted earlier, there is research that indicates many students who leave STEM majors are academically capable students who are able to do the work
associated with STEM majors but freely choose to leave these disciplines (Seymour & Hewitt, 1997). As such, I focused my participant selection process on these students because I believed interviewing participants who have freely decided to leave STEM will yield more theoretically relevant data that can best help scholars and administrators alike better understand the process behind STEM attrition.

In addition, I utilized a form of purposeful sampling known as maximum variation sampling that aims to describe “…the central themes or principal outcomes that cut across a great deal of participant or program variation” (Patton, 1990, p. 172). Unlike extant qualitative investigations of STEM attrition and retention, this study did not limit its participant selection process to a particular demographic group of undergraduates, but rather, sought to recruit individuals of different demographic backgrounds in order to develop a grounded theory that can speak to the commonalities of undergraduates’ experiences that influence the STEM attrition process.

More specifically, participants were recruited who meet the following criteria:

1. Entered the College of Science during Fall 2011 or Fall 2012 semester²
2. Spent at least one semester enrolled in the College of Science
3. Maintained above a 2.0 GPA in core STEM courses that are required of College of Science majors
4. Left STEM major in the College of Science to major in non-STEM discipline
5. Currently majoring in non-STEM discipline

As such, I sought to recruit participants who were currently enrolled juniors or seniors (at the time of the study) who began their college careers as STEM majors but have since decided to

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² State University College of Science freshmen begin college as pre-majors later in their college careers. I will subsequently refer to participants as majors to avoid confusion.
switch their majors to other non-STEM fields of study.

Furthermore, participants were recruited with the assistance of the College of Science. The Associate Dean pledged the College’s support for my study and allowed the College to send out an email to the students who met the criteria listed above that described the nature of the research study and solicited (voluntary) participation in the study. Interested students were asked to directly email me for more information or to schedule a convenient interview day and time. I then contacted the prospective participants to set up an interview at a mutually convenient day and time.

The exact number of interviews was determined by the conventions of grounded theory investigations, which relies primarily on achieving theoretical saturation. According to Charmaz (2011), *theoretical saturation* is reached “…when gathering fresh data no longer sparks new theoretical insights, nor reveals new properties of your core theoretical categories” (p. 113). Therefore, this study initially aimed to conduct approximately 20-25 interviews and to continue interviewing suitable participants until theoretical saturation had been met.

Ultimately, I determined that theoretical saturation had been met after interviewing twenty research participants who answered the initial recruitment solicitation email that was sent out by the College of Science. Fifteen women and five men were interviewed at various private locations on the university’s campus that allowed the participants’ privacy to be maintained during the interview process. Interviews lasted approximately thirty to sixty minutes and were tape recorded and then transcribed. All participants have been assigned a pseudonym that allows
the participants to be described in the study while maintaining individual privacy. The list of participants, their assigned pseudonyms, and relevant categorical information is contained below.

Table 3.1: List of Participants

<table>
<thead>
<tr>
<th>Alias</th>
<th>Gender</th>
<th>Minority Status</th>
<th>Enrollment</th>
<th>Initial Major</th>
<th>STEM Grades</th>
<th>Time in STEM</th>
<th>Current Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mary</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Freshman Year: 3.5 GPA</td>
<td>2 semesters</td>
<td>Sociology</td>
</tr>
<tr>
<td>Sarah</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology</td>
<td>Chem 100: B-</td>
<td>2 semesters</td>
<td>Elementary Education w/ Minor in Special Education and Dance</td>
</tr>
<tr>
<td>Scott</td>
<td>Male</td>
<td>No</td>
<td>Senior</td>
<td>Physics</td>
<td>First semester: 2.92 GPA Chem 100: C+ Physics: B</td>
<td>1 semester</td>
<td>Risk Management w/ Option in Actuarial Science</td>
</tr>
<tr>
<td>Jane</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Forensic Science w/ Focus on Biology</td>
<td>Chem 100: B+ Freshman year: 3.8 GPA <strong>Chem 102: D Microbiology: dropped</strong></td>
<td>3 semesters</td>
<td>Criminology and Art History</td>
</tr>
<tr>
<td>Eric</td>
<td>Male</td>
<td>No</td>
<td>Senior</td>
<td>Chemistry</td>
<td>N/A</td>
<td>3 semesters</td>
<td>Finance</td>
</tr>
<tr>
<td>Kate</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Forensic Science w/ Chemistry Option</td>
<td>First semester: 3.22 <strong>Chemistry: D’s</strong></td>
<td>2 semesters</td>
<td>Criminology Spanish Global and International Studies</td>
</tr>
</tbody>
</table>

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3 All participants were assigned pseudonyms to protect their identity. All information contained in this chart was self-reported by participants. The course numbers have been changed to further protect participant identity.
<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Married</th>
<th>Year</th>
<th>Major</th>
<th>Courses Taken</th>
<th>Semesters</th>
<th>Major Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cynthia</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Bio 100: B+ Math 100: B Math 102: B First semester: 3.2 GPA Chem 100: F; D</td>
<td>2 semesters</td>
<td>Psychology w/ Focus on Neuroscience</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Chemistry</td>
<td>N/A</td>
<td>1 semester</td>
<td>Chemistry Education</td>
</tr>
<tr>
<td>Madison</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Pre-Med</td>
<td>Bio 100: B+ Chem 100: B+ Math: C's</td>
<td>3 semesters</td>
<td>Rehabilitation and Human Services</td>
</tr>
<tr>
<td>Charlotte</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biochemistry</td>
<td>Physics: C Chem 102: B+ First semester: 3.7 GPA</td>
<td>3 semesters</td>
<td>Psychology</td>
</tr>
<tr>
<td>Heather</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Biology</td>
<td>Bio 100: A</td>
<td>1 semester</td>
<td>Human Development and Family Studies</td>
</tr>
<tr>
<td>Sophia</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Chemistry</td>
<td>Math 100: B+</td>
<td>1 semester</td>
<td>Psychology</td>
</tr>
<tr>
<td>Robert</td>
<td>Male</td>
<td>No</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Bio 100: B Math 100: C+ Bio 200: C+ Chem 100: dropped Chem 101: C First semester: 2.7 GPA</td>
<td>2 semesters</td>
<td>Risk Management w/ Real Estate Option and Concentration in Finance</td>
</tr>
<tr>
<td>Evelyn</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology</td>
<td>Bio 100: B+ Chem 100: dropped</td>
<td>1 semester</td>
<td>Secondary Education w/ Focus on English Communications and English Minor</td>
</tr>
<tr>
<td>Christina</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology</td>
<td>Chem 100: A- Bio 100: B Math 100: D</td>
<td>1 semester</td>
<td>Enterprise Risk Management</td>
</tr>
</tbody>
</table>
Data Collection

Interviewing has been selected as the primary method of data collection for this study for a number of reasons. According to Charmaz (2011), “…intensive interviewing permits an in-depth exploration of a particular topic or experience and, thus, is a useful method for interpretive inquiry” (p. 25). Therefore, this method of data collection facilitated the collection of “rich data” that illustrates the processes that guided undergraduates’ decisions to not continue in STEM majors.

<table>
<thead>
<tr>
<th>Student</th>
<th>Gender</th>
<th>International</th>
<th>Year</th>
<th>Major/Minor</th>
<th>Courses (Semesters)</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexandra</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Math 100: C Bio 100: A Chem 100: B Chem 101: B+</td>
<td>Psychology w/ Neuroscience Focus</td>
</tr>
<tr>
<td>Danielle</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology w/ Neuroscience specialty</td>
<td>Chem 100: A-Bio 100: A-Math 100: B</td>
<td>Human Development w/ Minor in Psychology</td>
</tr>
<tr>
<td>Brian</td>
<td>Male</td>
<td>Yes (international)</td>
<td>Junior</td>
<td>Math w/ Actuarial Science</td>
<td>Math 101: A-Math seminar: A</td>
<td>Accounting</td>
</tr>
</tbody>
</table>
As mentioned above, I conducted one interview with each participant that lasted approximately thirty to sixty minutes\(^4\) in a private location on campus that allowed for the maintenance of participant privacy. All interviews were recorded and then transcribed. Nvivo 10 for Mac qualitative software was used to store the recordings and transcripts. In addition, the Nvivo 10 for Mac qualitative software was used to facilitate the coding and analysis of the transcripts for salient themes that addressed the study’s research question.

In order to collect “rich data,” the initial interview protocol included open-ended questions intended to encourage the participants’ forthright retelling of their experiences and perceptions of their STEM attrition stories. Such open-ended questioning is a common element of grounded theory research, designed to elicit participants’ authentic retelling of the phenomena and processes under investigation, as well as reduce researcher bias (Charmaz, 2011).

However, the initial interview protocol not only included these open-ended questions. As Dey (1993) explains, “In short, there is a difference between an open mind and an empty head. To analyze data, we need to use accumulated knowledge, not dispense with it” (Dey, 1993 quoted in Strauss & Corbin, 1998, p. 47). As such, a core approach to data collection in the grounded theory tradition is theoretical sensitivity, that is, the ability of researchers to apply their preexisting knowledge and experiences to the process of data collection and analysis. In this way, researchers are able to compare and contrast how the collected data relates to various conceptual elements that have previously been associated with the phenomenon under investigation. This process contributes to the development of the emergent grounded theory, as well as illustrates the potential originality of the research findings (Strauss & Corbin, 1998).

\(^4\) It should be noted that one interview audio recording ended approximately five minutes early.
Therefore, this study’s interview protocol included both open-ended questions and several thematic categories that were discovered during this study’s literature search and discussed in the above literature review (e.g. demographic characteristics; academic preparation; achievement motivation; STEM instructional methods; and participation in co-curricular programming).

**Interview protocol.** I developed an initial topical interview protocol that was used in the data collection for this study that was influenced by the conventions of grounded theory research and balanced the needs to pose open-ended questions and respect theoretical sensitivity. This initial interview protocol is included in Appendix D below. However, it is important to remember that this initial interview protocol was only a set of foundational questions that guided the interview process. As Kvale (1996) notes, the process of qualitative interviewing consists of many different question types that are designed to respond to the interviewee and elicit as much useful information as possible that sheds light on the phenomenon under investigation. For example, interviewee responses to the above questions might require further probing on the part of the interviewer, or might require the interviewer to ask interpretive questions designed to either clarify or expand upon the interviewee’s initial responses (Kvale, 1996).

**Theoretical sampling.** Interview protocols in grounded theory investigations are inherently fluid and add questions as needed through the process of theoretical sampling. Theoretical sampling refers to a data collection process in which new interview questions emerge based on the results of the ongoing data analysis. Therefore, as concepts and themes emerged in initial interviews, questions regarding these issues were added to the interview protocol to elicit participant responses to these more specific topics. In this way, I was able to more clearly
elaborate on and develop important concepts that appeared in the data and further enhance the emerging grounded theory (Strauss & Corbin, 1998). The additional interview protocols that were used to guide later participant interviews are contained in the Appendix below.

**Ethical Considerations**

I took various steps throughout the research process that ensured this study maintained the highest ethical standards. For example, before data collection commenced, I filed an IRB application with the participant institution in order to ensure that all appropriate regulations were followed in the collection and analysis of this study’s Human Subject data. IRB approval was received before beginning data collection, and the study was granted “exempt” status. I also received informed consent from all participants before beginning interviews; participants were given an informed consent form that requested their voluntary participation in my study and described the purpose of the study and the ensuing research process. Participants were asked if they had any questions about the study before they signed the informed consent form. This form is also included in the appendix below.

Furthermore, I assigned all participants pseudonyms to ensure that their privacy is respected throughout the data collection and possible future publication processes.

**Data Analysis**

The data analysis for this study, based on the conventions of grounded theory research, utilized inductive qualitative coding. As such, I sorted the data gleaned from the interviews into systematic patterns and themes. Coding refers to an interpretive analytic process that involves “naming segments of data with a label that simultaneously categorizes, summarizes, and
accounts for each piece of data” (Charmaz, 2011, p. 43). Coding is the foundation of all data analysis in qualitative research and helps researchers move “…beyond concrete statements in the data to making analytical interpretations” (Charmaz, 2011, p. 43).

More specifically, the data analysis for this study occurred in several stages. First, I engaged in the process of open coding. Open coding refers to an “…analytic process through which concepts are identified and their properties and dimensions are discovered in the data” (Strauss & Corbin, 1998, p. 101). I used verbal representations to describe the various concepts contained in the interviews. During this process, I consistently compared the different concepts as they arose in the data, grouping similar concepts into common categories that possessed the ability to summarize the essential properties and dimensions of the similar concepts (Strauss & Corbin, 1998). In order to facilitate this process, I wrote extensive memos reflecting on the nature of these initial codes that helped me more clearly define their characteristics and relationships to other codes.

Once open coding had been completed and various concepts and categories established, the process of axial coding took place. During the axial coding process, I further delineated the core properties and dimensions of the categories established during open coding, as well described the relationship between different categories. I carefully scrutinized nuances in the data to evaluate how the different categories relate to one another, thereby generating the foundation of the grounded theory. In order to accomplish this task, I classified the categories into one of Strauss & Corbin’s (1998) four PARADIGM components based on their conceptual nature: conditions; actions; interactions; and consequences. By classifying the different thematic categories in this way, I was able to understand the process in which participants interacted with
their social world and thereby develop a theoretical perspective that explained the process behind
STEM attrition from the perspective of the participants.

Ultimately, I was able to classify data into five “top level” codes that described the
STEM attrition process from the perspectives of the participants interviewed for this study:
tenuous motivation (condition); encountering obstacles (action/interaction); employing strategies
(action/interaction); deciding to switch (action/interaction); and achieving non-STEM satisfaction
and success (consequence). Viewing the categories in this way facilitated my ability to
understand the relationships between the different categories (Strauss & Corbin, 1998).

Finally, I engaged in selective coding, once open and axial coding had been completed.
In selective coding, I continued to reflect upon the relationships between different categories and
develop a series of relational statements to describe how the categories relate to one another.
Once again, I wrote a series of memos that allowed me to reflect on the “big picture” presented
in the data and how the different “top level” codes related to one another. A central category that
possessed the needed explanatory power to capture the essence of the aggregate data was
selected (Strauss & Corbin, 1998).

By engaging in these processes, I developed an emergent-grounded theory that describes
the expressed reasons and inferred processes that instigated participants’ decisions to leave their
initial STEM majors to pursue non-STEM courses of study.

Validity

According to Maxwell (2013), validity in qualitative research “…refer(s) to the
correctness of credibility of a description, conclusion, explanation, interpretation, or other sort of
account” (p. 122). Validity is a central consideration of any research study and researchers must take proactive steps to ensure that their study meets certain criteria that establish its credibility with external audiences (Maxwell, 2013). I took several steps to address the validity of this study’s rendered grounded theory. For example, during the coding process I often reread my initial coding scheme and utilized the constant comparative process to define core properties of individual codes and utilized memoing to extrapolate the meaning of these codes in participants’ STEM attrition stories. Memoing was also utilized in selective coding to reflect upon the core essence of the data and develop a central theoretical category that describes the reasons and processes behind participants’ STEM attrition stories.

In addition, Charmaz (2011) states that grounded theory investigations must consider several criteria in addressing the validity of grounded theory studies. In particular, I took steps to address three of the criteria outlined by Charmaz (2011): credibility; originality; and usefulness. In meeting such criteria, grounded theory studies establish their validity and confirm their ability to provide valuable theoretical frameworks that adequately explain the phenomenon under investigation (Charmaz, 2011). I also took steps to meet these three specific criteria.

The first criterion that establishes the validity of grounded theory investigations is credibility. Credible studies provide ample evidence that their conclusions are warranted by the collected data and demonstrate the accuracy of their findings (Charmaz, 2011). In order to meet the criterion of credibility, I have provided ample verbatim examples of text collected from the data that illustrate the essence of the participants’ STEM attrition stories and support the grounded theory’s conclusions regarding the reasons and processes underlying STEM attrition (Maxwell, 2013).
I also provided evidence that supports the study’s originality. Grounded theory studies exhibit originality when they demonstrate that their findings contribute to the extant theoretical literature by producing new insights that had not been previously discussed (Charmaz, 2011). To demonstrate this investigation’s originality, I have utilized theoretical sensitivity to compare my grounded theory with the relevant theoretical literature discussed in this study’s literature review. This comparative process highlights areas where my study’s findings either confirm, refute, or add to the extant literature, or perhaps even suggest new concepts involved in the STEM attrition process that had not been previously discussed (Strauss & Corbin, 1998).

Finally, I also took steps to demonstrate the usefulness of this study’s findings. By reflecting on the study’s findings, I will provide evidence in the Discussion section that the rendered grounded theory meets the intellectual and practical goals outlined in the Introduction, as well as generate recommendations that might assist STEM faculty and practitioners reduce the number of students who decide to leave their initial STEM majors.

Limitations of Study

Like all research studies, this grounded theory investigation of STEM attrition is limited by several factors. First, similar to other qualitative investigations, this study’s conclusions will not be able to be generalized to a population due to the research design’s limited sample size and utilization of purposeful sampling (Maxwell, 2013). However, it should be noted that this is not the goal of grounded theory investigations. This grounded theory investigation of STEM attrition seeks to develop a theoretical framework that describes STEM attrition based on the experiences of a select group of participants attending a single university who have something to
say about the phenomena under investigation. My analysis of participant experiences revealed this theoretical framework that can then be applied by interested higher education stakeholders to the problem of STEM attrition at similar college campuses across the country (e.g. large research universities).

This study’s ability to develop such a framework rests on my skills in several areas. In particular, my interviewing and data analysis capabilities influenced the quality of the rendered grounded theory. In order to develop a useful grounded theory that adequately captures the experiences of the participants and describes the reasons and processes underlying STEM attrition, I needed to rely on my training in grounded theory methodology, as well as remember the tenets of grounded theory research such as inductive data analysis and the constant comparative method.

Finally, this study’s broad methodological focus that seeks to interview undergraduates from a wide variety of demographic backgrounds might be seen by some to be a limitation. In developing a grounded theory based on the experiences of such participants, I run the risk of missing the nuances of specific student populations’ STEM experiences. I feel this is a risk worth taking for several reasons. As mentioned above, the extant qualitative literature on STEM attrition largely focuses on the experiences of particular student populations such as women and underrepresented minorities. My study therefore contributes to the literature by generating a grounded theory that speaks to the experiences of many different student populations and describes the STEM attrition experiences that undergraduates hold in common. My grounded theory is especially valuable as a tool that not only contributes to the academic discussion of
STEM attrition, but assists practitioners in their attempts to develop programs and policies that are capable of reducing STEM attrition among a wide range of students.
CHAPTER 4: RESEARCH FINDINGS

The goal of this study was to produce a grounded theory of STEM attrition that describes the process behind undergraduates’ decisions to leave STEM majors for non-STEM courses of study. The study addresses the following research question:

What process describes and explains undergraduate students’ decisions to discontinue in STEM majors at large research universities?

In order to address this research question, I interviewed twenty undergraduates at State University who had begun their college careers as STEM majors but ultimately decided to leave these initial STEM majors to pursue non-STEM courses of study. In total, fifteen women and five men were interviewed. All interviews were recorded and transcribed, and then analyzed according to traditional grounded theory methods of data analysis. Data analysis did not reveal any significant differences in the responses of participants regarding the central research question along gender lines. I will now report on this study’s findings, beginning with a brief overview of the findings, and then subsequently describing the central theoretical category that describes why this study’s participants decided to leave their initial STEM majors. I will then explain the various subcategories that informed the development of the central category.

Overview of Findings

My analysis of the participants’ STEM attrition stories revealed a multidimensional process that acted as the driving force behind participants’ decisions to leave STEM disciplines to major in non-STEM majors. Through a process of open and axial coding that utilized the constant comparative method and extensive memoing, I identified five “top level” codes that
represent the phases of the process that describe why undergraduate students decide to discontinue in their initial STEM majors at a large research university. A series of main “sub level” codes were then organized into these “top level” codes to provide further insight into why and how participants decided to leave their initial STEM majors:

Table 4.1: Code List

<table>
<thead>
<tr>
<th><strong>TENUOUS MOTIVATION</strong></th>
<th><strong>ENCOUNTERING OBSTACLES</strong></th>
<th><strong>EMPLOYING STRATEGIES</strong></th>
<th><strong>DECIDING TO SWITCH</strong></th>
<th><strong>ACHIEVING NON-STEM SATISFACTION AND SUCCESS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic Motivation</td>
<td>Competitive Culture</td>
<td>Taking Non-STEM Courses</td>
<td>Talking To Academic Advisors</td>
<td>Achieving Satisfaction</td>
</tr>
<tr>
<td>Extrinsic Motivation</td>
<td>Disengaging Curricula</td>
<td>Researching Non-STEM Pathways</td>
<td>Talking To Peers</td>
<td>Achieving Success</td>
</tr>
<tr>
<td>Uncertain Motivation</td>
<td>Disappointing Grades</td>
<td>Talking to Friends</td>
<td>Taking Non-STEM Courses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demanding Time Commitment</td>
<td>Embracing Familial Examples</td>
<td>Talking To Academic Advisors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unappealing Career Options</td>
<td></td>
<td>Talking To Peers</td>
<td></td>
</tr>
</tbody>
</table>

I also utilized memoing to identify a central category that could illustrate the main narrative of each participant’s STEM attrition story. The central category that describes why participants made the decision to leave their initial STEM majors is *locating alternative pathways*. Participants were able to locate non-STEM majors that allowed them to best pursue their intrinsic interests and extrinsic goals without having to encounter the same obstacles that
they faced in their initial STEM fields of study. I contend that the five theoretical phases described above explain the how and why behind the central theoretical category.

More specifically, tenuous motivation and encountering obstacles explains why participants were demotivated from continuing along their initial STEM pathways and motivated to locate and pursue alternative non-STEM pathways, while employing strategies and deciding to switch highlights how participants were able to locate the alternative pathways that would become their new non-STEM majors and the decision-making process behind their decisions to ultimately switch majors. Finally, achieving non-STEM success represents the consequence of locating alternative pathways and deciding to switch. Participants are satisfied with their decisions to leave their initial STEM majors and have achieved success in their new non-STEM fields of study.

**Figure 4.1: Category and Phases of Grounded Theory**
Locating Alternative Pathways

The central theoretical category that describes and explains why participants elected to leave their initial STEM majors and pursue non-STEM courses of study is *locating alternative pathways*. Data analysis of participants’ STEM attrition stories revealed that participants considered their initial STEM majors as kinds of academic pathways. By following these academic pathways, participants believed that they would be able to both pursue their intrinsic interests in STEM subject areas and accomplish various extrinsic goals, such as securing a particular type of employment or appeasing forms of familial pressure.

However, participants became demotivated from continuing along their respective STEM pathways when they encountered obstacles during the course of taking introductory STEM coursework. Encountering these various obstacles, such as *disengaging curricula* and *demanding time commitment*, discouraged participants from continuing along their initial STEM pathways and encouraged them to locate alternative (non-STEM) pathways that would allow them to continue to pursue their intrinsic interests and extrinsic goals, without having to encounter the same kinds of obstacles they faced in their introductory STEM coursework. In essence, participants’ early collegiate experiences helped them to better understand the nature of introductory STEM coursework and broadened their perspectives to different academic pathways that represented suitable alternatives to their initial STEM majors.

Several types of alternative pathways were identified in the data analysis. In some cases, participants located and elected to follow alternative pathways that allowed them to pursue similar interests and career goals that they were initially pursuing by following their original STEM pathway; other participants located and elected to follow alternative pathways that
allowed them to pursue an earlier secondary interest that they had in high school before they decided to initially pursue a STEM pathway; and finally, some participants located and elected to follow an alternative pathway that allowed them to follow in the footsteps of older family members who have graduated from college and are now successfully employed. I contend that these three types represent prototypical alternative pathways; the STEM attrition stories of all twenty participants can be fit into one of these prototypes.

In order to better illustrate this central theoretical category of locating alternative pathways, I will now further describe each of the three prototypical alternative pathways by providing an in-depth case study of one participant who located and elected to follow the particular type of alternative pathway.

**Maintaining interest but switching majors.** Upon entering college in the fall semester of 2012, Danielle initially declared a biology major. Danielle attributes her decision to declare an initial biology major in college to having developed an interest in science in high school and, in particular, the workings of the human brain. This interest in studying the brain was developed by taking a particularly interesting high school anatomy and physiology class. Danielle explains her burgeoning interest in the brain and her subsequent decision to initially pursue biology in college:

My junior year, in particular, in high school I took an anatomy and physiology class where we were learning about the body and the different functions of the body. We did a chapter on the brain, and I just totally fell in love and I was like, “I love this, it's so
interesting, so fascinating.” I knew that I wanted to end up in neuroscience. So from what I knew, biology would be a good place to start as a major.\(^5\)

For Danielle, pursuing a biology major was a kind of academic pathway that would allow her to satisfy her intrinsic interest in the brain while also preparing her for a career as a neuroscience researcher.

However, Danielle’s motivation to continue along this initial academic pathway began to wane after she enrolled in college and encountered several obstacles that demotivated her from continuing in the biology major. The main obstacle that Danielle encountered in her introductory STEM coursework that demotivated her from continuing along her initial STEM academic pathway was the fact that many of her classes were rather broad and did not directly address her specific interest in learning more about the brain. Danielle explains this first obstacle:

In general, science, I think I'm interested in it, but it's more of an interest, rather than something to pursue as a career. I think if I had taken more specific science courses I would have liked them more, but having been in really general biology and chemistry classes, it just wasn't really hitting where my specific interest was in science. I think probably one of the biggest negatives about staying as a bio major is that the course load is really broad, and you have to take all kinds of organic chemistry, and all kinds of biochemistry, and then you have to take physics, and then you have to take plant biology and animal biology. Really, my biggest interest was just in the brain, but I was going to have to take dozens of classes that weren't necessarily my interests.

\(^5\) In some cases, I have amended the participants’ language to improve their clarity of expression.
Why was Danielle unwilling to take these courses? In her mind, it was simply not worth the time and effort to do so. When asked if it might have been worth her time and effort to stick with the biology major until she was able to take more specific courses that more closely aligned with her interests, she stated, “Yeah, I did think about that, but there were definitely enough classes that I didn't want to take that I don't think it would have been worth it…Especially physics. I didn't see any reason why I had to take physics as a bio major.”

In addition to having to take many STEM courses that were not related to her interest in the brain, Danielle also disliked the more mundane aspects of writing lab reports that were necessary for conducting research, “Yeah. But I was in the Bio 101 lab portion and also Chem 102 - the lab that goes on with Chem 101 - and I just didn't like it. I didn't like being in the labs. I was really surprised with that because I liked labs in high school. I liked doing the lab but I didn't like writing the reports, which was definitely a red flag to me that like, ‘Oh, that's what being [a researcher is].’” Once Danielle realized she disliked writing lab reports, she began to further question whether she wanted to remain following her initial STEM pathway and pursuing a career as a neuroscience researcher.

Danielle’s unwillingness to take courses that did not directly address her intrinsic interest in the brain and put up with the more mundane aspects of conducting research such as writing lab reports is also related to the fact that she was able to locate an alternative (non-STEM) academic pathway that allowed her pursue intrinsic interests and extrinsic goals, without having to encounter the same kinds of obstacles that she faced in her original STEM pathway.

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6 I have amended the course numbers (but not the disciplines) to further protect participants’ identity.
Concurrent with taking her introductory STEM courses during her first college semester, Danielle also took introductory psychology—a course that she loved. Taking the introductory psychology course gave her the opportunity to study more specifically what she was interested in—the brain—as well as various theories of human behavior that peaked her interest. Simply put, Danielle enjoyed the content matter of her psychology course more than the more general content matter in her STEM courses and began to realize that majoring in a non-stem field such as psychology or human development would give her more of an opportunity to study the brain and learn about subject matter that is more connected with her interests. Danielle explains, “I really liked psychology. I thought it was really interesting and we talked a lot about the brain. It extended beyond just the structure of the brain but went into the theories of why our brains work the way they do.” Danielle continued, “Well, we learned a lot about a lot of theories about human behavior and kind of like the result of brain functions. And I started to see, ‘Oh wow, this is really interesting,’ and see how that would come out in my own life or like, ‘Oh this is my brain process that's making me do this.’”

Danielle’s college experience, in addition to helping her locate an alternative pathway that was more aligned with her intrinsic interest in neuroscience, also helped her develop different extrinsic goals. Upon entering college Danielle had thought that she wanted to pursue a career as a neuroscience researcher. However, after taking the introductory psychology course and experiencing new kinds of social relationships, Danielle began to think about pursuing a career as a therapist. Danielle explains how she came to that realization:

Well, we learned a lot about a lot of theories about human behavior and kind of like the result of brain functions [in introductory psychology]. And I started to see, "Oh wow, this
is really interesting," and see how that would come out in my own life or like, "Oh this is my brain process that's making me do this." And that was really fascinating to me. And even in my personal experiences, I went through a couple of friendships where I was acting it like a guider to them. And so I started to realize, "Oh wow maybe with some more training and more education this could be an area where I would actually do this as career.

Once Danielle’s interest in psychology had been peaked and she began to reconsider her original extrinsic goals, how did she locate her alternative pathway and identify human development as her new major? She was able to locate this alternative pathway by talking with a friend who was already majoring in human development and enjoying her experience pursuing this field of study. After conversing with her friend regarding the human development major, Danielle began to further research the human development major and took several human development courses that she also enjoyed. Danielle explains the appeal of human development, “So, in the human development psych classes, there seemed to be more application. I could see where-- I could see in my own life or in other people around me lives how this pertained and how it was actually a real thing…And I think just as part of my personality I really like being able to make connection and apply things.”

Danielle not only enjoyed the kinds of classes she would get to take by majoring in human development, but the career flexibility offered by the major:

The last day of the fall semester. I had a friend who was in-- her major was human development. And so I didn't change to psych as a major because I mean I've heard all of the, "Well, you can't do anything with psych if you don't get a graduate degree [?]." And
human development is more of-- so there are a lot of people that go on to grad school and become therapists in the field, but there are a lot of other options. You can go into a lot of different fields from there and that was really appealing to me, that even if I wasn't quite sure where exactly that I wanted to end up, that I had a lot of options.

Ultimately, Danielle decided to leave her initial biology major and pursue a human development major instead. Pursuing a human development major allowed her to take courses that were more aligned with her original interest in neuroscience, without having to encounter obstacles that were present in the initial biology major such as taking general science courses unrelated to her interests and completing mundane aspects of the research process such as writing lab reports. Furthermore, completing a human development major allows Danielle to gain preparation to achieve her newly developed extrinsic goals of becoming a therapist and working more directly with people, while retaining career flexibility.

**Returning to earlier interest.** Evelyn initially declared a biology major upon entering college in the fall of 2012. Like Danielle, Evelyn declared an initial biology major because she considered it to be an appropriate academic pathway that would allow her to pursue her intrinsic interest in anatomy, while also gain preparation for her future career as a physician. Evelyn’s desire to pursue her intrinsic interest in anatomy and the extrinsic goal of becoming a physician was strongly influenced by several familial role models who are currently working as physicians, “I would say the fact that because I did have family members in the [medical] field, it was kind of easy for me to talk to them about it, because not many people in my family have been to college. So in talking to them about what I should do, it was kind of easier to think along the path that they'd already gone in.”
The fact that she saw these various successful familial role models working in the medical field, along with her perception of the practicality of the field, convinced Evelyn to initially declare a biology major in preparation for a future career as a physician, despite the fact that she was also strongly interested in English and loved to write. Evelyn states:

Definitely there is that— at least I feel that pressure that kind of not my parents or anything, but maybe it was just the people I’m friends with or the society as a general, but those are the places that are worthy to go to, like I was very interested in English and I did very well in English and all that, but there is the idea like, ‘Oh, you are going to get nowhere if you go there,’ but if I was to go into something in a science field. I saw that as a very practical thing to do, as well, and useful.

Evelyn’s motivation to pursue this initial academic pathway, however, diminished after she encountered several obstacles during her introductory STEM coursework. For example, Evelyn earned disappointing exam grades in her introductory chemistry course and decided to “drop” the class rather than risk receiving a poor course grade that would threaten her overall GPA. Evelyn became demotivated from continuing along her initial STEM pathway and admits to being “scared” by receiving these poor grades because she was accustomed to always doing well in school, “I guess it was kind of a mixture of factors at the time because I was-- I don't know. I've always just been very-- I want to get the highest score that I can. I've always been like the grade jumper or whatever, I don't know. So that kind of scared me because I've always done well and not being up in an ‘A’ was kind of terrifying.”

As a result of receiving such disappointing grades in the introductory chemistry course, Evelyn began to question whether or not she could even attain a degree in biology, given the fact
that she would be required to take several additional chemistry classes. In response to a question regarding whether or not she would have stayed with her biology major if she had done better in Chem 101 course, Evelyn stated, “I would say that's definitely accurate. If I had felt that it [receiving a biology degree] was attainable and that I wasn't going to be miserable through every single chemistry class that I took, then I would have probably stayed.”

Furthermore, Evelyn was also demotivated by the demanding time commitment required of STEM majors and the future STEM careers that many students aspire to. Evelyn discussed feeling “overwhelmed” by the initial STEM workload and being “worked up” by the fact that she felt constantly busy by work that “was kind of a pain.” She disliked the fact that she was so busy and particularly disliked having to do lots of work in classes like chemistry and math that she did not enjoy.

Perhaps more importantly than just being “overwhelmed” by the initial STEM workload and disliking being constantly busy with school work, Evelyn recognized that in order to achieve her initial goal of becoming a physician she would have to endure years and years of being busy and taking classes that she did not enjoy. She admits that she was unwilling to persevere through this situation. She describes her decision to leave her biology major by stating:

…looking ahead and seeing that I'm going to face chemistry again, I'm going to be in math classes again that are difficult for me. It is like realizing all that and thinking, really all I am interested here is taking biology classes and getting to a path to be a physician. It's a long road, and you can be in a school for a long time and I am going to be taking these classes for a long time. I was miserable, I wasn't willing to be in that situation for years…
Concurrent with her diminishing motivation to continue along her initial STEM pathway, Evelyn took a creative writing course during the first semester of her freshmen year. She greatly enjoyed the course and found joy in taking it. She specifically contrasts her experience in STEM courses with her experiences in the creative writing course by saying:

Yeah, I didn't get many opportunities to write in high school, like that kind of material essays and things like that. And I've always been a reader so to be able to have that opportunity was really nice for me - to be able to express myself. I didn't feel like I was able to express myself really in any of the other classes I was taking in a creative way - like I felt I needed.”

This combination of being demotivated from continuing along her initial STEM pathway by encountering various obstacles and taking an exciting creative writing course, a subject that she was already interested in from high school, led Evelyn to question her initial decision to major in biology and ultimately switch majors. Evelyn explains, “…because at that time my mind was already kind of having its own little inner turmoil kind of stuff going on. So then having that one thing for me to latch onto, that I was enjoying, that I felt like I was succeeding in, it just kind of made me think, ‘You've always been interested in this, why didn't you? Maybe this is where you're supposed to be. This is where you're happiest right now.’”

As such, Evelyn decided to pursue her earlier interest in writing, as well as her extrinsic goal of securing stable employment, by majoring in secondary education with a focus on English communications, and minoring in English. This combination of major and minor allows Evelyn to still take the English classes she enjoys while preparing her for a future career in high school teaching. In this way, Evelyn can explore her interests and possibly a career in writing, while
also preparing for a more stable career in teaching, all without having to encounter the initial obstacles she faced in her introductory STEM coursework.

**Following in family footsteps.** Christina decided to declare an initial biology major when she began college at the State University in the fall of 2012. When discussing why she was motivated to pursue a STEM major upon enrolling in college, Christina expressed an intrinsic interest in biological subject matter, but also admits to being motivated by several extrinsic factors, most notably the influence of her father on her decision-making process.

In particular, Christina says her father, a State University alumnus who graduated with a business degree, wanted her to earn a more challenging baccalaureate degree than he did. Christina explains, “…I do better in-- I have done better in school than he did. So he thinks I'm smarter than him, so he thinks I can achieve more than he can achieve.” Christina’s father “wanted” her to pursue a STEM degree despite Christina’s misgivings, “So he [my father] wanted me-- he was like throwing out petroleum engineering and nuclear engineering, and I'm like, ‘Are you kidding me? I can't even get to chemistry, so I don't know how's that going to work.’ But he really pushed me to try biology and then if it fails you can just do business.”

Christina, a varsity athlete at State University, wanted to challenge herself academically upon enrolling in college. This competitive streak also contributed to her decision to major in biology, a subject that she deemed to be particularly challenging:

Well, I also wanted to challenge myself because I had never taken any business classes. So I thought, “Well, you know, it can't be that hard. You deal with people. You deal with numbers. I'm not bad at math. I'm not the strongest math person but I can understand it.” So, I figured if I can get through biology then I can probably go back into
school and do business if I really wanted to and combine the two. But yeah, I think just wanting to challenge myself and also my dad was a big influence.

As such, Christina’s initial biology major represented a kind of academic pathway that allowed her to pursue her intrinsic interest in biology, while also meeting her extrinsic goals of appeasing familial influence and satisfying her inherent competitive streak.

Like other participants, Christina’s motivation to continue along this STEM pathway diminished as she encountered several obstacles that demotivated her from continuing in the biology major. For example, Christina lacked a specific STEM-related career goal. Christina knew that she did not want to pursue a career as a physician or a career in biological research—the only two careers she knew were possible for biology majors. Christina states, “I didn't have a goal, I didn't know what I wanted to do after college, I didn't want to be a doctor - the only other option was working in a lab. So I think that the lack of a goal in the biology major also did not help me become successful in that field.”

Christina also felt that receiving disappointing grades in her introductory calculus course diminished her initial motivation to study biology in college. Despite doing relatively well in the majority of her courses during her first semester, Christina felt “defeated” by receiving disappointing grades in her introductory calculus class. Christina immediately decided to leave her initial biology major and pursue a business degree, like her father had done, after taking the final exam in the calculus class. Believing she had done poorly on the final exam, Christina wanted to make a change, “But, I remember after that exam, I went to practice, and then after practice, I went to go see my counselor…And I went to her, I'm like, ‘I just failed my math exam. I'm not doing science anymore. I want to do business.’”
Christina explained that receiving disappointing grades damaged her self-esteem because she was already feeling overwhelmed by the combination of taking a challenging STEM course load and participating in varsity athletics as a “walk on” athlete:

Bio and math, college, swimming, everything. I was not ready for it. And I think that--so, all right, let's back up a little bit. So I'm a walk-on on the swim team. So I wasn't even recruited. So I called in the spring and I'm like, "Yo, I'm coming [chuckles]. I'm coming, I know I'm not that fast, but this is what I want to do and this is where I want to be. And I'm going to do everything I can to be here.” So, I think that being defeated in the bio or in the math... Like my self-esteem already-- well, it wasn't that. Confidence in your academic ability wasn't that high, because I wasn't doing as well as I had in high school on my exams.

Once she decided that she no longer wanted to pursue the biology major, Christina almost immediately decided that she wanted to pursue a business major, like her father had done at the same institution several decades earlier. In effect, once Christina decided to leave her initial STEM pathway, she was able to (initially) locate an alternative pathway by simply looking at her father as an example and deciding to “follow in his footsteps.” The decision to pursue a business degree was made without taking any business classes. Christina states, “…I didn't know what I wanted to do in business, but I knew that's what I wanted to do.”

As such, Christina’ decision to “follow in the footsteps” of her father makes several important assumptions. Since before entering college, Christina always considered majoring in business as her “backup” option, assuming that she would enjoy majoring in this field and pursuing a business-related career. Before she even took any business courses, Christina
believed that majoring in this field would satisfy her evolving intrinsic interests and extrinsic goals, without presenting any of the same obstacles (e.g. disappointing grades; unappealing career options) that demotivated her from continuing along her initial STEM pathway.

**Summary.** Regardless of the specific alternative pathways participants eventually elected to pursue, the decision to leave initial STEM majors was actively made by participants. After being discouraged from continuing in their initial STEM majors by encountering various obstacles, participants were able to locate non-STEM majors that allowed them to pursue intrinsic interests and extrinsic goals without having to face the same kinds of obstacles they encountered in their STEM majors. In some cases, participants were able to locate alternative non-STEM majors that allowed them to pursue the same kinds of interests and goals that they were originally pursuing by following their initial STEM pathways. In other cases, participants located alternative non-STEM pathways that allowed them to pursue an earlier secondary interest that they had in high school, or follow an interest that was rooted in observing familial examples.

Data analysis revealed the following prototypical alternative pathways that were pursued by participants:

1. Maintaining Interest But Switching Majors
2. Returning to Earlier Interest
3. Following in Family Footsteps

**Originality.** The identification of the central theoretical category, locating alternative pathways, represents a significant contribution to the extant literature on STEM attrition. As mentioned in the literature review above, most of the extant literature that examines STEM attrition has utilized quantitative methods that identify correlations between STEM attrition and one or more variables that can occur before or during the collegiate experience. However, the
results of this grounded theory investigation of STEM attrition reveals that undergraduates’
decisions to leave their initial STEM majors is a more nuanced phenomena that involves students
actively deciding to leave their initial STEM majors to pursue non-STEM majors. The process of
STEM attrition, therefore, involves participants not only deciding to leave STEM, but locating
and pursuing non-STEM majors that represent “better fits” for pursuing their intrinsic interests
and extrinsic goals.

**Tenuous Motivation**

While data analysis revealed the central theoretical category, *locating alternative pathways*, as describing why participants decided to leave their initial STEM majors to pursue non-STEM fields of study, it also highlighted several interrelated theoretical phases that more finely demonstrate the *why* and the *how* participants come to locate these alternative pathways.

Early on in this study it became apparent that the story of STEM attrition is largely a
story of motivation—the decreasing of participants’ motivation to pursue STEM baccalaureate
degrees and the concurrent increasing of participants’ motivation to study some other non-STEM
discipline. According to Schunk (2011), *motivation* “refers to the process of instigating and
sustaining goal-directed behavior” (p. 397).

More specifically, some educational psychologists believe there to be two main types of
*motivation*—*intrinsic and extrinsic motivation*. *Intrinsic motivation* “refers to a desire to engage
in an activity for no obvious reward except task engagement itself” (Schunk, 2011, p. 386).
Individuals are said to be intrinsically motivated, therefore, when they are motivated to pursue a
particular goal due to interest in, and enjoyment of, the pursuit of the goal itself. On the other
hand, *extrinsic motivation* “involves engaging in an activity for reasons external to the task. This activity is a means to an end; an object, a grade, feedback, or praise, or being able to work on another activity” (Schunk, 2011, p. 389-390).

The first theoretical phase that helps explain *why* participants decided to leave their initial STEM majors to pursue non-STEM courses of study is *tenuous motivation*. In this theoretical phase, participants developed intrinsic interest in STEM subject matter, as well as various extrinsic goals related to studying STEM majors and securing employment in STEM careers after college.

According to the Merriam-Webster dictionary, the term *tenuous* means “not certain, definite, or strong; flimsy, weak, or uncertain.” I believe this term accurately describes participants’ initial motivation to pursue STEM majors in college because data analysis revealed that participants’ *tenuous motivation* to pursue STEM majors in college was often based on a single impactful experience that facilitated an interest in studying STEM disciplines in college, and the perception that pursuing STEM majors in college represented a kind of “safe” academic pathway.

Many participants believed that majoring in STEM disciplines in college would allow them to pursue post-college economic security, as well as the ability to appease familial influence and achieve positive self-identity. Furthermore, many participants also expressed sentiments that called into question the strength of their initial *tenuous motivation* to study STEM disciplines in college. Because participants’ *tenuous motivation* to study STEM was largely based on such shaky footings, they were unable to successfully overcome the obstacles that would lie ahead in their introductory STEM courses.
Intrinsic interest.

*Enjoying high school science courses.* Perhaps the most common motivating factor that drove participants to initially declare STEM majors when enrolling in college was intrinsic interest. The vast majority of participants indicated that they were at least partially influenced to declare STEM majors by a general interest in STEM-related subject matter that was often facilitated by taking a particularly engaging high school science course. For example, when asked about how she came to select her initial biology major, Heather gave the following response:

In high school I was really interested in science in general, it was one of my favorite subjects and more specifically life sciences...I took anatomy and physiology in high school. It's something that we were offered, and I really liked the human aspect of biology, so I think that was my favorite part of it.

In Heather’s case, the interest in her future pre-major, biology, was sparked by interesting high school courses that she enjoyed. This is a common refrain—interest or “liking” the sciences due to particularly enjoyable high school classes and interesting high school teachers. For example, Scott describes a similar experience when explaining how he selected his initial physics pre-major. He states:

I chose it because - it's a really stupid answer honestly. I took physics in high school, and I love my physics teacher. I loved the class. It just made sense to me because physics is more of a math-based course than a lot of the other sciences, and I really enjoyed the
calculations, and like how it all made sense about how everything is the world worked. I also took classes like chemistry in high school and biology, and I enjoyed those too… Yeah, definitely my high school physics teacher just because he played baseball in high school and like he-- we had like this project where you have to create carton to protect an egg from a ten-foot-drop, a fifteen-foot-drop, and if its survives with those you had put on the tee and strength the baseball bat, and if it survives that, you get extra credit, or whatever. Just like the way he thought it, and he helps understand it, it made me understand it, and I thought that's where I could see myself going. He definitely influenced my decision.

Danielle also attributes much of her decision to declare an initial biology major in college to having developed an interest in science in high school. Danielle describes influential high school science classes that were taught by particularly good teachers. These engaging classes served to facilitate her interest in the sciences. She describes her experiences studying the sciences in high school:

My freshman year I was in an earth science class. It was honors earth science and my teacher - his name was Mr. Jones\(^7\) - and he just like-- it was literally the most boring class - I'm not interested in that aspect of science - but he made it so fascinating and really got us engaged. So he was really good and also my AP chemistry teacher, my senior year. It was a really hard class and I hadn't had the best honors chemistry teacher and so I didn't really know what I was doing

\(^7\) The names of individuals who are mentioned in participants’ STEM attrition stories have been changed to protect their identities.
because in honors chem I just got by without having to do a whole lot of work,
but AP chemistry was really rigorous, and so I sought help a lot from her and she
was more than willing to help me and go through practice problems. She was
definitely a hard teacher, but I think I learned a lot from it.

Furthermore, Danielle’s decision to declare an initial biology major was largely due to her
particular interest in learning more about the brain and how it functions. This interest in studying
the brain was developed by taking a particularly interesting high school anatomy and physiology
class. Danielle explains her burgeoning interest in studying the brain and decision to declare an
initial biology major when enrolling in college by saying:

My junior year, in particular, in high school I took an anatomy and physiology class
where we were learning about the body and the different functions of the body. We did a
chapter on the brain, and I just totally fell in love and I was like, ‘I love this, it's so
interesting, so fascinating.’ I knew that I wanted to end up in neuroscience. So from what
I knew, that biology would be a good place to start as a major.

Similarly, Cynthia’s initial decision to declare a pre-med major upon entering college was also
influenced by her interest in the subject matter that had been cultivated by taking engaging high
school science courses taught by a particularly influential teacher. Cynthia explains the origin of
her interest in studying STEM in college:

So my senior year of high school-- well, my whole high school year I was really involved
in science courses in my high school in math and all that and I took an anatomy class - a
human physiology anatomy class - and we did a lot of dissections. And my professor was
a former doctor that decided to retire and do teaching instead, at a high school. So I really
looked up to him, and he was really a close mentor to me. And I just knew from then on I wanted to be a surgeon really, really, really badly.

She goes on to explain that upon graduating from high school she was torn between declaring a pre-med or psychology major in college, but her experience taking this one influential course was the deciding factor in her decision to declare pre-med. Cynthia explains, “Well, I didn't know what I wanted to do when I was graduating high school. I initially liked psychology from the start. It was one of my options that I would study then in high school-- in college. But I also knew I liked science, so I was torn. Then once I took that [human physiology] class, I said, ‘All right. This is for me.’”

**Impacted by childhood experiences.** In addition, other participants traced the root of their interest in STEM-related subjects to influential childhood experiences that sparked an interest in the sciences. In Jane and Kate’s cases, their desire to pursue forensic science majors was sparked by long-time interest in crime-related issues that was brought on by watching television programs when they were younger. This interest encouraged them to initially declare forensic science majors. Jane explains:

I was they call it the-- in the forensic major, it was-- first of all, I was always really interested in forensic science with crime and everything. I have always wanted to be kind of like the superhero who solves the crimes to make sure there's no more bad people. That's what started me off in the forensic science path, and I had been interested in it since I was-- I would say maybe the beginning of high school. Also, I watch all those shows and I thought it would be really cool to be a forensic scientist. So that's what got me into it. That's actually why I came to State University in the first part because they
have one of the top forensic science programs here. So that's what made me start apply to the [College of Science]. That's where I started. I guess that was pretty much it, just being really interested in the whole crime aspect of it, the science-y part of it and the labs and stuff.

Kate’s decision to declare a forensic science major was also impacted by watching similar television programs as a child. She explains, “I was always interested in those TV shows - Long Rider, CSI, blah, blah, blah. So I took it upon myself to apply to schools of forensic science programs.”

**Extrinsic goals.**

**Helping others.** Many participants also reported being extrinsically motivated to initially declare STEM majors upon entering college. For many participants, pursuing STEM majors is not only an interesting academic pathway, but a means to achieving a specific end that is external to the task itself.

For instance, several participants perceived their majoring in STEM disciplines as preparation for future careers that would allow them to help others. This desire to help others can be traced back to influential childhood experiences. For example, two participants’ interest in studying pre-medicine in college, Luke and Natalie, were inspired to pursue careers as physicians by personal experiences dealing with health issues during childhood. Luke had surgery on his legs during high school and became “…fascinated by everything that went on in the hospital.” As a result of this experience, Luke pursued an opportunity to shadow the surgeon who performed the operation on his legs and thereby became even further interested in pursuing
a career in medicine. Similarly, Natalie described her desire to study pre-medicine and pursue a career as a physician as a result of her personal struggle with acne during childhood:

I've had acne my entire life, so it was a very personal journey for me, that I was just like, you know, this is something that I feel could be easily fixed. I still struggle with it to this day. So it's like, I wanted to be part of the clinical intervention, not necessarily just, like, a bystander or a consumer of that… I think it was the root of that I had a problem, and it was like I thought, ‘That's exactly what I wanted to do.’ And I don't know. I think that if I didn't have acne I would have been something completely different. I just think that your experiences in life really do mold who you become.

Eric also had a similar childhood experience that sparked an interest in pursuing a career as a plastic surgeon. In Eric’s case, his initial desire to pursue a chemistry major with the intention of going to medical school was heavily influenced by an experience from childhood in which he had a first-hand encounter with a child burn victim. This experience sparked an interest in medicine and a desire to pursue a career as a physician in order to help victims suffering from similar ailments. Eric describes the origins of his interest in medicine:

I think it all started when I saw a burn victim when I was like three-years-old. I was just out with my family and this girl went out to blow out her marshmallow and she lit her face on fire, and the whole thing just went up… So, I was like, “You know what? Maybe there's some way to fix that, because she's going to have that the rest of her life.” And then I found out about skin graphs and stuff like that, and I was like, “You know what? I could be a plastic surgeon. There's some other cool stuff they could do.”
Pursuing economic security. Several other participants were extrinsically motivated to pursue STEM baccalaureate degrees by the desire to pursue the economic security they associated with careers in STEM disciplines. For example, although Alexandra reported her interest and desire to study pre-medicine as a primary motivating factor for her decision to declare her initial pre-med major, she also reported being heavily influenced by extrinsic motivating factors—in her case, her desire to pursue an academic field that would prepare her for a secure economic future. Alexandra explains, “And my mom liked the idea of me going to medical school, but she would've been okay with anything. But it was definitely because my family worked in healthcare that I was just around that, and I knew that that's the field that's always hiring. It's not like business where you have to sell things to make a living.”

Several other participants also reported being heavily influenced to pursue STEM majors by the desire to obtain the economic security associated with STEM fields. Similar to Alexandra, Jennifer was also motivated to initially study chemistry by her desire to pursue a field with high job placement rates—secondary education. Jennifer planned on studying chemistry in college in order to pursue a position as a high school chemistry teacher right out of college. She explains, “I always loved teaching. I think one reason that I chose to do secondary education is because there's not really a demand at all for elementary ed, and I'm really hoping to get a job out of college.”

Scott’s motivation to pursue a physics degree was also influenced by his desire to pursue economic security and his perception of STEM’s easier job placement. Scott explains:

I think the thing that I was thinking at the time was just that sciences are like up and coming. It's all about where the world's going. Like that's where you want to be in order
to get a job and everything… I think I only chose that [physics] because I thought that careers would be easier to come by. And in a way, that's planning ahead, but it's just planning ahead to be successful and not to be happy.

Furthermore, in some cases, participants’ desire to pursue economic goals served as the deciding factor in selecting STEM majors over non-STEM majors that they were equally interested in studying in college. For example, Evelyn admitted to being interested in English, as well as biology, in high school, but initially decided to major in biology in college due to her perception that STEM fields are more inherently “practical” than non-STEM fields such as English. Evelyn describes her rationale for initially declaring a biology major upon entering college:

> Definitely there is that—at least I feel that pressure that kind of not my parents or anything, but maybe it was just the people I’m friends with or the society as a general, but those are the places that are worthy to go to, like I was very interested in English and I did very well in English and all that, but there is the idea like, ‘Oh, you are going to get nowhere if you go there,’ but if I was to go into something in a science field. I saw that as a very practical thing to do, as well, and useful.

**Appeasing familial influence.** Several other participants also reported being extrinsically motivated to initially declare STEM majors by the desire to appease various forms of familial influence. For example, several participants reported feeling a certain degree of familial pressure to follow in the footsteps of family members who are currently employed in STEM fields. For example, Charlotte initially declared a biochemistry major upon enrolling in college largely due to the influence of her parents, both of whom graduated from State University with biochemistry degrees. Although her parents tried to remain unbiased when discussing possible majors and
future careers with Charlotte, “they were inherently biased” when the possibility of Charlotte’s majoring in biochemistry was raised. Charlotte explains the impact her parents had on her decision to initially declare a biochemistry major, “They wanted to be unbiased. They didn't want to push me in any direction, but they were inherently biased because they love biochemistry and they saw that I like science. They were not trying to push me in that direction, but they were anyway. Does that make sense?”

Similarly, Sophia also reported feeling a certain degree of familial pressure to follow in the footsteps of both her father and grandfather who both graduated from college with chemistry degrees. Although her father stated that he did not want to pressure Sophia into declaring a chemistry major in college, Sophia wound up declaring one anyway. Sophia explains her initial decision to major in chemistry, “My grandfather has his post-doctorate from MIT, so that's kind of why my dad ended up going into the field. My dad doesn't even really do anything with chemistry any more, which is actually interesting. But they both did chemistry so I was just like, ‘I'll go in with that idea and maybe I'll change my mind,’ but it was more just because that's what my dad did.”

Other participants reported being motivated by different forms of familial pressure. Christina, Madison, and Natalie all reported being extrinsically motivated to study STEM majors by the pressure to exceed the accomplishments of family or community members. In Christina’s case, she was pressured by her father to study Biology in order to “achieve more” than her father has in his career. Christina explains:

But he's not-- [chuckles] I do better in-- I have done better in school than he did. So he thinks I'm smarter than him, so he thinks I can achieve more than he can achieve. So he
wanted me-- he was like throwing out petroleum engineering and nuclear engineering, and I'm like, ‘Are you kidding me? I can't even get to chemistry, so I don't know how's that going to work.’ But he really pushed me to try biology and then if it fails you can just do business.

Madison also reported feeling a similar pressure from her mother, who is a nurse, to initially pursue a pre-medicine major in college. She states, “Well, for me, I think a lot of it was my mom's pushing. She was a nurse and she wanted to go to medical school, and she never continued on. So, a lot of it was that… I kind of went with what was pushing on me, which was my mom.”

Natalie also felt a somewhat similar pressure from her father, an MRI technician, and from her local rural community, to study pre-medicine in college. Natalie notes that “smart” students are often pushed by her local community to study medicine and pursue careers as physicians “Because they [community members] just think that that's-- if you're smart, that's what you should do.” While Natalie admits that her father would have been supportive of any major that she would have wanted to pursue in college, she also felt a certain degree of pressure from her father to pursue a career in medicine. She explains, “I think that my family was kind of pigeonholed to that idea too. And my dad is an MRI tech so he sees like the medical side of everything, he's like, ‘You're smart, you can do it. So it's not hard to do for you.’”

Furthermore, several other participants were extrinsically motivated to study STEM disciplines due to familial influence that emphasized the economic rewards associated with studying STEM majors and pursuing careers in STEM disciplines. For example, Luke, who had initially declared a pre-medicine major upon enrolling in college, was considering majoring in
psychology or another social science field but initially decided on pre-medicine due, in part, to the influence of his extended family. Luke says:

I also heard from-- when some of my relatives were asking me what I was interested in getting into, I told them about the social sciences that I was taking, and psychology, and stuff like that. And they sort of pushed me in that direction and they said, ‘Psychology is great, but you're not going to make any money. It's going to be difficult being a social worker, and you should really consider a STEM related field.’ It wasn't necessarily explicitly stated that way, but that's the sense that I got from them. They're really pushing me on that direction.

Sarah told a similar story of feeling familial pressure to major in STEM when she was contemplating the merits of majoring in biology or elementary education. Ultimately, she decided to initially declare a biology major at the urging of her parents. Sarah explains, “And I had always been on the fence between orthodontist or being a teacher, but of course my parents - because I had grades and SATs - were like, ‘Go for medical field more than education first.’” When she was asked why her parents had told her to “go for the medical field more than education first,” Sarah stated, “Definitely for money. For money, for stability, and for jobs. They were like, ‘It's probably going to be easier to get a job if you do that, versus education.’”
Feeling special. My data analysis also revealed that many participants also initially select STEM majors when enrolling in college in order to pursue feelings of superiority over their peers and praise from those around them. A key extrinsic motivating factor that influenced Charlotte’s decisions to initially select a biochemistry major was her desire to “impress” people. She explains, “…I just wanted to pick like what's the hardest thing I can do. I'm the super-smart kid. I'm just going to do whatever. I wanted to impress people which I realized is a dumb reason to pick a major - to be impressive. I wanted to do science.” Jane also revealed that part of her initial decisions to declare a forensic science major was her own desire to “look good” to others by studying such a challenging subject in college. In describing an important lesson that she learned from her personal STEM attrition story, she reveals part of her rationale for selecting an initial STEM major:

Probably just-- important lessons? I guess, just stay focused. And I guess, back-- like I was in pre-major, I think, just to make sure that I was actually-- I guess, an important lesson was to really think about what I wanted to do rather than what I thought everybody else wanted me to do. So, I figured it was always a constant battle between what would look good, would it look better for me to stay in the science. I was always really all about what people thought about me. I still am, it's my personality. I think, I thought if I stayed in science, it would have look better.

Sophia and Scott told similar stories of being partially motivated to study STEM disciplines due to their desire to impress others. Sophia’s initial decision to declare a chemistry major was influenced by her perception that majoring in a STEM field was more impressive than majoring in a non-STEM discipline, “Yeah, and I think that might have been it. I mean it seemed practical
to me. It seemed like I could do something that my family would be proud of or that other people would think is admirable. I mean, people definitely like it when you tell people, ‘I'm a psych major,’ they think, ‘Oh, you don't do anything.’” For Scott, his decision to declare an initial physics major was motivated by his desire to pursue a field that not many others could handle academically. He explains, “I was thinking that not a lot of people are great at sciences. I'm doing well in my science courses in high school, so why not try to pursue a science career just because I can do it and other people can't, so it would like help me. I thought that put me above everyone else.”

**Seeking challenge.** Finally, many participants also reported being extrinsically motivated to study STEM disciplines due to their desire to pursue challenging academic subjects. For these participants, STEM majors were perceived to be the most challenging academic fields that one could study in college, and they wanted to push themselves by studying such fields.

For example, Christina, in addition to being motivated to declare an initial biology major by her interest in the subject matter and the influence of her father, was partially motivated to do so by her desire to challenge herself by selecting the hardest academic major possible. Christina is a varsity swimmer at State University and initially enjoyed the academic challenge presented by selecting a STEM major and figured she could always “go back into school” and complete a non-STEM major such as business if she found biology too challenging. Luke told a similar story of wanting to challenge himself upon entering college and initially deciding to pursue a pre-med major instead of a social science field such as psychology in part due to the fact that he perceived pre-med to be “more rigorous” than social science fields.
Mary’s initial decision to declare a pre-med major was motivated by similar sentiments. Before enrolling at State University, Mary had wanted badly to attend a particular Ivy League university; however, when Mary decided to attend State University due to financial reasons, she was motivated to select a particularly challenging academic major as a way of suggesting the rigor of the institution. Mary explains her rationale for selecting an initial pre-med major, “But I felt it [State University] wasn’t the caliber of school I wanted. So, I was like, ‘I should do something hard, pushing myself.’ So, I was interested in it, but I don’t know if my interest in medicine or biology was the biggest pull towards it. I think it was more I thought I should be challenging myself.”

Uncertain motivation. Furthermore, some participants called into question the strength of their original motivation to study STEM in college. For example, participants often described their initial decisions to enter college as STEM majors in terms of their having a general interest in studying science and viewing their initial STEM majors as starting points from which they would then evaluate their evolving interests. Luke, who initially declared a pre-med major when enrolling in State University, explains,

And so I was pretty comfortable in the hospital environment and interested in medicine, so when I came into college, I figured that the pre-med major would be a good place to start. So that's basically why. I didn't really have a more specific focus. And the pre-med major seemed like a pretty broad medically-related major...I thought I wanted to go to med school. I wasn't really sure. A big part of me didn't want to put myself through med school and all of that. But I knew that I was interested in
working with people and I have experience in a hospital, so I figured it [pre-med] would be at least a good starting point.

Mary described her initial motivation to study pre-med in college in similar terms, “And I thought, I didn’t really know what I wanted to do, so I thought, ‘Ok, well, I’ll continue with what I know, and what I like,’ and I thought eventually I would want to do something in medicine, so that’s sort of, I decided from there.” Scott went a step further than Luke and Mary and described his initial decision to declare a physics major in more haphazard terms, “[Choosing] physics as a major was just on a whim. It's just because I took one physics class in high school and enjoyed it, and that's why I decided. I didn't even take AP physics my senior year. I just ended up taking AP biology, because I heard it was easier than AP physics. So I don't know. I definitely think it was because I didn't put a lot of thought into it before college.”

For Madison, selecting an initial pre-med major was also a kind of academic starting point because she did not know that much about possible majors or careers. Madison explains her initial decision to major in pre-med,

Well, for me, I think a lot of it was my mom's pushing. She was a nurse and she wanted to go to medical school, and she never continued on. So, a lot of it was that. I also think I didn't really have a lot of resources to help me learn about what kind of jobs were out there from my high school maybe, or just something like that. I kind of went with what was pushing on me, which was my mom. I didn't really have any external things to look at.
Participants also explained how they declared initial STEM majors despite enjoying only one particular STEM subject. For instance, both Christina and Evelyn declared initial biology majors despite disliking non-biology STEM classes in high school. Evelyn states,

In high school it was always like, "[I’m] not really a math or science person." But I always liked chemistry. That was there. No, I did not like chemistry, [I liked] biology. And I always liked English and social studies that was always kind of how it was. So, knowing - like I said - I went into college, already not looking forward to the chemistry and the math that I knew that I would have to be taking. But it was just kind of a means to an end, I guess.

Christina also initially declared a biology major despite disliking chemistry in high school,

But in high school I loved biology. Maybe it was because I had great teachers and everything. And I really enjoyed the class, and I understood the concepts. And then physics is hard, but it's kind of cool. But the thing that I really didn't like was chemistry, and I didn't understand how much chemistry was in the bio major. So once I got here, the bio class was great - it was kind of hard, but I ended up doing okay in it, but then I don't know.

In Sophia’s case, she declared an initial chemistry major in order to pursue a career in neuropsychology despite the fact that she was actually more interested in studying psychology (her current major) in college. Sophia describes her initial decision to major in chemistry,

I've always thought of things as in, "Well, if I'm a psych major, God knows how I'm going to get a job," or stuff like that. Whereas everyone tells you, well people say like, "Don't be a psych major, you can't do anything with that," which obviously isn't true. And
then people would say like, "If you're science or like math major, anything like that, you'll definitely get a job, blah, blah, blah." So I think that might have been why I kind of originally strayed away a little bit from that, but I definitely liked my psych classes in high school more than I liked my other classes, I think.

**Summary.** The first phase of the process that describes why participants who initially entered State University as STEM majors in the College of Science ultimately decided to pursue non-STEM majors is tenuous motivation. In this first phase, participants developed an tenuous motivation to study STEM disciplines in college that was often based on a single impactful childhood or high school experience, as well as the perception that pursuing STEM majors in college represented a kind of “safe” academic pathway that would lead to future economic security and the ability to appease familial influence and achieve positive self-identity. In addition, participants sometimes expressed sentiments that called into question the strength of these initial motivating factors.

Participants’ *tenuous motivation* lays the groundwork for future STEM attrition. Since much of participants’ initial motivation to pursue STEM disciplines was based on very limited childhood and high school experiences and, in some cases, uncertain foundations, participants were not be able to successfully overcome the obstacles that they would encounter in introductory STEM courses.

**Originality.** This description of participants’ tenuous motivation to pursue STEM majors in college contributes to the literature on STEM attrition by helping STEM faculty and administrators better understand the motivating factors behind undergraduates’ decisions to enter STEM. According to Tobias (1990), many scientists and engineers attribute their own decisions
to pursue STEM careers to the strong intrinsic motivation that they developed long before they entered college, and much less to the various extrinsic and uncertain motivating factors that were mentioned by the participants in this study. Therefore, this study’s findings regarding tenuous motivation can help STEM faculty better understand that the students whom they are teaching in their classrooms might not possess the same kinds of motivation to study STEM that they exhibited when they were college and perhaps encourage them to tailor their pedagogy to spark the continued interest of their students.

In addition, this study’s description of participants’ tenuous motivation supports the findings of some earlier extant research. As Suresh (2006) discovered, undergraduates’ decisions to pursue STEM majors “…was not always the result of informed decision making.” Lichtenstein et al. (2007)’s study of engineering attrition similarly found that undergraduates’ initial decisions to pursue STEM majors were often based on little “exposure” to engineering and that undergraduates were “…anything but highly intent on entering and completing a specific engineering degree” (p. 3).

Furthermore, as mentioned above in the literature review, several studies have discovered links between length of interest in STEM and STEM undergraduate retention (Tai et al., 2006; Kokkelenberg and Sinha, 2010; Maltese and Tai, 2011). While some participants interviewed for this study described the childhood origins of their tenuous motivation to study STEM majors in college, many other participants attributed their decisions to declare initial STEM majors to impactful high school experiences and various other extrinsic motivating factors.
Encountering Obstacles

The second phase of this theoretical process that explains why participants decided to leave their initial STEM majors occurs during college when students begin to take introductory STEM courses. In these classes, participants reported encountering various obstacles that decrease their initial (tenuous) motivation to pursue STEM majors. Data analysis of participants’ STEM attrition stories reveals that participants often encountered the following obstacles that acted as demotivating influences over their initial desire to complete STEM baccalaureate degrees:

1. Competitive Culture
2. Disengaging Curricula
3. Disappointing Grades
4. Demanding Time Commitment
5. Unappealing Career Options

**Competitive culture.** Many participants reported perceiving an overly competitive culture within STEM courses that created an unwelcoming learning environment for many students. According to participants, many faculty created an unwelcoming culture in their classrooms that sent the message that introductory STEM courses were specifically designed to “weed out” students who either could not handle the academic workload, or did not truly want to study STEM disciplines in the first place.

For example, Mary, who spent a year as a pre-med major before switching to sociology, described such a “weed out” culture in her introductory STEM courses that she found to be “frustrating” and “unfair.” Mary explains:
Since I was only there for a year, the classes are big and designed to weed people out, which I felt was frustrating. I think, it’s just a different level of competitiveness, in majors like pre-med, everybody is going to be a doctor and they have their heart set on it, and so competitive about it. It was just, I don’t know, an environment that [didn’t] appealed to me. I think that’s what I most remember about it, particularly in the early biology and the early chemistry classes. I liked biology, I always have and am good at it. But those classes, are clearly made difficult to weed people out. And I remember thinking that it seemed both unnecessary and unfair.

How did Mary receive the message that these introductory courses were made unfairly “…difficult to weed people out”? She says that she received this message straight from the faculty themselves, “They [faculty] flat out told us that in the early chem classes, they were difficult and made to weed people out of the program…Which is intimidating when you are 18 and you just got to college, the biology program, mostly what I remember, the classes being huge. And I think that says a lot about a program.”

Alexandra, also an initial pre-med major, similarly reported being turned off and disliking the “weed out” culture she encountered in her first STEM courses:

It would be, a lot of the teachers I feel like they know that everyone wants to be a doctor and they kind of want to see who’s taking it seriously, and they put too much emphasis, I feel like, on trying to weed out those people rather than just-- I don't want to say they give unfair exams, but they are harder than they would be in other school, probably, and it shouldn't be so competitive. Their goal should just be to teach what you need to know rather than trying to weed you out of something that you want to do.
In addition to noting the existence of the “weed out” culture in early STEM courses, Danielle also commented on the impact she believes this culture has on students’ motivation to continue in STEM majors:

And I think the weed-out would foster like competition among the students that actually---like that really are interested. But then for the students that are still unsure, it kind of creates a lack of motivation. Because if you're being told that it's so hard that you're not going to get through it anyway then, I mean, there's kind of that effect of, "Well, maybe you're right. Maybe I can't get through it."

Danielle herself was demotivated by this “weed out” culture and believed that if STEM faculty were serious about helping students reach their full academic potential, they should spend more time trying to help students master the difficult STEM coursework and less time trying to separate students into two groups: those who can and those who can not:

I guess I was turned off by that. If someone's really passionate about teaching, part of that is they want to help students advance in their interests, and to have someone say, "If you don't already know it, then I'm not going to help you know it," [chuckles] is kind of disappointing because that's not really helping people to follow the direction they want to go. That's kind of saying, "You either have to know it, or you don't, and that's it."

Perhaps perceptively, Jane questions why STEM faculty would want to promote such a “weed out” culture in their classrooms when there has been much media and scholarly attention on the supposed shortage of STEM graduates in the United States:

…It was kind of a weird dynamic because you would think you would want people to be in the STEM major especially because its one of those fields that is really growing and
really striving now. So, I feel like instead of you wanting to weed people out of it, you'd want to encourage people to be in it more so. I always felt like it was the opposite, like they were always trying to discourage people from joining the STEM majors.

Additionally, some participants perceived a competitive culture within their STEM introductory classes not from their faculty, but from their fellow students. Being surrounded by peers who are ultra-competitive and primarily motivated by extrinsic factors presents unique challenges to students and serves as a different kind of demotivating influence to stay in STEM majors. Luke believes that being around such peers who were primarily motivated by extrinsic factors and less by intrinsic interest acted as a demotivating influence for him:

I just didn't like how it seemed like everybody around me didn't know why they were a pre-med major. They were just pre-med majors because their parents wanted them to be a pre-med major or because they thought that was the right thing to do and the smart thing to do. It didn't seem like people had experience in hospitals like I did, or particularly understood what it meant to be interested in working with patients the same way. I don't think that the professor, the faculty adviser did anything to really help with that either. It was all about, "These are the things you have to do. This is going to be hard." And so, in that sense, I didn't like it at all.

**Disengaging Curricula.**

*Abstract content.* The biggest obstacle to participants’ remaining motivated to pursue STEM baccalaureate degrees and continue along their initial STEM pathways is the perceived abstract nature of the curricula of STEM introductory courses and the inability of students to
understand how course content relates to their original interest in STEM and future career goals. Participants frequently described being unable to understand how the content they were learning about in their introductory courses related to their interests, thereby becoming frustrated and disinterested in STEM classes.

For example, several participants who entered college as pre-med majors become frustrated with their introductory STEM courses because they failed to see connections between what they were learning in these courses and their initial interest in medicine. For example, Eric, an initial pre-med major who was interested in pursuing a career as a plastic surgeon, identified the necessity of studying topics and taking classes that he did not understand to be relevant to his interest in medicine as a demotivating factor that contributed to his decision to leave pre-med:

I think if there was a more - I don't even think it's possible in a standard university setting - but I think that if there was a more specific path that only dealt with medical conditions after you get past the basic bios and chems and stuff, I think I would have definitely stayed on that. But knowing that I would have to continue with these other chemistry classes, like the physical chem and other stuff that was really almost irrelevant to my career path, it's just not worth it… I don't need to learn about photosynthesis five million times in every single class. That will never pertain to me, ever. I don't need to learn about the circuitry in physics. I'm not going to be an engineer. I'm not going to be working on stuff like that. But if you want to give me a how-to of how to perform a surgery, what medicines are used, why they need to be used, okay, I'm really going to be interested in that.
Luke, another initial pre-med major, echoed a similar theme and, in particular, failed to understand the necessity of taking introductory chemistry courses:

I didn't want to have to keep learning about some protein here or there that doesn't to me relate to the kind of work that I want to be doing with people as much…For example, I'm in bio-chemistry right now and I sit there and we're learning about the stereochemical configuration of Carbon 3 in a chain of sugar and it's like, "Well, great," and it bothers me that I have to memorize this and I have to learn this detail that surely is never going to be useful to me at all, whether I'm a physician or not. I've talked to doctors, and they talk about how they literally never use the organic chemistry that they learn. Yes, it's important to understand some of that basic stuff, especially when you're learning early on in med school, but in practice, it's not useful at all.

Participants like Eric and Luke failed to grasp how the rather theoretical content of these courses pertained to their interest in medicine and future careers as physicians, and wished they could take courses that seemed more “useful” and relevant to their desired outcomes. As Cynthia points out, pre-med majors often wish they could begin their college careers studying “…the part of medicine that…happens in grad school” and therefore become disinterested when they realize that is an impossibility due to the nature of introductory undergraduate STEM curricula, which focuses on basic concepts and requires students to take a wide variety of STEM courses. Sarah describes her own personal disinterest in the initial STEM courses she was required to take:

And I wanted to dive into the material right away, and going in and learning about plants and animals and the periodic table when, in my mind I'm thinking of - because I had been in the doctor's office before and the orthodontists’ office - of the tools and how he does
stuff. I was more, "I can't see myself doing this to get to my goal." I just felt like it was so far away until I got into classes where I would really truly enjoy doing more of that stuff. This frustration with the STEM curricula was not limited to just the initial pre-med majors, however. Participants who initially declared majors such as biology and math expressed similar frustrations regarding the abstract nature of courses and being required to take many additional classes that do not pertain to their specific interests. For instance, Danielle, who initially declared a biology major due to her interest in learning more about neuroscience, explains:

I think probably one of the biggest negatives about staying as a bio major is that the course load is really broad, and you have to take all kinds of organic chemistry, and all kinds of biochemistry, and then you have to take physics, and then you have to take plant biology and animal biology. Really, my biggest interest was just in the brain, but I was going to have to take dozens of classes that weren't necessarily my interests.

Brian also believed that his initial math major did not allow him to study the kinds of topics that he was most interested in exploring. Brian’s decision to initially declare a math major with a specialization in actuarial science was based largely on his perception that this major would allow him to study more “practical” applications of math that relate to the business world. However, after taking some introductory courses, he began to understand that he would still be required to take the kinds of theoretical courses that he did not want to take:

And I remember taking the first day of seminar class in math and it was one of the main reasons, I guess, that I decided to move out. Because it was interesting, but at the same time it's telling me that what I'm going to take maybe in my third year or fourth year is not something that I want… Yeah, because even though I wanted the actuarial option,
most classes I'm going to take are math, so it's like that part of the process [taking theoretical courses] is inevitable.

For many participants, therefore, taking required STEM courses represents an obstacle in and of itself because they are often times unwilling to take classes that do not directly relate to their initial interests and career goals. In many cases, participants do not realize that they would be required to take such a broad curricula upon entering college and declaring STEM majors, and are surprised to find out just what kinds of courses they will actually be required to complete in order to earn a STEM baccalaureate degree. In the end, many participants decided that the benefit of receiving a STEM degree was not worth the cost of taking such courses they deemed disinteresting.

**Passive pedagogy.** Participants frequently reported not only being disinterested in the content being taught in introductory STEM courses, but frustrated with the rather passive pedagogical methods that were utilized by professors to convey the material. Introductory STEM courses were almost universally taught in lecture halls, and professors were often characterized as predominately lecturing to their students, as opposed to facilitating discussion or deeper understanding of the course material. Participants frequently criticized this mode of instruction and believed it contributed to their general lack of engagement, inability to ask pertinent questions, and difficulties paying attention.

For example, several participants described the professors of their introductory STEM courses as relying primarily on lectures and power points to convey course material, and how these instructional methods contributed to their lack of academic engagement. Mary, an initial pre-med major upon enrolling in college, described the dominant pedagogical methods used in
these courses, “There’s lots of power points, something I’ve always hated, but that’s kind of unavoidable in any college class… There is no discussion—that’s one of the big things I remember.” Mary believed that this lack of discussion and reliance on lectures and power points as the dominant pedagogical modality contributed to her lack of academic engagement with the course subject matter. Mary explains, “I think, now, I don’t know if I spend a whole lot of time, I’m thinking how to phrase this, I don’t spend a lot of time thinking about my class material when I was pre-med. I would leave class and it would be gone until I came back to it later and actively looking at it. I think that’s partly because we don’t talk about it in class. They are just kind of speaking at us.”

Sarah concurs with Mary’s assessment of the instructional methods utilized in introductory STEM courses. For Sarah, it felt impossible to remain engaged and retain information during lectures due to the lack of discussion and reliance on lecturing by the professors,

   Because even for me, I’m here to tell you, I didn't sit in the back and text. I was up front trying to retain everything, but I felt like she was just talking really quick, and she just kept hitting the slides and I was trying to write, and I wasn't retaining anything. And by the time you go home and you try to get homework done it's out of your mind after the full day. You go back and look at your notes you are like, ‘Oh, goodness what is this?’

Sophia likewise believes that STEM subjects need to be taught in a more interactive manner that emphasizes student participation and engagement with their professors, “I guess this is how it is for a lot of classes, but I think that teaching that way for chem was just not right. It didn't really
work… Whereas with chem, it's almost like it needs to be hands-on. You need to be talking back with the professor, and it's so much more confusing… I don’t know how to explain that.”

This perceived lack of ability to ask questions of professors during class lectures is a common refrain among participants as contributing to their inability to remain academically engaged. For example, Charlotte sharply criticized the large lecture hall setting and the professors’ reliance on lecturing as the dominant mode of instruction because, in her opinion, it contributed to her inability ask questions and delve more deeply into course material, “The big thing that I didn't like about the courses were the huge class size, question asking during lecture wasn't really encouraged.” Even though Charlotte, like other students, was offered the opportunity to speak with professors during office hours, she would much rather have had opportunities to ask questions during class when they first arise, “It's not the same. I need to be able to say, 'Well, what about this?' I like to ask about contingencies. I like to get deeper into things, so I do like a more personal learning experience, especially for material that's going to be trickier.”

Eric also sharply criticized STEM professors for their reliance on lecturing and discouraging their students from asking questions during class. Eric tells one particular story in which a chemistry professor rebuked one of his classmates for interrupting his lecture by asking a question:

But what really turned me off from the entire thing was, we started one time - we were in an organic chemistry lecture with one of the professors here - and some girl just asked a question. People think it's okay to ask questions in class, which it should be. And this professor just went off on her. "Are you kidding me? You are so stupid, why did you not
"I read the book. I did the homework. I got it right and I was still confused about that. So, why can't you just explain that like you're getting paid to instead of making this girl feel like absolute crap in front of 300 other kids. And I was so appalled by that, I was like, "If I see this again, I'm going to be done." So, that happened a couple of times that semester with that same professor and I was like, "The fact that this university will even employ a low-life piece of garbage like that, and he's tenured, and all that stuff, I want nothing to do with this anymore."

Madison and Scott also disliked the large lecture hall settings of the courses and believed it contributed to their lack of understanding of course material, which ultimately contributed to their decisions to leave STEM. Madison, an initial pre-med major who entered college with a perceived weakness in mathematics, did not enjoy learning math in such a large setting where she was not able to ask for clarification immediately after questions regarding content arose,

Yeah, I mean I know you don't come to State University for one-on-one help. But specifically in math classes, that's where I struggle. Like I said, I do all right in other classes and lectures; I honestly don't mind. But with math, I remember in high school if I had a question, the teacher knew me. I could ask her, and she would explain it. But in a lecture…

As a result of the large lecture hall setting where she felt like she could not ask questions, Madison felt like she was left in the dark, "I try to follow it, but...I don't know how to put a word to my feeling. For me, it was trying to follow it, trying to write it down, and then get what they were saying, and see the steps of the problem, but it just didn't happen."
Scott echoed a similar sentiment regarding his perceived inability to ask questions in large lecture classes contributing to his underperformance in some of his introductory STEM courses. Scott believes that he would have done better in a smaller environment that more readily encouraged the asking of questions during class, “It's so big. It's not very personal at all. I feel like if the classes were like more of a-- if like I felt more comfortable like raise my hand and ask questions, like just a smaller basis, I feel like I would've done a lot better.”

In addition to participants’ believing that large lecture courses discouraged them from asking questions, some participants’ also felt like the large lecture classes interfered with their ability to pay attention and remain intellectually engaged during lectures, largely due to the distracting nature of being surrounded by so many peers. For example, Natalie believed having such large lecture classes are particularly challenging for entering freshman who are used to learning in smaller environments:

It [introductory pre-med courses] was huge classes, like lecture halls, 600 plus people. I think, if I took 15 credits, I think four out of my five classes was in 102 Smith, the humongous lecture hall. And in that kind of environment it was like, first of all, it's hard to pay attention… Second of all, it's there's so many other people that like I felt that if I slipped by that like there was other people in my class, that they could, I don't know, help me if I was struggling or whatever so I never really took the proactive approach to be like I'm going to write down all my notes the day before class and like read all the textbooks. Because we had study groups, like people in my dorm and stuff. So it was kind of they

8 The names of classroom buildings have also been changed to further protect the identity of participants.
were sort of my crutch, not necessarily like a benefit or a harm to me, but it was just like, "So and so understands it better than I do, so I could just get them to explain it later and then I'll just play on my laptop during lecture." You know what I mean?

Robert also believed that the transition from high school to college and the university’s use of large lecture classes to teach introductory STEM courses posed a challenge for his ability to pay attention and remain engaged:

I guess the first big jump was going from a small classroom with a teacher that I knew - going back to the honors/biology topics - that was like a 15-20 person class, and I had known the teacher for a couple of years, and then going from that to Bio 100 and a 600 person lecture room with a professor who was 300 feet away from me [chuckles]. Just kind of, I guess that was a big shake, and I don't know, that was a hard transition to go through… I just think when you have a class to that scale, there are just so many more people are on their laptops and blatantly not paying attention that it sort of just catches your eye a little bit more.

Furthermore, participants believed the STEM instructors they encountered in these introductory courses were often “impersonal and “not relatable,” and at times disinterested or unable to provide quality instruction. At the heart of many participants’ complaints about faculty is professors’ perceived inability to convey course material in understandable ways that can easily be digested by undergraduate students who are just beginning their STEM studies. Mary explains, “I don’t think the professors know how to learn that material because it seems so simple to them at that level.” Charlotte agrees,
People in the hard sciences, a lot of them are there for research. A lot of people who are brilliant, I've noticed, in maths and the hard sciences, have a lot of trouble teaching it because their brains work differently, especially people who are… math geniuses. So it's really hard for them to go and say to someone who has a brain that works much differently, “How can I teach a student in a way that would be interesting, that would be accessible?”

As a result of the professors’ advanced academic training and experience teaching STEM disciplines, they often struggle to offer effective instruction that makes sense to their students. Scott relays his experience taking introductory STEM courses, “A lot of my math courses, a lot of my science courses. It's just like they're [the professors are] very smart individuals, and I understand that, but they're not good teachers. They don't know how to help students learn, or how to communicate the processes that are involved. And it's just like this is how it works and you should be able to understand that. They don't teach it; they just tell it, I think.”

In addition to not being able to convey course material in clear and easily understood ways, professors often made assumptions about what students knew upon entering their courses; these assumptions, according to participants, were often incorrect and contributed to their additional difficulties understanding course material. Cynthia, who entered college as a pre-med major and ultimately decided to leave STEM largely due to experiencing academic difficulties in her introductory chemistry course, explains, “So I just-- I think they [the professors] felt like we should have already known it because this is what we wanted to do, so we should have already worked into several levels of chem, but I didn't. And the people that did well, had taken AP chem and have taken all of those courses, but I never did. So I think that's why I struggled.”
Madison also believed such assumptions made by professors may have contributed to her inability to do well in her introductory math courses, the main source of her academic struggles, “I feel like they would lay out the work, and I-- there was a lot of assumptions that instructors had that I felt should have known, like what certain letters or symbols mean.” Furthermore, professors often gave the impression that the material being taught in these introductory courses was “easy” and that students should not need additional assistance. Sarah states, “And the professor is very nice, but the same thing, "This is it, here it is. This is easy, right?' And it was like, "No, it's not. It's not easy. You probably have a PhD in this and I don't!'”

**Disappointing Grades.** A third obstacle that frequently demotivated participants from continuing along their initial STEM pathways were the academic difficulties they often encountered in STEM introductory courses. Although the participants I interviewed for this study were all academically capable students who maintained above the 2.0 GPA in core College of Science courses that was required of STEM majors, they sometimes struggled to pass one particular course or received grades that did not meet their own personal standards. These grades often demotivated participants from continuing in their initial STEM majors in several important ways.

**Lowering self-esteem.** For many participants, struggling to pass a course or receiving grades that do not meet their own personal standards damages their self-esteem and motivation to continue in STEM disciplines because they entered college as academically talented freshman who received excellent grades in high school. For example, Christina, who entered State University as a biology major and was a varsity athlete on the school’s swimming team, felt dejected by doing poorly in her introductory calculus course and knew immediately that she
wanted to drop her initial biology major after she thought she had failed the course’s final exam. Christina explains the impact struggling to pass this one course had on her decision to leave STEM:

I felt terrible because I was a successful student in high school. I knew I could do better than that. My coach was even like, "Is there anything we can do? We know you can do better than that, also." My dad-- I don't even remember what my dad said. But, I remember after that exam, I went to practice, and then after practice, I went to go see my counselor… And I went to her, I'm like, "I just failed my math exam. I'm not doing science anymore.

Evelyn also struggled to pass one particular course, in her case it was introductory chemistry, and likewise became demotivated to continue in her initial biology major as a result of these struggles. Evelyn decided to “drop” the course after receiving several poor exam grades, fearing that her final course grade would diminish her overall GPA. Evelyn describes her experience struggling with chemistry, “I've always just been very-- I want to get the highest score that I can. I've always been like the grade [jumper] or whatever, I don't know. So that kind of scared me because I've always done well and not being up in an ‘A’ was kind of terrifying.”

Although Evelyn attributes much of her decision to leave Biology due to her lack of interest in taking classes in “the other sciences” besides biology, she also admits that her perceived lack of interest in taking these classes might have been related to her poor grades. Would she have continued in her initial Biology major if she had been receiving better grades in chemistry? Evelyn states, “I would say that's definitely accurate. If I had felt that it was
attainable and that I wasn't going to be miserable through every single chemistry class that I took then I would have probably stayed.”

Like Evelyn, Luke also experienced some academic difficulties with chemistry and described these struggles as “humbling” and placing “…a check on [his] confidence” in light of the fact he was an excellent student in high school who was granted admission to State University’s prestigious honors college. Entering college as a pre-med major, Luke eventually switches to psychology, a decision he largely attributes to his burgeoning interest in psychological subject matter. However, Luke also admits that his academic difficulties and the difficult nature of the pre-med curricula may have also played a role in his decision to switch majors, “But it was more so that it was whether I wanted to put myself through that. And through my freshman and sophomore year, there were times when I really questioned it, because it was hard. So that was what it was - do I really want to put myself through this?”

Receiving disappointing grades in one particular course demotivated Cynthia from continuing in her initial pre-med major, as well. Despite receiving “B’s” in her biology and math courses, she struggled to pass a key introductory chemistry course, and did not believe the struggle to pass the course, along with the accompanying stress, was worth staying in her initial STEM major:

I didn't want a struggle in my life forever. It was bad, like the second time I took the class, they let us grade ourselves. After the final-- I knew what I needed on the final, and I didn't get it. When I graded myself, I didn't get what I needed. I cried, and I cried, and I cried for days because I was like, "I just failed this class again. I'm barely there." But fortunately when she released the curve and she put the grades online, I somehow got a
C, but it was still-- I hyperventilated over a class which is ridiculous to me. That's not how I wanted to live my life.

As a result of her struggles, Cynthia decided to leave STEM the very next semester. Would she have left had she not struggled to pass the introductory chemistry course? “No. I would've never thought about it for a second,” Cynthia explained.

In addition, comparing one’s grades to the grades of classmates also acted as a demotivating influence for several participants because it left several individuals feeling inferior to their classmates, even when they themselves were doing relatively well academically. Sophia explains how such peer comparison demotivated her from continuing in her initial chemistry major:

Definitely those first round of exams, getting back and realizing, "Oh, maybe I'm not doing as great a job as I thought I was then." It's hard too coming to a school like this, there's so many smart kids around you. And seeing other kids get 99s and 98s on things, and you're like, "Okay, what's wrong with me? This probably isn't the right field for me, because if there's other kids getting As in everything, and I'm getting Bs and Cs, then I must not fit in right."

**Negative cost-benefit ratio.** Receiving disappointing grades and experiencing academic difficulties demotivates students from continuing in STEM disciplines due to the lowering self-esteem and stress that comes along with these struggles. However, for other participants, the demotivating influence of receiving disappointing grades is more related to the *cost-benefit ratio* of putting forth maximum effort only to receive these disappointing grades despite their best efforts. In other words, some participants believe it is simply not worth their time and effort to
struggle for good grades in STEM majors when they come to believe they can not realize their personal academic goals.

For instance, Natalie, whose academic struggles were a demotivating factor behind her decision to leave STEM, describes how it can be very discouraging for students to receive poor grades despite their best efforts:

I mean, I wasn't burnt out at that point, but it was just the point where just like, "This isn't easy and it's not fun to work on." You don't want to sit in the library for six hours and try to figure out your organic chemistry homework. Because I felt that no matter how much I studied, I would still have gotten no more than a 70%... I just felt that I was-- I was very overwhelmed with the amount of work, and it was just like, a lot of stuff. I don't know, it's very tiring to put in all this time and effort, and then you don't get the A on your paper.

Natalie would have stayed with STEM if she believed the effort she was putting into her studies was better reflected in the grades she was receiving in her courses, “If I would have gotten good grades-- I feel like if I would have reached the benefits of good grades while also putting in all the work that I did, I would have stuck with pre-med up until this point. But I was putting in so much work and still not getting good grades. That's how I felt - that I was just wasting my time kind of.”

Sometimes students can become demotivated by their perceived cost-benefit ratio even when they receive good grades. For example, Eric, an initial chemistry major who wanted to pursue a career as a physician, received relatively good grades in his courses but was demotivated by what he felt were capricious grading policies in one of his chemistry courses.
Eric explained how he needed to spend much time and effort devoted to completing the laboratory assignments for the course, but believed he would be unfairly punished for receiving lab results that were out of his control:

It was like a cost-benefit. I'm going to spend six hours here [in the lab] not being distracted, doing exactly what I want and what I think is right. And if there is some little mess up and I don't get the quantity of precipitate that I need at the end, or whatever, I don't get the right product at the end and I just wasted those six hours because I failed it. I was like, "That doesn't appeal to me whatsoever."

Eric goes on to further explain that despite the fact he was receiving good grades, his perception of the cost-benefit ratio of receiving those grades still acted as a demotivating factor behind his decision to leave STEM, “They [my grades] were fine. They were good. It wasn't like I was getting bad grades and was like, ‘God, this is too hard.’ I was getting good grades, and I realized that it's not worth my effort for this, with this faculty, with this type of work, and with this kind of non-reward, essentially of doing this. So I moved on.”

**Signaling future difficulties.** Receiving poor grades or grades that do not meet individual standards can act as a demotivating influence over participants’ decisions to continue in STEM majors due to the fact that such grades may signal the possibility of students experiencing future difficulties. Some participants came to believe that if they were having academic difficulties with introductory courses, they may not be able to pass more advanced STEM coursework, or gain acceptance into graduate or medical school.

Christina, the participant who discussed above how she decided to leave her initial biology major after believing she failed one of her final exams, explains that this initial academic
difficulty made her doubt her future academic prospects, “…if I did this terrible in Math 101, how the hell am I supposed to get through Math 102 with all the effort and time and hours I spent studying? The amount of effort that I put in did not reflect the final grade that I got. So if I put this much effort into this class, there's no more room-- time in my life to put into this other class.” Cynthia expressed a similar sentiment when discussing her initial struggles with chemistry, “Yeah. I cried a lot and it just-- if I couldn't get through the first level, how am I going to continue on?”

For Sophia, her early academic “difficulties” signaled both future challenges excelling in more advanced STEM coursework, as well as gaining admittance to graduate school. Sophia entered college as a chemistry major but was deterred from continuing by her early academic struggles:

And I think, for me, I kind of had this idea, "I want to go to grad school." So it was kind of similar. And I think I started realizing if I keep going down this path - if I'm getting Bs now, these classes are only going to get harder - and then if I don't need to be taking--kind of what I said before. If I know I'm not going to be doing that well in these classes, this could hinder my acceptance to a grad program down the road if they're saying, "Oh, she did awful in these classes."

Madison also experienced similar thoughts about her early academic struggles impeding her ability to gain acceptance into medical school. Beginning college as a pre-med major, she received “C’s” in several introductory math courses and began to doubt her ability to successfully attain her goal of medical school acceptance. She was fearful of continuing in this initial STEM major and after not being able to gain acceptance into medical school, being left
with few post-college opportunities, “I didn't want to have this pre-med major and be like, ‘What do I do? I can't go to med school.’”

**Demanding time commitment.** Another obstacle that participants frequently cited as a demotivating factor that contributed to their decision to abandon their initial STEM pathways was the demanding time commitment required by many STEM majors, both in terms of the amount of study time many STEM majors require of successful students, and the number of years it takes to complete the undergraduate and graduate degrees required of certain STEM careers.

**Study time.** Participants used words such as “brutal” and “taxing” to describe the workload they faced while they remained STEM majors. According to Evelyn, she remembers, “…always being busy” when she was a biology major, and the STEM curricula “…was kind of a pain” due to the amount of work that was involved in completing assignments and studying for exams.

As a result of the exhaustive time commitment required by STEM disciplines, participants often felt like they were being forced to give up essential aspects of the “typical” college experience, such as participating in extracurricular activities, and came to realize that they were unwilling to give up these experiences in order to remain committed to their initial STEM pathways. Luke told a particularly revealing story in which one of his STEM professors explained the workload that successful pre-med students needed to take on, “The overarching message was this is going to be extremely difficult and you can do it if you work constantly and put a ton of effort into it, but it's going to be difficult. But if you can do it, you're the best of the best and if you put in the time and the effort then you'll be able to do it.” Luke recalls being told
that successful pre-med students could only have two sides of a “…triangle of sleep, social life, and academic life.”

Many students do not wish to engage in such a stressful academic-centered lifestyle during college. For example, Luke says he was “deterred” by hearing this message, and wanted a college experience in which he could have a vibrant social life. Other participants also found it difficult to balance the demands of the STEM curricula with their extracurricular interests. Eric explains:

It [STEM curricula] was just time consuming. I'm also on the cheerleading team, I'm involved in a fraternity here, so I kind of had my hands full with other things, and there were always just too many time constraints involved with the whole science program. And it would come through my e-mails. I don't know if there was specifically an honor's college science thing, that you'd be required to do this, go here, come to this lecture and meet with this professor or whatever. It was a lot of time that I didn't have in the day.

Heather also notes that she was demotivated by the exhaustive time commitment required of her initial STEM major, and did not want to be like other peers who were compelled to give up extracurricular opportunities due to majoring in challenging disciplines:

When I first started school I joined a sorority, and that was something that I wanted to give time to in regards to leadership. I had seen older sisters who had done harder majors and they hadn't had time for things like that, or even other clubs or any other kind of organizations. They would literally be like, "Okay. I have school and that's all I really have time for." And then they do the bare minimum just to stay in the club basically, and
that's not what I wanted. I wanted more of a kind of all-around wholesome experience that would include more than just school.

As a result of her decision to leave her initial biology major, Heather has been able to have “an all around experience” that includes a greater academic-extracurricular balance:

I was able to take on several large leadership rolls within my sorority, and those were very time consuming, so I don't necessarily see myself being able to do those if I hadn't had enough free time. In my junior and senior years, I've been able to volunteer like 15 hours a week, at a local human service agency. And I definitely don't see-- wouldn't see myself doing that had I had more school work, and more school related responsibilities.

**Time to degree.** In addition to being demotivated to continue in their initial STEM majors by the amount of study time it took to complete the necessary assignments and study for exams, participants also described being deterred from continuing in these initial pathways due to the number of years it would take to complete the necessary baccalaureate and graduate degrees to begin their desired STEM careers. For instance, Heather, in addition to being demotivated by the daily time commitments associated with studying her initial biology major, was also turned off by the prospect of attending medical school after college:

Because on top of the undergrad, the idea of going to med school for all those years, and then having to do the rest of the schooling for that, was-- it seemed like a good idea in high school, but then realizing that I was going to be that much in debt and not starting my career until I was almost 30 was not so appealing as I got older. So I think that was another driving force, and that was probably the biggest one, actually, now that I look back - is seeing that I didn't want to be in school for that long and working for that long.
Natalie was also demotivated by the prospects of attending medical school after college due to the sheer number of years she would have to devote to her schooling before reaping the rewards of her original goal, becoming a dermatologist:

It was not only the present-day time or like you are spending 10 hours a day in the library, in the lab, trying to figure out what the heck is going on in class, but also the idea that undergrad is four years, medical school is four years, you have to do an internship. I wanted to specialize in dermatology, that's another two years. By 35, am I still going to even want to do this? It was that kind of idea where it's just like, "This is such a long journey to get to where I thought I wanted to be. Is that really what I wanted to do?" Because who knows what they want to do when they're 18? I sure as heck didn't. It was one of those things where there's so much time involved and years upon years, and I had the fear I would just like, "Is that really what I want to do?"

Furthermore, for some participants, the idea of spending so many years in undergraduate and graduate school discourages them from even considering their ideal STEM career due to their desire to raise a family after college. For example, Danielle entered college as a biology major with the intention of pursuing a career as a research scientist studying the brain, but never really considered becoming a physician, an occupation that she describes as her “dream career,”

So more of like - this is a really lofty goal - but a neurosurgeon or somehow working-- I don't know. I like the concept of surgery, and the brain, but I wouldn't have wanted-- probably going into college, I would've considered that as like, "Oh, that would be like a dream career," but I think I more - not settled - to work in a lab, but I was like, "This is a more practical way." I never really considered actually following the path because of the
time. And I think especially for me, I value more having a family, and being able to raise children and I didn't think that that was really an option.

**Unappealing Career Options.** A final obstacle that influenced participants’ decisions to leave their initial STEM majors was the perception that completing STEM majors led to unappealing careers. After taking several introductory STEM courses, some participants came to the realization that their initial STEM majors led to careers that were not as interesting or exciting as they imagined they would be when they were in high school. This realization demotivated participants from continuing along their initial STEM pathways.

For example, several participants, once they took several introductory STEM courses, decided that they did not want to pursue the research careers that they initially felt they wanted to pursue while they were in high school. Charlotte, an initial biochemistry major whose parents are both working as biochemists after graduating from State University themselves, explains a major impetus behind her decision to leave her initial STEM pathway, “Then my spring semester, I realized that I didn't like it as much as I thought I was going to like it. I took the freshman seminar and I was like, "Uh." It was when we started talking to the PhDs. When we started talking to people who were in it, I was like, "Uh, I don't actually know if I like"-- they were talking about what they did and they're really excited about it and they love it, but I'm like, "I don't know if I want to do that." Charlotte continues, “I was like, I don't like what I've seen from the biochemist. I did not like what I was seeing PhDs doing. It was too microscopic. I like macroscopic thinking a lot more than micro thinking.”

Danielle told a similar story of being demotivated from continuing in her initial STEM pathway once she gained more insight into what researchers have to do on a daily basis as part of
their jobs. Initially declaring a Biology major because of her interest in neuroscience and her desire to study the brain, Danielle realized that she did not want to continue down this initial STEM pathway once she started completing lab assignments as part of her initial STEM coursework:

But I was in the Bio 101 lab portion and also Chem 102 - the lab that goes on with Chem 101 - and I just didn't like it. I didn't like being in the labs. I was really surprised with that because I liked labs in high school. I liked doing the lab but I didn't like writing the reports, which was definitely a red flag to me that like, "Oh, that's what being [a researcher is like]… If I'm going to go on to be a researcher, I have to write lab reports and I don't like that.

Before she realized that she did not particularly enjoy working in laboratory settings, Danielle had applied to work in a research lab on campus to gain more experience. Working in this research lab further confirmed these earlier experiences and helped her realize that she did not want to pursue a research career.

Jane and Kate, who both initially declared forensic science majors upon enrolling in college, also become demotivated from continuing along their initial STEM pathways once they gained more insight into the nature of forensic science careers. For instance, Jane, who was initially motivated to pursue a forensic science degree by her interest in helping solve crimes and enjoyment of watching various “CSI” type television programming when she was younger, began to doubt her initial STEM pathway once she realized forensic science majors typically go on to work in research settings after college:
…I went and talked to my science adviser and was talking to her about forensics in general and I was telling her about how-- I asked her job-wise what really you would do with forensics and she let me know that most people who graduate from [State University] with a forensic degree work in a lab. And once I heard that I was kind of like, "Okay, I don't really know if the labs are the direction I want to go especially after taking the chemistry class and not doing very well and taking all these and not enjoying the classes I'm doing and not enjoying my first semester sophomore year."

Kate also became demotivated from continuing in forensic science after talking with her advisors who informed her that most forensic science graduates go on to work in research labs, “So that I think with my choice of going forensic science, because I went to a lot of my advisers just like asking them. I told them like how I felt, and they were like, ‘You will be in the lab a lot of the time.’ So that’s kind of what switched.”

Several other participants also began to question their initial STEM pathways once they were enrolled in college and began to learn more about their future career options. Luke, an initial pre-med major who was interested in pursuing a career as a physician, began to doubt this decision when he learned more about the emotional and physical toll the medical profession often places on doctors by watching a documentary that was presented in his pre-med seminar course:

…at the end of the seminar, towards the end of the semester, we watched a documentary. I don't know what it's called, but it was about the experiences of seven different medical students who went to Harvard. It basically traced their life from getting into med school residency, and then years later. And that definitely made me question even more whether
I wanted to be a physician, because pretty much all of them had major life issues. So a lot of it was discouraging.

Another initial pre-med major, Madison, also became discouraged from continuing along this STEM pathway once she was enrolled in college and began contemplating what a career as a physician would actually entail, “I think a lot of what scared me about staying in the major and possibly going to med school was like, having someone's - I remember saying this all the time to my roommate - I just don't know that I can have someone's life in my hands in that way or have that kind of responsibility, that leadership.”

For many participants, therefore, various collegiate experiences afforded them the opportunity to learn more about their future (intended) STEM careers and caused them to question whether or not they really wanted to continue on their initial STEM pathways.

**Summary.** The second phase of the theoretical process that explains why many students ultimately decide to leave STEM majors occurs during college when participants encountered various obstacles that discouraged them from continuing along their initial STEM pathways. Data analysis revealed five major obstacles that were often encountered by participants during the early stages of their STEM experience:

1. Competitive Culture
2. Disengaging Curricula
3. Disappointing Grades
4. Demanding Time Commitment
5. Unappealing Career Options

As a result of encountering such obstacles, participants became discouraged from continuing along their initial STEM pathways and subsequently begin to consider locating alternative academic pathways that allow them to best pursue their interests and gain preparation
for future careers and graduate school placement. In fact, in the absence of encountering these obstacles that are inherent within the STEM academic experience, many participants would never have considered leaving their initial STEM majors.

For example, Jane, who encountered several of these obstacles during the early semesters of her college career, explains how her being demotivated by receiving disappointing grades led her to locate an alternative academic pathway:

I still studied as much as I did. I didn't switch my study routines. I would still go to the library and study-- so I was kind of like, wait what's going on? What's wrong? Why is this not working out the way it was before? So, I think I would probably say it was initially I was motivated and the bad grades kind of demotivated me and then I think all of it in general just was like a really big slide [italics mine] where I was demotivated from the STEM major and then took that demotivation to motivate me in something else.

Eric concurs with Jane’s assessment that the process of encountering obstacles during the early stages of his STEM experience contributed to his declining interest in continuing to pursue a STEM major and his concurrent willingness to locate an alternative academic pathway. When asked if he would have continued in his initial Chemistry major rather than switch to Finance if he had not encountered various obstacles in his early STEM coursework, Eric states:

Yes, absolutely. I don't think I would have had-- or even crossed my mind that maybe there is something else I would rather do. Because I even came in and kind of looked down on the business school and the business majors. "Oh, these lazy kids. They want to take these easy classes and just kind of coast along and wear a suit everyday and do this
and that and the other thing." So if I wasn't turned off from it, then I wouldn't have [wanted to switch majors].

Therefore, *encountering obstacles* in the early stages of the STEM experience lays the groundwork for future STEM attrition by discouraging students from continuing in their initial STEM pathways and encouraging them to seek out alternative non-STEM pathways that can better help them pursue their intellectual and career goals.

**Originality.** These findings both confirm and expand upon the extant literature’s discussion of STEM attrition in several important ways. First, this study’s findings regarding the impact of disengaging STEM curricula confirms the extant literature’s discussion of the relationship between negative curricular experiences and STEM attrition (Tobias, 1990; Alberts, 2005; Mervis, 2010), while also giving voice to particular student’s experiences in introductory STEM courses.

These findings also shed light not only on the impact of instructional methods on STEM attrition, but on other aspects of students’ curricula experiences that also act as demotivating influences. For example, similar to the findings in Suresh (2006) that discovered that many STEM students “…did not appear to understand the connection between the theoretical courses they had to study during the first two years and their relevance to their major,” this study found that many participants decried the fact that the STEM content taught in introductory courses seemed abstract and divorced from their initial interests and career aspirations, and therefore unrelated to their specific major. Similar to Strenta et al. (1994) and Suresh (2006), this study also highlighted participants’ perceptions of the competitive academic culture embedded within STEM majors and how such competitive cultures may act as demotivating influences.
This study’s findings regarding the negative influence of academic performance on STEM attrition also confirms some earlier findings in the academic literature. For example, Rask (2010) found that, "Absolute grades are one of the largest and most persistent factors in the attrition of undergraduates from STEM departments. There is also some evidence that relative grades are important in some STEM disciplines" (p. 18). In addition, Seymour and Hewitt (1997) note that although many talented students actively choose to leave their initial STEM majors and are not forced to leave due to poor performance, many students (23%) at least partially attribute their decisions to leave STEM majors due to poor grades. This study’s findings further highlight how receiving disappointing grades impacts students’ decisions to leave their initial STEM majors, while also illustrating more specific aspects of how receiving disappointing grades impacts students’ self-esteem and belief that they will be able to successfully complete future STEM coursework.

Finally, this study has also contributed to the extant literature on STEM attrition by highlighting the impact of two variables that have not been discussed in previous research: the demanding time commitment associated with pursuing STEM degrees and students’ perceptions of unappealing STEM career opportunities.

**Employing Strategies**

The third phase of this process explains how participants come to locate the alternative pathways that will become their new non-STEM majors. After participants enter their initial STEM pathways on shaky motivational and academic footings that contributed to their eventual discouragement from continuing along their initial STEM pathways, they begin to employ
strategies that help them locate alternative pathways. These alternative pathways allow them to pursue intrinsic interests and extrinsic goals without encountering the same kinds of obstacles they faced in their initial STEM majors.

Participants employ several strategies for locating these alternative pathways. Some of these strategies that are utilized for locating alternative pathways are purposefully employed by participants to locate new majors after they have become disinterested in their initial STEM majors; other strategies are more serendipitous and are employed by participants during the course of taking STEM coursework before they even realize they may want to discontinue along their initial STEM pathways. These strategies can be classified into the following categories:

1. Taking Non-STEM Courses
2. Researching Non-STEM Pathways
3. Talking To Friends
4. Embracing Familial Examples

**Taking non-STEM courses.** The most common strategy employed by participants in order to locate alternative pathways is taking non-STEM courses. Taking non-STEM courses often sparks an interest in a different subject matter and helps participants understand that there are alternative academic pathways that they can pursue that do not present the same kinds of obstacles they faced in their original STEM majors.

Charlotte, the initial biochemistry major who planned on pursuing a career as scientific researcher upon entering college, is one participant who decided to switch majors to a non-STEM field after taking several non-STEM courses. Charlotte was discouraged from continuing along her initial STEM pathway after encountering a variety of obstacles, including taking STEM courses that, in her opinion, featured disengaging curricula. After having a “rough
personal semester” that contributed to her receiving a poor GPA that threatened her status in State University’s honors college and membership in a prestigious scholarship program, Charlotte decided to take several non-STEM courses:

I want to stress that it wasn't the classes themselves that pushed me out. It was more that I started with having a rough personal semester, which drove my GPA down and forced me to keep scholarships and my standing in the honors college. I needed a 4.0. There was no wiggle room. I was not going to mess around and taking a hard science course because I know those courses, they are courses that I worked my butt off and got a B plus. I couldn't get an A minus. It needed to be 4.0. So I took easy courses.

One of the “easy courses” that Charlotte took was an introductory psychology course that she enjoyed. Charlotte explains, “I really love[ed] psychology. I took 100 honors [psychology], and it was the first text book I read cover to cover and didn’t mind reading it cover to cover.” The course sparked a deep interest in psychology, which she found to be particularly engaging and able to address the kinds of “macro level” questions that she enjoyed and felt were missing from her introductory STEM courses. Charlotte liked that psychology felt more “hands on” and less abstract than her introductory STEM courses. Charlotte states, “Yeah, I think I like working with people. I wanted to help people. That was with biochemistry. But then I realized I didn't want to help people that way [chuckles]. It [STEM] was too microscopic, too much in a lab with microscopes, very much on the cellular level, and it wasn't with people. It wasn't as hands-on. The effects weren't as obvious.”

Furthermore, Charlotte enjoyed not only the content of these psychology courses, but the ways in which they were taught. Unlike the introductory STEM courses which she felt did not
allow her to ask questions or indulge her natural curiosity, the psychology classes featured a more “positive class environment” that encouraged students to ask questions. Describing one of the introductory psychology classes she took, Charlotte says:

They'll [STEM professors] just rush through an answer and then keep going, but it always was-- they were like, "Oh yeah, that's a good question. Let me answer." I think the first course that was larger that was psychology was social psychosis, the 200 level social psychology course. I'm (?) "Oh, yeah, good question." He would think about it and if he didn't have an answer, he would email the course afterwards with an answer, or he'd say, "Hey, come talk to me right after class." It was much more like-- when I asked a question, it was almost like positively re-enforced by, "Oh, good question. Let me actually think about the answer.

Charlotte ultimately decided that majoring in psychology represented a better academic pathway that allowed her pursue her newfound interest in psychology, while preparing for graduate school and a future career as a psychological researcher. By majoring in psychology, Charlotte is able to pursue her intrinsic interests and extrinsic goals, without having to encounter obstacles such as disengaging curricula and disappointing grades that she faced in her initial Biochemistry major.

Mary is another participant who decided to switch majors after locating an alternate pathway by taking non-STEM coursework. Originally declaring a pre-med major upon enrolling in college, Mary planned on attending medical and graduate school after college in order to pursue a career as a medical researcher. However, she became discouraged from continuing along this initial STEM pathway after becoming disillusioned with the disengaging curricula and competitive climate that she faced in her introductory STEM courses. As a result, Mary began to
slowly realize that she was becoming more and more disinterested in her STEM coursework. During the second semester of her freshman year, she took an introductory sociology course as a general education requirement that peaked her interest “...because [she] thought, ‘I can probably still do research.’” Mary decided to switch majors “slightly on a whim, because I had taken that one class and liked it.”

The first sociology class Mary took was like a breath of fresh air compared to her STEM classes. Mary says, “Going to my first soc class and I was like, ‘oh my god, we’re talking!’” Mary became more and more interested in sociology and appreciated the discussion-based pedagogical methods that were utilized in her sociology courses. She believes these pedagogical methods positively influenced her interest in the subject matter and ability to grasp the course materials. Comparing her experiences in STEM courses with her experiences in the sociology classrooms, Mary explains:

…I’m thinking how to phrase this, I don’t spend a lot of time thinking about my class material when I was pre-med. I would leave class and it would be gone until I came back to it later and actively looking at it. I think that’s partly because we don’t talk about it in class. They are just kind of speaking at us. So, definitely, in the sociology department, and I think in other departments that are liberal arts, since we do more discussion, the information stays with you. I’ll find myself sitting somewhere thinking about something we were doing in class, or thinking about what I was reading. That could be because I’m just more interested in it [sociology] because I’m sure there are people who leave biology and are thinking about it. And that’s great. But I think, now, it stays with me more. I
think I spend more time now thinking about the material than I did [in pre-med] but I spend less time studying.

Like Charlotte, Mary decided to leave her initial STEM major and pursue a non-STEM pathway. Mary is content with her decision and admits to finding the study of sociology “compelling.” She is currently considering applying to graduate school. As such, for Mary, sociology represented an alternative pathway that allowed her to pursue interesting subject matter and extrinsic goals without having to encounter the same kinds of obstacles faced in STEM courses.

**Researching non-STEM pathways.** For other participants, researching non-STEM pathways allowed them to locate alternative pathways after they were discouraged from continuing in their initial STEM majors. For example, Madison, who initially declared a pre-med major upon enrolling in college largely due to the influence of her mother, decided to take the initiative to research other possible majors after encountering disappointing grades in her introductory calculus course and believing that earning medical school acceptance might not be possible.

As a result of this initial discouragement from continuing in STEM, Madison began researching other pathways, “I think I was exploring things, because I knew I wanted to work--my ultimate goal from that school was to work with people with disabilities. I was thinking, ‘Well, if I can't do the med school route, maybe I should look into the special education.’ So I was shadowing there, and I learned about occupational therapy.” In course of doing additional research on occupational therapy, Madison learned that State University offered a rehabilitation and human services major. Madison was attracted to pursuing a rehabilitation and human services major, “I feel like I was learning more about what kind of jobs were out there. Like I
said, I didn't really know much. I also feel like my major - the rehab major - it's another way that you can help people. I'm hoping to go to occupational therapy school, but it's not med school. It's more doable, but I'm still going into the medical field.”

By majoring in rehabilitation and human services, Madison has been able to gain preparation for graduate school and a future career in the medical field, without having to take the more challenging courses required of pre-med students, such as organic chemistry and calculus. Madison explains, “Yeah, I could do-- I have taken the ananomies, physiology, biology, things like that, and I've done okay. But that's not all pre-med requires [chuckles].” In this way, Madison has been able to locate an alternative pathway that allows her to pursue her original intrinsic interests and extrinsic goals without having to encounter the perceived obstacles inherent in her original STEM major.

Brian also took the initiative to research alternative pathways after encountering obstacles in his initial math major. More specifically, Brian was initially pursuing the mathematics-actuarial science option major that prepares students for careers as actuarial scientists. Brian was attracted to this major because it allowed him to pursue his interest in mathematics while also gaining practical preparation for a career in the business world. In shot, the mathematics-actuarial science option major allowed Brian to “maximize” his intrinsic interest in mathematics and his extrinsic goal of securing stable employment after graduation.

However, Brian was discouraged from continuing along this initial STEM pathway early in his college career when he began to realize that he would have to take many types of math courses that he found too theoretical and divorced from the more practical side of the business world. Brian was also discouraged when he learned more about the actuarial science licensure
exams that he would be required to take in order to get his first job out of college. Brian had heard his older classmates complain about the difficulty of these exams and was fearful that he might not be able to pass them after completing his major. Brian explains:

It was really towards the end of the semester. What really caused the decision to switch majors to a business major from the actual science major - or even being an actual scientist – is the fact that being an actuarial scientist is a more narrow career. By that I mean, I was assuming that I was good enough to get through all the exams. Which, coming into college and having listening to the actual scientist club people share about their experiences, all the kind of stuff, and you slowly realize that it's not that easy to through all exams. And because of the things that I learn in that-- in a math major in actuarial option is so different than like other kind of the majors, you know what I'm saying? It's really different, so if I had wanted to switch to something else, it would be difficult.

As a result of encountering these obstacles, Brian began researching other majors online, “Yeah, online. On the State University website. Like which college--which kind of majors that I could be interested in. I landed a few, and then I just compared them. I compared the one that I have now and the few that I may want to switch into.” By the end of his first semester Brian had turned his attention to possibly majoring in accounting. Brian describes how he was able to locate this alternative pathway, “Narrowing down to a couple of majors and they are mainly majors in the business college, accounting was the one that required more work right now. I wouldn't say it comes out the best afterwards, but learning more right now is really what could be turning out best later on.”
Brian was primarily attracted to accounting because it allowed him to pursue his initial intrinsic interests in math and business, as well as receive preparation for immediate entry into the workforce, without encountering the obstacles he faced in his initial Math major. For example, unlike the Mathematics-Actuarial Science option major that required Brian to take many theoretical classes, an accounting major was “…one of the faster ways to get yourself involved in business. It's like the engineering, the language, inside business.”

Furthermore, Brian saw his decision to pursue an accounting degree as a flexible choice that would allow him to pursue a variety of majors down the road if his interest in the subject began to wane. Comparing the accounting major with his initial mathematics-actuarial science option, Brian says, “I was thinking about the other side of the actuarial science, that if I was in the business college. And if I wanted to switch my sophomore or even junior year, I had all the courses that I need to switch to other things. So that I had another option for myself, if I did not like what I was doing.” Therefore, Brian believed accounting was the better alternative pathway that best fit his desire to pursue his intrinsic interests and extrinsic goals.

Talking to friends. In addition to locating alternative pathways by taking non-STEM courses and researching non-STEM pathways, some participants were able to find non-STEM courses of study talking to friends after they were initially discouraged from continuing along their initial STEM pathways. Scott, who initially declared a physics major when enrolling in college “on a whim” due to the fact that he enjoyed a physics class in high school and “really enjoyed the calculations, and like how it all made sense about how everything is the world worked,” is one such participant.
The main obstacles that Scott encountered during the first semester of his freshman year were the disengaging STEM curricula and receiving disappointing grades. Scott found it difficult to pay attention in the large lecture classes and although he did well in his introductory physics course, he struggled in chemistry and began to question whether he wanted to continue in STEM:

The way that I was performing in Chem 101 - Chem 101 was a requirement for every STEM major. I knew it wasn't up to par. I was probably struggling to pass the course, so I would have to take it again. I ended up later dropping it, and it would put me behind and just to know that there is another Chem 102 I have to take and Chem 103, and it just-- I felt like since I wasn't up to par with all the other students that are in the same shoes as I am, I felt like I wasn't performing as well as I should have been if that's where I belonged.

In addition, Scott also believed that many of his peers majoring in physics planned on pursuing advanced degrees after college, something Scott did not want to do, “Honestly, my coming to college, I've never planned on going to grad school and looking at the physics majors now, I feel like grad school is in the path of a lot of them. So, I just wanted to go to school for four years and be done, honestly.”

Scott ultimately decided that he was not enjoying his physics major and decided to leave this initial course of study to pursue a risk management with an actuarial science option major that he learned about after talking to a friend at a party, “But the way that I found the major that I ended up choosing and liking is that one of my friends up here, who is also a freshman with me, her brother was a fifth-year senior majoring in actuarial science, and I was just over at his house
drinking one day and we were talking about it and it just seemed like something that I would be interested in.”

After locating a possible alternative pathway, Scott began taking business courses and realized he not only enjoyed the classes, but excelled in them. For Scott, majoring in risk management represented an alternative pathway that allowed him to pursue his intrinsic interest in mathematics and calculations, without having to deal with receiving the disappointing grades he received in his initial STEM major. Furthermore, this new alternative pathway is preparing Scott for a job right out of college, something he did not believe the physics major would do. In responding to a question about his satisfaction level with his new major, Scott says, “I don't regret it at all, because I enjoy my major now a lot more than I enjoyed physics. Honestly, my coming to college, I've never planned on going to grad school and looking at the physics majors now, I feel like grad school is in the path of a lot of them. So, I just wanted to go to school for four years and be done, honestly.”

**Embracing familial examples.** Finally, some participants were able to initially locate alternative academic pathways by looking at examples of successful family members and the academic and professional fields they have chosen to follow. Robert is one such participant who was able to locate an alternative pathway by simply deciding to follow in the footsteps of successful family members who are currently working in the business world.

Robert, who initially enrolled at State University as a pre-med major, was motivated to follow this initial STEM pathway due to a combination of intrinsic interest and extrinsic goals. Although Robert admits to being motivated by an “interest in science” that was facilitated by taking engaging high school science classes and “liked the idea of being a doctor and helping
people,” he was also “sort of pushed towards pursuing something in science” due to the fact his older sister had graduated from State University with a biology degree. Therefore, “it just made sense” that Robert would follow a similar academic pathway in college.

However, Robert was quickly discouraged from continuing along his initial STEM pathway after encountering various obstacles that forced him to reconsider his commitment to majoring in pre-med. The primary obstacle Robert encountered when taking his introductory STEM courses was the disengaging curricula:

I'd say for the most part I didn't enjoy it [STEM classes]. Chemistry, to me, I always hated even in high school I did what I needed to do and I got out. To me, it just never-- I could never wrap my mind around it, and it just didn't really make-- I could never have it make sense in my head. I could memorize the things they needed you to memorize to do well on the exams but it just still never-- it didn't feel like a practical study to me. It just didn't feel like something that would personally coming from a chemistry lecture that I could like personally benefit from that in my real life… I was like I'm not going to have to walk up to a patient and recite the periodic table of elements or like stuff like that. It always felt like a stepping stone that you had to get past to be able to enter the medical school.

Robert’s lack of interest in the disengaging STEM curricula also contributed to early academic struggles, which further discouraged him from continuing in pre-med. Robert explains, “I think the lack of enjoyment and interest built up. The disinterest in the subject that probably reflected in my study habits that year. And that just became a vicious cycle that just led to not wanting to study, and then having to study, and then cramming and not doing well.”
Robert decided by the end of his freshman year that he no longer wanted to continue on his initial STEM pathway. How did he locate a superior alternative pathway? Robert decided right away that he wanted to follow in the footsteps of several of his family members who were successful in the business world, “My entire family is pretty much in business. My father's in business and so is his brother and his other brother's a lawyer, and I just kind of started playing with the idea of getting a business degree and pursuing possible post grad educations. Whether it would be going to law school or getting your MBA.”

As a result of this decision, Robert started taking business classes in the fall semester of his sophomore year and quickly realized he had found his passion. Robert excelled in these introductory business classes and enjoyed them. Unlike his STEM courses, which were rather abstract, Robert found the business classes to be engaging and focused on “real world stuff.” Robert explains, “They [business classes] were different. We never went over stuff like that in high school, I never took an accounting course or a finance course. They were fun, and it was all new material because we never went into more real world data and math before. And I enjoyed them. I really do think that I found where I belonged, because I was enjoying going to classes more.”

Robert soon realized that majoring in business represented a superior alternative pathway, “I sort of felt like that was where I belonged. It was those [business] courses that were just sort of clicking again. I felt like a good student again, and I had gone my whole life never experiencing what it’s like to be a C or a D student. I didn't get a C until I got to college. It felt good to be back doing well again and being able to call home and be like, ‘Hey. I got an A on that exam.’ Not being afraid to call home because you didn't do very well.”
Summary. The third phase of the theoretical process that explains how participants decided to leave their initial STEM majors once enrolled in college is employing strategies. After entering STEM majors with tenuous motivation and encountering obstacles, participants utilize various strategies that help them locate alternative pathways. Data analysis revealed four main strategies that were employed by participants:

1. Taking Non-STEM Courses
2. Researching Non-STEM Pathways
3. Talking To Friends
4. Embracing Familial Examples

For some participants, employing strategies represents a conscious effort by participants to find non-STEM majors after they had been discouraged from continuing along their original STEM pathway. For others, employing strategies is more serendipitous and occurs concurrently with their taking introductory STEM courses before they may realize they do not want to continue pursuing their initial STEM majors.

Ultimately, participants decisions to leave their initial STEM majors is the result of their employing strategies that facilitate their ability to locate alternative non-STEM pathways that they find intellectually stimulating and provide adequate preparation for graduate school and the work force. These alternative non-STEM pathways are preferable to their original STEM pathways because they do not present the same kinds of obstacles that were presented in their initial STEM majors.

Originality. This grounded theory’s discussion of employing strategies as a major component of the STEM attrition process represents an original contribution to the literature. As mentioned above, most of the extant literature examining STEM attrition has utilized
quantitative methods that simply draw correlations between one or more independent variables and STEM attrition, and therefore do not illustrate the complex decision-making process behind undergraduates’ move away from STEM majors and towards non-STEM disciplines. By illustrating participants’ utilization of various strategies to locate alternative non-STEM majors, this grounded theory reimagines STEM attrition as a multidimensional process that involves undergraduates taking active measures to not only move away from STEM, but towards non-STEM disciplines that allow them to best pursue their intrinsic interests and extrinsic goals, and thereby illustrating the how of STEM attrition for the first time.

**Deciding to Switch**

The fourth phase of the theoretical process that also explains how participants decided to leave their initial STEM majors is deciding to switch. After participants engaged in employing strategies for the purpose of locating alternative pathways, participants take various actions that ultimately help them decide to leave their initial STEM majors in order to pursue non-STEM courses of study. These actions have two distinct consequences—to either further push participants away from their initial STEM majors, or pull participants towards non-STEM alternative pathways. Data analysis illustrated five main categories of actions:

1. Talking To Academic Advisors (*pushed away* from STEM)
2. Talking To Peers (*pushed away* from STEM)
3. Taking Non-STEM Courses (*pulled toward* non-STEM)
4. Talking To Academic Advisors (*pulled toward* non-STEM)
5. Talking To Parents (*pulled toward* non-STEM)

These actions constitute the participants’ decision-making processes and convince the participants that deciding to switch majors is in their best interest.
Talking to academic advisors (pushed away from STEM). When deciding to switch majors, many participants talk to their academic advisors to ask for advice and gain further information about either their initial STEM majors or the non-STEM majors they are interested in pursuing. As such, academic advisors play an important role in helping participants’ understand that pursuing the alternative pathways they have located may be beneficial.

In some cases, advisors provide participants with honest assessments of their academic performance in introductory STEM courses; these assessments often discourage participants from continuing along their initial STEM pathways. For example, when Cynthia was struggling in introductory chemistry and considering switching her major to psychology, she went to see her pre-med advisor in the College of Science:

I asked her [pre-med advisor], ‘What is my likelihood of getting into med school, even this early on with my grades looking like this?’ And she just told me, ‘Not likely.’ So, it was very hard. It was a very hard conversation with her, but she just told me, ‘Not very likely.’ And we talked about other options… It just was—from then on. I was like, ‘All right.’ I got the paper to switch majors.

Natalie had a similar experience when she was contemplating switching her major from pre-med to health policy administration. Natalie had struggled in several of her pre-med courses and began questioning whether or not she would be able to gain acceptance into medical school after college:

I remember talking to my adviser about it, before I dropped my two classes. I told her-- I was just like, "I really don't think I'm going to be able to get above a C in either of these." And then I think she was the one who would just encourage me to explore other majors.
She wasn't like, "Oh, you should change your major." She was like, "Well, maybe look at other stuff," in a nicer way, but at the same time she was like-- she would say it without saying it, being like, "Your grades really aren't as good as they probably should be," if that makes sense.

Natalie decided to switch her major to health policy administration.

In other cases, talking to academic advisors provides participants with a more accurate understanding of their current STEM majors and the kinds of careers that the typical student who graduates from these majors is likely to pursue. In the cases of Jane and Kate, the two participants who enrolled in college as forensic science majors, talking to their academic advisors helped them better understand that the forensic science major at State University typically prepared graduates for careers as research scientists—a career path that neither of them was interested in pursuing. These conversations helped both participants decide that pursuing a forensic science degree was not what they wanted to do. Jane explains:

I remember I just kept asking her [the academic advisor] over and over again and I was like, if I stay with the forensic degree what will I be doing with the job? That's when she said most people with that major work in the lab because of the training that we give you here. We give you more of a science based training rather than a law or criminology based training and I think because I finally realized that the lab route really wasn't what I really wanted to do after all the science classes and stuff, that's when I realized, okay, she's telling me that this is my outcome if I stay here, whereas I switch to the crim [criminology] major my outcome will be more law and more hands on with the criminal aspect, rather than the lab science-y stuff. So, I think hearing her confirm that it would be
labs pretty much if I worked with-- if I stayed in science was-- so that's how the science adviser convinced me to switch.

Both participants decided that majoring in criminology represented an alternative pathway worth pursuing because it allowed them to explore non-scientific aspects of criminality and prepare for non-research careers that were of greater interest. These decisions were aided by their talking to their respective academic advisors.

In addition to these positive examples of academic advisors helping participants realize they may be better served by pursuing non-STEM academic pathways, data analysis revealed several examples of participants being pushed away from their initial STEM majors by having negative experiences with their advisors. For example, Mary considered her experiences talking with her pre-med advisor to be “incredibly frustrating” and “the worst part of [her] pre-med experience” due to the fact that the advisor seemed “…scattered between all the things she was supposed to be doing.”

More specifically, Jane attributed her academic struggles at least partially to the advice given to her by her forensic science advisor. One of the main obstacles that discouraged Jane from continuing along her initial STEM pathway was receiving disappointing grades during her sophomore year after excelling academically as a freshman. Jane describes how her advisor contributed to these struggles:

Yeah. I took a super heavy load. It was ridiculous. When I look back on it I don't even know how I finished the semester. Also the forensic science major, they had the advisers weren't advisers at the time, they were just professors. So she-- I don't blame her for it, but I think if I had an adviser it would have helped me work because she was just telling
me in order to stay on the path of forensics I should take a lot of these courses because I was already behind because of chem 101. So, then I just followed her lead and was like okay, I'll take all these classes. I was fine. She was like, "Yeah, you a B+ you should be okay with all of it." So, then I listened to her and went that way, and I think if I would have had an adviser who actually knew how it's better to even stuff out I might have done a little better.

Sarah also wished that she had received better academic advising and more encouragement when she was considering switching her major from biology to elementary education:

… when I went in tried to ask them [advisors], "I'm not really liking this." It was kind of like, "Oh, stick through it." They didn't try to say, "You need to stay, because you're doing well." Anything to even say, "Look, here's your goal. It's not too far away." Explain anything to me. It was just very like, "You'll be fine." And that's hard to hear when you feel like you're very pressured and you're stressed and you're like, "I need to hear more than that. I need guidance." It's really what it is, I needed guidance to know what the heck I was supposed to do, basically.

Sarah also contrasted her experience talking with her STEM advisors with her experiences discussing the possibility of switching majors with the advisors in education:

Where education was like, "Let me help you." I don't know. It was interesting. It was definitely a different feel, but it wasn't just even education. Any of guidance counselors I talked to, when I went to the DUS school [division of undergraduate studies], I was like, "Oh, I'm kind of interested in this field." The counselors would e-mail me right away and
be like, "Come in and talk to me," and it was nice. But I felt like science was just kind of...they'd send me an e-mail afterwards like, "Oh, why did you leave?"

Sarah believed these contrasting experiences contributed to her decision to leave biology and pursue elementary education instead.

Finally, some participants’ decisions to leave their initial STEM majors was facilitated by a different kind of negative experience talking with their academic advisor in which they felt pressure to stay committed to STEM when they raised the possibility of wanting to switch majors. For instance, after taking a creative writing course that peaked her interest, Evelyn initially wanted to explore her interest in English while still completing requirements for her initial biology major. She felt resistance when discussing this possibility with her STEM advisor:

They [STEM advisors] were definitely trying to make me stay. And they were very-- it kind of made it a little bit more difficult in that sense because I really wanted explore this other area and see if, okay, will this make me happier than this? Or was it just my professor for this chemistry class or something that wasn't getting to me, or was it-- because at that point I still-- like even know I think being a doctor would be a great thing. So it was kind of hard to work with the advisors in that sense because it seemed like they didn't have as much - which I wouldn't expect them to - as much knowledge in the other route that I was looking at. So it was hard for them to envision that, which put more pressure on me to try to bridge the gap between the two for a short period of time, which never really happened anyway, I guess.
Jane felt similar pressure to stay committed to forensic science when she raised the possibility of switching to criminology with her STEM advisor after she had encountered academic difficulties during her sophomore year:

I think it became awkward once I admitted to the adviser that I was thinking it was hard and that I wanted to switch. Once I mentioned that I was second guessing the science major, it got weird because she was like, "No, no, no don't switch stay in forensics." You should stay here rather than asking me why, she was more like just stay. That's when she was like, "You can do this, you got a B+. I think you'll be fine. You can take all these courses." When I said, "Well I didn't do well in these courses." She was like, "Well it's okay it was just one semester." It was more of instead of asking me, "Well how can I help you?" It was more you can just stay. It was awkward because it was forced. They wanted me to stay.

**Talking to peers (pushed away from STEM).** When deciding to switch majors from their initial STEM majors to non-STEM courses of study, some participants talk to their peers. These conversations serve a variety of purposes and act to push participants further away from STEM and confirm their interest in pursuing non-STEM alternative pathways. Jane explains that taking to her peers helped her realize that the fact she was not enjoying her STEM major was an indicator that she should leave Forensic Science, “It was just me, myself, I kind of realized. And I would talk to so many people, I'd be, 'Hey, how do you guys feel on this?' And hearing them I think they were really happy and enjoyed it, and then realizing I was not happy was also like, "Okay, well maybe this is not what I want to do."
Natalie also engaged in a similar process of comparing herself to other peers in her introductory STEM classes and realizing that her initial pre-med major was not what she wanted to pursue in college:

Yeah, I think I had that moment where it was just like, "Am I the only one who hates this, because everyone else seems completely content?" In class and stuff I was just like, "Am I really the only one who's rolling my eyes at the idea of being here for 60 minutes, or is everyone else just like completely okay with the fact that none of this is fun?" kind of thing. I felt like I was compare-- I always compare myself to people, but it was just like everyone else was not having a problem with writing a 15-page research paper about photosynthesis. And I was just like, "This seems horrible."

This process of self-comparison had a big impact on her decision to leave STEM:

Yes. Definitely. Because, I felt like I was completely miserable and everyone else just seemed like they were content. And I was just like, "This doesn't feel right for me to be the only miserable one in my class." And every one else was just like, "I don't understand what you're complaining about." I think that was a big part of it too.

Sarah talked to her roommate, another biology major, when contemplating whether or not to leave STEM. Sarah and her roommate commiserated about their mutual dislike of their introductory STEM courses:

And I mean, my roommate and I definitely discussed it a lot, because she was in the same major as me and we had the same classes. We just were like, "I don't know what to do. This is a big deal. I wish we had more time." But we just knew something was off, compared to-- because we were putting the...what was it? It was the higher achievement
building my freshman year. It was all kids who were in science and did really well, and there were a lot of kids that really liked what was going on. They were very into it, just loved it. And we were just not. We were just like, "We're kind of interested in seeing what other people were doing, what other majors there are." I still wish I had, like I said, had more time at State University just to explore other things that you wouldn't expect.

**Taking non-STEM courses (pulled toward non-STEM).** In *deciding to switch* majors, participants not only took actions that served to *push* themselves *away* from their initial STEM majors, but *towards* the non-STEM alternative pathways that they had located and identified as possible new courses of study worthy of further exploration. These actions that pulled participants towards non-STEM alternative pathways helped participants to realize that pursuing non-STEM courses of study would allow them to pursue intrinsic interests and extrinsic goals without having to encounter the same kinds of obstacles they faced in their initial STEM majors.

For example, for some participants, *taking non-STEM courses* confirms their interest in the non-STEM subject matter that they had located and identified as worthy of further exploration after *employing strategies* such as *researching non-STEM pathways, talking to friends, or embracing familial examples*. Brian is one such participant.

After *encountering obstacles* in STEM and *locating an alternative pathway* by researching possible business majors online, Brian decided that he wanted to pursue an accounting degree. However, it was not until he started taking accounting courses that his interest was confirmed, “…I was having accounting in my head. We don't actually declare until sophomore spring. So all that [time] I just studied the pre-major courses and waited until sophomore spring. And that's when I actually confirmed that [by taking accounting classes].”
Commenting on how he enjoyed the first accounting classes he took, Brian stated, “It was pretty good. Nothing went wrong and-- I wouldn't say I got perfect scores, but because it was also a new concept that I had. But knowing what it really does and how to do that kind of made sure that I wanted accounting.”

Robert told a similar story. After locating an alternative pathway by deciding that he wanted to pursue a business degree due to the fact “[his] entire family is pretty much in business,” Robert started taking business courses that confirmed his interest in pursuing this course of study. Robert explains:

I liked them [introductory business courses]. They were easier, to say the least. They were different. We never went over stuff like that in high school; I never took an accounting course or a finance course. They were fun, and it was all new material because we never went into more real world data and math before. And I enjoyed them. I really do think that I found where I belonged, because I was enjoying going to classes more. And once that round of exams came in, I was doing a lot better.

In describing his enjoyment in taking these introductory business courses, Robert emphasized two factors that acted to pull him towards pursuing this non-STEM alternative pathway—the practical content matter that the business courses emphasized and his ability to excel academically in these classes:

But they were interesting in their own way in the idea that they're more-- we did like more real world stuff, like it was cool to like look at the fall and rise of companies and go over different scandals and stuff like that… I sort of felt like that was where I belonged. It was those courses that were just sort of clicking again. I felt like a good student again,
and I had gone my whole life never experiencing what it’s like to be a C or a D student. I didn't get a C until I got to college. It felt good to be back doing well again and being able to call home and be like, “Hey. I got an A on that exam.” Not being afraid to call home because you didn't do very well.

Talking to academic advisors (pulled toward non-STEM). Talking to academic advisors also helped pull participants towards the decision to switch their majors from STEM to non-STEM courses of study. Participants’ conversations with their academic advisors served a variety of roles in their decision-making processes and helped them to understand that switching majors was a viable option that would allow them to pursue their interests and career goals.

For example, in some cases academic advisors provide participants with specific advice about particular non-STEM majors or opportunities that they did not know about previously; this newfound information then helps participants to better understand their academic options and facilitates their deciding to switch majors. In Christina’s case, she had initially located her non-STEM pathway by deciding that she wanted to follow in her father’s footsteps into the business world after she had been discouraged from continuing along her initial STEM pathway. However, it was only after talking to her academic advisor that she learned about the particular business major that she would eventually select as her new course of study:

So then, I don't remember if it was the spring, I was talking to my DUS [division of undergraduate studies] adviser, I cannot remember her name right now—Mrs. Smith. Really great. She was very, very helpful. She would sit with me, talk to me about the different majors, what possible jobs would be like, she talked about finance, accounting, marketing, management, supply chain, and then she talked about enterprise risk
management which I was like, "Oh, what's that?"… I talked to Mrs. Smith some more, and that just sounded like something that I was interested in.

Danielle’s decision to switch majors from biology to human development was also facilitated by her talking to her academic advisor. Danielle already had an idea that she wanted to switch majors after taking an interesting psychology course, but talking to her advisor helped her to understand that majoring in human development might offer her more employment opportunities both immediately after college and further down the road:

She [my advisor] just told me more about the program [human development] and gave me a list of career paths that you could go into. One really appealing thing was that you can go into research from that area. So, even if I changed my mind [to pursue a research career], I could still end up in that area. I think hearing about how many opportunities could come from being in that major was really appealing.

Similarly, Sophia’s decision to talk with her academic advisor also further pulled her towards declaring a non-STEM major. Sophia had initially declared a chemistry major in order to pursue her interest in neuropsychology. After being discouraged from continuing along this initial STEM pathway by encountering obstacles such as receiving disappointing grades and taking an interesting introductory psychology course that she excelled in, Sophia was considering switching majors from chemistry to psychology. Talking with her academic advisor helped her realize that she could major in psychology and still pursue her interests and career goals:

And I remember going to talk to my chem adviser about it and then he set me up with a psych adviser who I was with over in Smith building. And I remember talking to her about the things I was planning on doing and she told me about the whole neuroscience
option where I could still incorporate in my science classes, and things like that, and the psych major, so that was the clinching factor for me. I guess knowing that all these classes I could take and wouldn't go to waste and I could still potentially do the things that I had been thinking about doing.

Luke also had a similar experience talking with his academic advisor. Beginning to contemplate switching majors from pre-med to psychology but still interested in possibly pursuing medical school down the road, Luke spoke with his pre-med advisor who assured him that he could still gain acceptance to medical school by majoring in psychology:

I talked to my pre-med adviser, who is actually the head of the pre-medicine department and developed the major, and he was actually surprisingly open to the switch. He wasn't in the least bit offended. He was used to people switching out of the pre-med major and doing other things, especially switching into psychology, and I think he recognized that the pre-med major is like a landing spot for people to sort of-- then figure out often times, then figure out what else they want to do. Sort of like when you go to med school then you specialize later. He didn't really push me in either direction but definitely knowing that-- he told me that it will be perfectly fine for me to do that and I wouldn't be compromising my chances of getting into med school or anything so that played into my decision.

In addition, other academic advisors helped participants decide to switch majors in more indirect ways, less by providing specific information, and more by facilitating the participants’ decision-making processes. Robert was struggling academically in his early STEM courses and contemplating leaving his initial STEM major when he met with his advisor:
This is the point where I was really questioning what I wanted to do. I was back in the boat of like, "I don't know what I want to do." Picked up a-- I spoke with one of the-- she was great, I forget her name. She was one of the advisers for pre-medicine. I spoke with her about this and she was like, "This is extremely common. You're not the first person to go through this." She told me that I could always come back to the major, but she switched me to DUS [division of undergraduate studies] to have an adviser to talk to about potential options with the idea that I could always come back if I wanted to… And the advice that the DUS adviser gave me was to just to sort of sit down and write about what you like and dislike about the major that you're in right now. What you think you could do, where you think you’d be most successful, and then her last piece of advice, I remember saying, “I have a chemistry exam tomorrow and there’s too much going on.” She’s like, “Just study tonight. Get a good night’s sleep and worst-case scenario, just walk out in the middle of the exam because you know that’s not what your calling is.”

Robert followed his advisor’s advice, “I remember going through the exam and reading through the problems and knowing how to do probably 10 to 20% of them. I just got up and left the room [laughter].” He left his initial pre-med major at the end of that semester.

Talking to parents (pulled toward non-STEM). Finally, talking to parents also helped pull participants toward switching to non-STEM majors. The majority of participants’ parents were quite understanding of their children’s decisions to leave STEM and offered support to their decision-making process, thereby reassuring them that leaving their initial STEM pathways was an acceptable course of action.
For example, when Evelyn was contemplating leaving her initial biology major, she talked to her parents who gave their blessing for her to switch majors, “They were just kind of like, ‘You need to calm down. It's okay. It's fine if you want to switch you major, just make sure that you're doing what you actually want to do.’” Luke experienced a similar reaction from his parents when he discussed the possibility with them the possibility of switching from pre-med to psychology, “I talked to my parents about it [switching majors] and they were always supportive of what I wanted to do and they basically told me, ‘Hey, it sounds like-- switching into psych is what you really want to do, and you don't need to think about it in terms of what's going to look better or be harder. Just do what you want to do.’ And all that just played into my decision to ultimately switch.”

Sarah’s parents also supported her decision to leave STEM despite the fact that they had originally encouraged Sarah to pursue a biology major, “They've always been really-- they're really supportive and they know what type of kid I am. So, they knew I wasn't just giving up or I wanted to party and not do my work. So they supported me and they were like, ‘We want you to be able to do what you want to do.’ Even my dad was like, ‘I always pictured you being a teacher and being in that field, but because you said dentistry I didn't want to stray you away from it if that's what you wanted to do.’ But yeah, they definitely had a big thing in it [her decision to leave STEM].”

In some cases, parents lent their conditional support to their son or daughter’s decisions to leave STEM to pursue non-STEM courses of study. For instance, Alexandra’s parents supported her decision to leave pre-med for psychology but “…if I had majored in theater or something, they wouldn't have been supportive of that, but they were fine with psychology.”
Jane’s mother, a teacher, was initially hesitant about her daughter’s decision to leave forensic science but eventually lent her support:

I called my mom. So my mom was kind of apprehensive, but then after a while, she realized. She was like, "I just want you to do something that you enjoy whether you make a lot of money," because she's a teacher. She's like, "I don't make a lot so you can do whatever you want." [laughter] So she kind of made me feel okay. At first she's apprehensive, but then she was more open. So having her be like, "This is your decision. You're in college now. You do this," then I had the freedom on my own to be like, "Okay. What do I want to do?"

**Summary.** The fourth phase of this theoretical process that describes STEM attrition is deciding to switch; in this phase, participants ultimately decide to leave their original STEM pathways to pursue alternative non-STEM pathways by engaging in various activities that either push them away from STEM or pull them towards non-STEM and help them realize switching majors might be in their best interest. Data analysis revealed five main categories of actions:

1. Talking To Academic Advisors (*pushed away* from STEM)
2. Talking To Peers (*pushed away* from STEM)
3. Taking Non-STEM Courses (*pulled toward* non-STEM)
4. Talking To Academic Advisors (*pulled toward* non-STEM)
5. Talking To Parents (*pulled toward* non-STEM)

These activities served a variety of specific purposes that helped participants realize they might be better served by switching majors. For example, *talking to academic advisors* assisted participants in better understanding the relative nature of their academic performances and what employment opportunities might be available if they eventually followed STEM or non-STEM pathways. For some participants, *taking non-STEM courses* confirmed their interest and desire
to follow a non-STEM pathway that they had previously identified as a potential major, while *talking to parents* often times reassures participants that leaving STEM for non-STEM courses of study is an acceptable decision to make. In sum, these actions constitute participants’ decision-making process and guided participants as they ultimately decided to leave their initial STEM pathways.

**Originality.** Once again, by highlighting the decision-making process behind participants’ STEM attrition stories, this study has made an original contribution to the literature. No previous literature has examined the decision-making process that guides undergraduates as they decide to leave their initial STEM majors.

**Achieving Non-STEM Satisfaction and Success**

The fifth and final phase of the theoretical process that describes STEM attrition at a large research university is *achieving non-STEM satisfaction and success*. Participants’ decisions to leave their initial STEM pathways to pursue alternative non-STEM pathways have largely resulted in personal satisfaction and success. Participants are happy they made the decision to leave STEM and believe that they were able to locate and pursue a non-STEM major that allowed them to best pursue their intrinsic interests and career goals without encountering the same kinds of obstacles they faced in their initial STEM majors.

Charlotte, who switched from biochemistry to psychology, gave this response when asked if she was satisfied with her decision to leave STEM:

Yeah, I am. Like I said though, I'm taking a more scientific approach to the social sciences, so I'm actually really interested in looking at that intersection of evolution,
genes, neuroscience, biology, and how it affects behavior, and how culture ties into that. So that's another thing where I like teasing those things apart that you really can't tease apart. So that science aspect is coming back. That biology aspect, probably in grad school, and revisiting a lot of that where even beforehand, I'm probably going to end up revisiting some of that - those harder sciences - to some degree. But really, I'm happy where I am. I am very interested in what I'm doing, and it's all good stuff.

In addition to being satisfied with her decision to switch majors, Charlotte now plans on attending graduate school, “At this point, I think I'm going to go down more of a research route. When I started [in psychology], I was thinking therapist. Now I really like research and the more I study, the more questions I have.”

Evelyn also feels satisfied with her decision to leave STEM. Initially majoring in biology, Evelyn decided to pursue her earlier interest in English by majoring in secondary education with a focus on English communications, a decision that allows her to pursue a subject that is more interesting to her while also preparing for stable employment opportunities. Evelyn explains:

But I'm definitely happier now [that I switched majors] because I feel like I'm accomplishing, like you said, those goals that I had for myself in a way that is making me happy… it made such a big difference actually being interested in what I was learning about. Like I said, I was interested in biology, but to compare the two, I've always been I think more interested in English, and writing, and that kind of thing. So in my head, I feel like I'm learning something that's more worthwhile to me. So that whole aspect wasn't there as much as a freshman [studying STEM].
Evelyn is now planning on pursuing a career as a high school teacher but is hoping to be able to explore opportunities to write professionally, as well.

For Heather, switching from biology to a human development major has also resulted in satisfaction and success. Heather describes her human development major as a “better fit” for her interests and believes she will be “…much happier for sticking with this [human development].” After gradation, Heather is planning on attending graduate school for social work to prepare for a career in family counseling.

Mary, who has enjoyed her experience studying sociology and is hoping to attend graduate school, sums up the STEM attrition experience for participants, “I think now I view it [studying STEM] as more of an individual basis. So now I think, it wasn’t right for me, but it might be right for someone else. So I wouldn’t discourage someone from being STEM because it’s the right choice for some people. It just wasn’t the right choice for me.”

**Summary.** In closing, the fifth and final phase of this grounded theory, *achieving non-STEM satisfaction and success*, is the consequence of the first four phases of this process that explains STEM attrition. In this phase, participants have been able to achieve personal satisfaction and success from *locating alternative pathways* and deciding to major in non-STEM disciplines. Participants are satisfied with their decisions to switch majors and have developed encouraging plans for future career success. In the end, participants view STEM attrition and *locating alternative pathways* as process of discovery in which they have been able to find and ultimately pursue non-STEM majors that have allowed them to best achieve their intrinsic interests and extrinsic goals.
Originality. The realization that participants have been able to achieve personal satisfaction and success from deciding to switch away from their initial STEM majors represents a significant contribution to the STEM attrition literature. Literature discussing STEM attrition tends to frame the issue in a negative light from the national and institutional perspective. However, this study’s findings have managed to reframe the issue in a more positive light from the individual perspective; rather than feeling upset or depressed that they have decided to leave their initial STEM majors, participants are happy with their decisions to pursue non-STEM majors and have developed specific plans to pursue future educational and employment opportunities.

For participants, the process of STEM attrition is largely the process of discovery in which they realized a particular non-STEM major was a more suitable academic pathway to follow than their original STEM major.

Chapter Summary

In this study I interviewed twenty State University undergraduates who initially declared STEM majors when entering college but subsequently decided to leave these initial STEM majors to pursue non-STEM courses of study. Data analysis consistent with traditional grounded theory inquiries revealed a central theoretical category, locating alternative pathways, that describes how participants experienced a process of self-discovery during their first semesters of college that broadened both their understanding of the nature of their initial STEM majors, as well expanded their perspectives on suitable alternative pathways. Participants’ came to understand that non-STEM majors represented more desirable academic pathways that allowed
them to best pursue intrinsic interests and extrinsic goals without having to encounter the same kinds of obstacles they faced in their original STEM majors.

In addition to the central theoretical category, data analysis also revealed five specific theoretical phases that describes and explains the why and how participants ultimately decided to leave their initial STEM majors and locate these alternative non-STEM pathways. The first phase, *tenuous motivation*, describes how participants entered college as STEM majors due to their initial motivation that was sometimes uncertain or based on singular childhood or high school experiences. During the second theoretical phase, *encountering obstacles*, participants face various challenges in their introductory STEM courses and begin to question whether or not they want to continue as STEM majors.

However, participants’ decisions to leave their initial STEM majors was not solely based on their *encountering obstacles* during their initial STEM coursework. In the third theoretical phase, *employing strategies*, participants utilized various strategies to locate alternative non-STEM pathways that they would find intellectually stimulating and capable of providing suitable preparation for entering the work force and graduate school. In this phase, participants begin to understand that State University offers many possible academic pathways and that they might prefer pursuing non-STEM majors. Once participants have located these alternative pathways by *employing strategies*, they then engage in various activities such as talking to parents, advisors, and peers that help them come to the decision that leaving their initial STEM majors is in their best interest. In *deciding to switch*, participants’ interest in non-STEM majors is thereby confirmed and the decisions to leave STEM are made.
Finally, once participants have left STEM and begin majoring in non-STEM disciplines, they achieve non-STEM satisfaction and success. The participants interviewed for this study are pleased with their decisions to leave STEM and ultimately achieve a sense of personal satisfaction with their new non-STEM majors. By pursuing these alternative non-STEM pathways, participants develop postgraduate vocational and educational plans that leave them hopeful for future success.
CHAPTER 5: DISCUSSION

College graduates who receive training in STEM (science; technology; engineering; math) disciplines have always been prized in American society. Writing in 1945 at the close of World War II, Vannevar Bush states that the continued cultivation of well-trained scientific talent is a national priority of utmost importance due to the role these citizens play in helping our society fight disease, increase economic productivity, and ensure national security (United States Office of Scientific Research and Development & Bush 1945). However, at the beginning of the new millennium, there is some question as to whether the United States is producing enough of these STEM graduates to meet the needs of the nation. A recent government report anticipates a shortage of 1 million STEM professionals in the next decade that will threaten the United State’s “…historical preeminence in science and technology” and potentially hamper the nation’s economic competitiveness in the new global landscape (President’s Council of Advisors on Science and Technology (U.S.), & United States. Executive Office of the President., 2012).

A major reason for this projected shortage of STEM professionals is the high attrition rate among undergraduate STEM majors (President’s Council of Advisors on Science and Technology (U.S.), & United States. Executive Office of the President., 2012). As Chen and Soldner (2013) note, approximately half of all college students who begin their undergraduate studies as STEM majors do not complete STEM baccalaureate degrees. In order to better understand this phenomenon and accomplish several intellectual and practical goals, I conducted a grounded theory investigation of STEM attrition at a Mid Atlantic research university that sought to not only contribute to the extant scholarly literature on this issue, but also help the local faculty and administrators of State University better understand STEM attrition in their local
context. In addition, I hope the insights gleaned from this study’s findings can be utilized to contribute to the national conversation on STEM attrition and help guide faculty and administrators in their efforts to retain more students who initially declare STEM majors upon entering college.

**Study Overview**

Although the problem of high STEM attrition is a “hot topic” among federal policymakers and education scholars alike, relatively few qualitative studies examining this phenomenon exist. The majority of extant research investigating STEM attrition utilized quantitative methods that examined the relationship between one or more variables and undergraduates’ decisions to leave STEM. For example, much empirical research examines the relationship between STEM attrition and variables such as undergraduates’ demographic characteristics, pre-college academic preparation, elements of achievement motivation and various dimensions of the college curricula and co-curricular environments. While this research is helpful in establishing statistical relationships between STEM attrition and one or more variables, it is ill-suited to examining the deeper questions of the “why” and “how” behind undergraduates’ STEM attrition decisions (Meyer & Marx, 2014).

This study, therefore, seeks to contribute to the literature on STEM attrition by conducting a grounded theory investigation. In order to produce a grounded theory that describes the “why” and “how” of STEM attrition, I interviewed twenty undergraduates of a Mid-Atlantic research university who began their college careers as STEM majors but ultimately decided to leave these courses of study to pursue non-STEM majors. One advantage of grounded theory
investigations is that they are inherently inductive and seek to build theory directly from the perspective and experience of the participants rooted in a local context (Taber, 2000). In order to generate a theory of STEM attrition from the collected data, I asked participants a series of open-ended questions about their experiences as STEM majors and their decisions to switch majors.

Grounded theories are also developed utilizing the constant comparative method in which participant’s responses to open-ended questions are compared and contrasted with both previous academic literature and the responses of other participants (Strauss & Corbin, 1998). As such, my initial interview protocol included both open-ended questions and various thematic elements that were discovered by examining STEM attrition literature. My initial interview protocol was also amended several times during the data collection process as several prominent themes emerged during the interview process.

A grounded theory of STEM attrition, rooted in the perspective of the twenty participants interviewed for this study, was produced by utilizing data analysis procedures consistent with the conventions of grounded theory research. More specifically, I closely examined the collected data and engaged in a threefold coding process involving open, axial, and selective coding, as well as extensive memoing that facilitated deeper reflection on the major concepts and theories embedded in the data. This data analysis yielded a central theoretical category, locating alternative pathways, as well as five specific phases that described not only why participants elected to leave their initial STEM majors, but the decision-making process that guided their decisions.

In order to ensure the validity of the study and its trustworthiness and value to external audiences, I took several measures. First, I made sure to engage in the constant comparative
method to reflect upon my emerging theoretical categories and utilized extensive memoing to facilitate my deeper investigation of the data, as well as the development of the central theoretical category. I also provide evidence suggesting the study’s credibility, originality, and usefulness.

To suggest the study’s credibility, I made sure to include numerous verbatim texts that described my theoretical categories and phases from the perspective of the participants themselves. I also suggested the study’s originality by discussing the study’s findings in relation to the extant literature I was able to locate. Finally, the study’s usefulness will be demonstrated below when I reflect upon the study’s findings and discuss their implications for both future research and practice.

**Summary of Key Findings**

In addition to the central theoretical category and the five theoretical phases described above, data analysis revealed several prominent findings that are worthy of further description:

**Participants considered STEM attrition to be a positive phenomenon.** Although the academic literature examining STEM attrition often considers this phenomenon from a negative perspective in light of the nation’s economic needs and employment projections, the participants interviewed for this study viewed their STEM attrition experiences in a different light. Despite encountering numerous obstacles during their introductory STEM coursework that demotivated them from continuing along their initial STEM pathways, participants seemed to come to understand the totality of their collegiate experiences as a process of self-discovery. After experiencing instances of frustration and introspection, participants were able locate more
suitable non-STEM academic pathways that better suited their intrinsic interests and extrinsic goals. For example, Natalie, who switched majors from pre-med to health policy administration, described her time in college as a “journey” that led to her finding her true passion. Natalie states,

It sounds flowery, but that's the truth. I didn't-- I'm passionate about HPA, and I'm passionate about the economics and sociology that go into it. And I'm very involved in it, and I think about it in my free time. Like I'm just like, "I wonder what it would be like if..." You know, whatever. But I have no passion for calculus or chemistry or any of that.

I feel that it was definite a journey that led me to HPA.

From the individual perspective, therefore, participants were satisfied with their decisions to leave their initial STEM majors and pursue alternative non-STEM pathways.

While the STEM attrition literature has largely neglected to examine this phenomenon from the more student-centric perspective of self-discovery, psychological literature has described the collegiate experience in such terms. For example, Jeffrey Arnett’s (2014) theory of emergent adulthood described college as a period of identity and educational exploration in which young adults explore various academic fields in order to best understand what major and future career best fits their interests and talents. This idea of college as a time of exploration fits the participants’ descriptions of their STEM attrition experiences. Participants entered college believing they were interested in pursuing STEM majors but came to realize they were more interested in pursuing different non-STEM field of studies. This relationship between interest and major choice is supported by the empirical literature (Beggs et al., 2008; Calkins & Welki, 2006; Lee & Lee, 2006; Malgwi et al., 2005; Zhang, 2007).
For example, Danielle, who initially entered college as a biology major due to her interest in studying the brain that had developed during high school, realized during college that she was more interested in helping people more directly and wanted to become a therapist, a career that she never really considered before enrolling in college. Danielle explains,

…I think in high school I had-- so right now I want to become a therapist, so that’s my reformed career path. And in high school I thought about that, but I didn’t think I was really skilled in the area of being able to talk to people, and so being in a lab is the opposite. I started to realize freshman year, "Oh, wait. No, I actually want to work with people, and that's really important to me.”

Danielle switched majors to Human Development and is “totally fine” with her new field of study.

The severity of the nation’s STEM attrition problem might be overstated.

Interestingly, many participants elected to pursue non-STEM pathways that were similar to their initial STEM majors. Participants ultimately decided to pursue these non-STEM pathways because they considered them to be “better fits” in terms of their intrinsic interests and career goals and they did not present the same kinds of obstacles that were encountered in the initial STEM majors. For example, two participants, Jane and Kate, switched from forensic science to criminology, while three other participants switched from pre-med to psychology. Another participant, Jennifer, switched from chemistry to chemistry education, while two other participants switched from biology to human development.

The common theme in many of these examples is that the non-STEM major that was ultimately selected presented a better pathway that was not only more closely aligned with
participants’ interests and goals, but presented fewer obstacles. Luke, who switched from pre-med to psychology, realized that pursuing a psychology degree would allow him to study, in his opinion, more interesting subject matter, while still keeping the realization of his initial goal of attending medical school a possibility. In addition, studying psychology offered the added advantages of a less competitive curricular atmosphere and fewer required upper-level STEM courses compared to his initial pre-med major. Natalie, who switched from pre-med to health policy administration (HPA), also realized she was more interested in studying the content material covered by the classes in her new major, as well as the fact that her new non-STEM major did not present the same kinds of obstacles such as low grades and the lack of learning she countered in her introductory pre-med classes.

In light of participants often switching from their initial STEM majors to somewhat similar non-STEM majors, the severity of the nation’s STEM attrition “problem” can be called into question for several reasons. First, some of these participants who switched to similar non-STEM majors were still considering pursuing graduate degrees in STEM disciplines after college. And second, participants who switched from STEM to somewhat similar non-STEM majors were often planning to seek employment in the same employment sectors as if they had stayed committed to their original STEM pathways. This is especially prevalent for the healthcare sector. Several participants who initially declared pre-med majors and were planning on pursuing careers as physicians were now enrolled in social science majors and still planning on pursuing careers in the healthcare sector.

Participants entered college not fully committed to their initial STEM majors. As Arnett (2014) notes in his theory of emergent adulthood, students often enter college with only a
“general idea” of what they want to major in. More specifically, Lichtenstein et al. (2007)’s study of engineering attrition discovered that students who entered college intending to major in engineering disciplines were “…anything but highly intent on entering and completing a specific engineering degree” (p. 3). This study’s grounded theory confirms these findings. Participants entered college with only a “thin” layer of motivation to pursue STEM degrees that was often based on uncertain motivational foundations, or singular childhood and high school experiences. As such, participants were unable or unwilling to successfully navigate the various obstacles that they faced in their STEM classrooms.

This finding is particularly significant because it can help STEM instructors better understand the depth and nature of their students’ initial motivations to pursue STEM majors. Many students taking introductory STEM courses possess an initial, tenuous interest in studying STEM subjects on the college level, but may not have the same strength of intrinsic motivation that STEM professors exhibited in college. STEM professors should bear this fact in mind when designing their introductory STEM courses and take measures to incorporate curricular interventions and pedagogical methods aimed at developing students’ nascent STEM motivation.

Participants’ STEM curricular experiences demotivate them from continuing in STEM majors. Much STEM attrition research and numerous editorials on STEM education have discussed correlations between STEM educational offerings and STEM attrition. In short, undergraduates’ experiences in the STEM classrooms have been found to impact their decisions to leave STEM majors (Tobias, 1990; Seymour & Hewitt, 1997; Alberts, 2005; Mervis, 2010). Again, this study’s findings confirm much of what has already been discussed by previous literature. More specifically, the participants interviewed for this study often describe being
demotivated from continuing in their initial STEM majors and loosing interest in studying STEM because of their experiences in STEM classrooms. For instance, participants often criticized the competitive culture and disengaging curricula they encountered in introductory STEM courses. Similar to several other studies (Seymour & Hewitt, 1997; Rask, 2010), this study also found a link between students’ demotivation to continue in their initial STEM majors and the poor grades received in introductory STEM courses.

Furthermore, this study has been able to contribute to the extant literature by highlighting participants’ description of the demanding time commitment required of STEM majors, as well as the number of years of undergraduate and graduate school necessary to pursue desired STEM careers, as primary demotivating factors that contributed to their decisions to leave their initial STEM majors. This aspect of STEM education has not been explored in previous literature.

Finally, although students described their STEM attrition experiences largely in terms of “self-discovery” in which they came to realize a non-STEM major represented a preferable alternative pathway, they were undoubtedly “turned off” by their STEM curricular experiences and by the various “obstacles” they encountered in these introductory classes. This process of being “turned off” to STEM contributed to their decisions to leave STEM and seek out more suitable alternative pathways.

**Participants believed their high school academic preparation negatively impacted their performance in STEM coursework.** Although participants initially expressed great confidence in their abilities to succeed in STEM and reported above-average records of academic accomplishment in high school, several participants reported shortcomings in their high school academic preparation that, in their opinion, impacted their ability to succeed in STEM once
enrolled in college. These participants, who initially felt prepared to handle the rigors associated with STEM majors, revised their feelings of preparation upon entering college and experiencing college-level STEM coursework for the first time. What seemed like adequate or even excellent academic preparation, turned out to be inadequate preparation in the minds of some participants.’ Perhaps summarizing the feelings of several other participants, Madison described her revised understanding of her high school academic preparation thusly, “So, I came in as pre-med thinking I would succeed, and then that changes when you figure out how college works.”

Scott, who initially felt prepared entering college, changed his tune upon entering college, now realizing that his college STEM courses were way more challenging than the more basic courses he encountered during high school, especially in comparing high school and college chemistry. He says, “But they (high school courses) were no where near the difficulty of the chemistry at State University. My high school didn't really prepare me for that.” Robert echoed similar sentiments, “And it definitely was a rude awakening going from high school where I didn't really have to try, to college where you're not really pushed at all, and it's kind of like you've got to do all this, if you don't do it, someone else will.”

Several participants also linked their academic struggles in college with the fact that they failed to take specific high school courses that they believed would have offered greater preparation for success. For instance, Cynthia, who linked her decision to leave her initial STEM major to her struggles in introductory chemistry, explains, “And the people that did well [in introductory chemistry], had taken AP Chem and have taken all of those courses, but I never did. So I think that's why I struggled.” Cynthia elected to take the AP biology class in high school but did not take the AP chemistry class.
These findings both support and extend the extant literature that has linked STEM attrition with poor high school academic preparation. While much research has examined the link between STEM attrition and variables such as AP exam completion, grades, and standardized test scores (Ackerman et al, 2013; Espinosa, 2011; Kokkelenberg and Sinha, 2010), this study’s findings illustrate that some participants believe the general lack of rigor in high school science courses and the failure to take even one specific AP course can deleteriously influence STEM academic performance and retention.

Ironically, it is also worth noting participants’ positive experiences studying STEM in high school might not have adequately prepared them to handle the challenges associated with studying STEM in college. Many participants’ interest in pursuing initial STEM majors in college was rooted in positive experiences studying STEM content in high school. Participants often reported experiencing particularly enjoyable high school science classes and being positively impacted by engaging high school science teachers. In describing the differences between her high school and college STEM classes, Christina states,

The classes [in high school] were smaller, so that made it easier to ask questions. That's always a huge thing. But then I remember learning about ATP, we had our tables - they're basically like chalkboards - so we would make things of Play-Doh, we'd do the ATP and stuff, and we label all the cycles and we'd write on the things with chalk - like right on our tables with chalk. I worked with my partner next to me, and that helped me understand the hands-on, understanding more about it. Not just having a lecture, being taught it, given an assignment, exam.
While such experiences are valuable in facilitating students’ emerging interest in STEM-related subject matter, students are left unprepared to handle the large introductory STEM courses that are dominated by lecturing and passive modes of instruction.

**Participants’ social connections facilitated the STEM attrition process.** Perhaps one of this study’s largest contributions to the STEM attrition literature is its discussion of the role participants’ social connections played in the STEM attrition process. As Tinsley et al. (1982) note, college students are likely to ask for help from academic advisors, friends, and relatives when they are faced with career-related difficulties. My analysis confirmed this assessment. Participants’ decisions to leave STEM were not made in a vacuum, but were influenced by the various discussions they had with family members, peers, and academic advisors during the decision-making process. These conversations helped participants locate alternative non-STEM pathways after being discouraged from continuing in STEM, as well as make the final decision to leave their initial STEM majors to pursue non-STEM majors. In many cases, these conversations with social connections acted to either push participants away from STEM or pulled participants towards non-STEM majors.

**Participants’ discussions of STEM attrition also highlighted several positive experiences.** While the bulk of the interview process was dedicated to discussing the why and how of STEM attrition from the unique perspective of individual participants, participants sometimes described more positive aspects of their experiences as STEM majors. For example, participants often described achieving high grades in the majority of the STEM courses, and enjoying at least one of their introductory STEM courses. Some participants also described
enjoying participating in various co-curricular opportunities such as living-learning environments and State University’s prestigious Honors College.

How does one balance participants’ descriptions of the more positive aspects of their STEM experiences with their eventual decisions to leave STEM to pursue non-STEM majors? Simply put, the obstacles participants encountered during their introductory STEM coursework outweighed any positive experiences they may have also had during the early stages of their college careers. Furthermore, participants’ location of suitable alternative non-STEM pathways that did not present the same kinds of obstacles that they encountered in their initial STEM majors further bolstered their decisions to leave these initial STEM majors.

Implications for Future Research

This study’s primary intellectual goal was to contribute to the extant literature on STEM attrition by producing a grounded theory that describes the reasons and processes behind STEM attrition from the perspective of participants who have directly experienced this phenomenon. Utilizing the traditional methods of grounded theory data analysis, I have rendered a grounded theory that consists of a central theoretical category, locating alternative pathways, as well as five specific theoretical phases that describe the why and how of STEM attrition. This rendered grounded theory has several important implications for future research that I will now discuss in detail.

First, one of the primary strengths of this research study was that it examined the phenomenon of STEM attrition directly from the perspective of participants who decided to leave their initial STEM majors to pursue alternative non-STEM courses of study. All twenty
participants attended State University, a large Mid-Atlantic research university; as such, this study’s findings are rooted in the perspective of students who have attended a single institution. Additional qualitative studies are needed to further explore this phenomenon directly from the perspective of students who have attended different types of higher education institutions. While qualitative research does not intend to establish generalizability to wider contexts, the research examining STEM attrition, as well as STEM practitioners, would benefit from additional qualitative studies that investigate STEM attrition on a variety of college campuses in order to learn what variables consistently influence the process of STEM attrition.

Furthermore, one of the advantages of grounded theory research is that it inductively produces theoretical frameworks that can then be “tested” using quantitative methods (Taber, 2000). As such, quantitative researchers can also use this study’s findings to inform their research design and conduct additional studies that investigate the validity and generalizability of this study’s findings.

More specifically, additional research is needed that explores the relationship between STEM attrition and the various elements of the theoretical process that were described in this study’s findings. For example, issues such as study time and time to degree, as well as the influence of social connections on STEM attrition, should be more fully explored by future research.

Finally, many participants openly questioned the quality of instruction they received in introductory STEM courses and believed faculty were unable or unwilling to offer more effective instruction. These observations are particularly worrisome because many colleges and universities, including State University where this study was conducted, house teaching and
learning centers that offer various professional development opportunities for faculty. In light of this study’s findings, future research should also investigate the extent to which STEM faculty actually utilize such resources, and ways in which STEM faculty can be encouraged to make greater use of these professional development opportunities.

**Implications for Practice**

This study’s *practical goals* aimed to help reduce STEM attrition on both the local and national levels by helping STEM stakeholders better understand the theoretical process behind STEM attrition from the perspective of students who have experienced this phenomenon. In light of this study’s rendered grounded theory, I put forth the following recommendations to practitioners who are charged with reducing STEM attrition and hope to encourage more students to persist in their initial STEM majors:

*Expand access to academic advising before students enroll in college.* Participants often reported entering STEM majors when they first enrolled in college despite tenuous or uncertain levels of motivation. Participants reported not accurately understanding the nature of the STEM majors they initially selected, particularly with regards to the time commitment associated with completing STEM majors and the specific types of coursework they would need to complete in order to earn STEM baccalaureate degrees. This problem is perhaps exacerbated by the fact that the numbers of high school guidance counselors have been shrinking in recent years (Clark, 2014). If these participants had a better understanding of their initial STEM majors upon enrolling in college, they might not have selected these majors in the first place.
As such, students would be better served by having expanded access to improved academic advising before they begin taking college courses. For example, academic advising and the major selection process could be more heavily emphasized during pre-college summer orientations in order to help students better understand the various majors they are considering selecting. In this way, students would be better able to make informed initial major selections and not spend unnecessary time and tuition dollars pursuing majors that do not adequately fit their academic and personal interests.

**Expose students to college-level STEM coursework during high school.** Recently, there has been a trend in higher education to create various k-12 engineering summer programs that expose students to engineering education while in high school (Katechi et al., 2009). One such program run by Stony Brook University in New York, offers high school students the opportunity to participate in 2-week residential summer program that allows them to take academic coursework and participate in a range of hands-on activities in order to help them better understand the practice and discipline of engineering (Bugallo et al., 2012).

The expansion of such programs to include a range of STEM disciplines might be beneficial in exposing high school students to college-level STEM coursework and sparking a deeper level of curiosity that can sustain them during their introductory STEM coursework in college. Such programs might also do well to include a career-counseling component in which students are introduced to a wide range of possible STEM-related careers.

Furthermore, high school STEM teachers might also consider increasing the rigor of their courses in order to better prepare their students for college-level STEM coursework. As mentioned above, some participants believed that the quality of their pre-college STEM
academic preparation was lacking in light of the challenging STEM coursework they encountered during their first semesters in college. The rigor and pace of high school STEM courses, especially at the AP level, should be increased in order to better prepare students for the academic challenges that await them in college-level STEM coursework.

**Create more supportive and collaborative curricular environments.** A number of participants described the pervasive “weed out” mentality that they encountered in their introductory STEM coursework. Participants believed that some faculty explicitly created competitive curricular environments that were unwelcoming to students and existed to separate those students who could handle the challenging STEM workload from those who could not. Some students were discouraged by participating in this kind of curricular environment. Danielle explains,

> And I think the weed-out [culture] would foster like competition among the students that actually-- like that really are interested. But then for the students that are still unsure, it kind of creates a lack of motivation. Because if you're being told that it's so hard that you're not going to get through it anyway then, I mean, there's kind of that effect of, "Well, maybe you're right. Maybe I can't get through it."

As such, STEM faculty and administrators should consider taking measures to eliminate such competitive atmospheres from their classrooms and majors and encourage a greater sense of collaboration and support beyond faculty and students, as well as among the students themselves. Such a curricular environment would be more welcoming to students, especially those students, as Danielle notes, who might be “unsure” of their interests and abilities, thereby encouraging more students to remain committed to their initial STEM majors.
Offer professional development opportunities to STEM faculty. As Shulman (1986) notes in his classic discussion of *pedagogical content knowledge*, effective instructors not only possess strong discipline-specific content knowledge, but the ability to effectively communicate that knowledge to less experienced students. STEM professors who teach introductory STEM classes would do well to take Shulman’s advice to heart. The participants interviewed for this study were predominately taught in large lecture courses and frequently criticized their introductory STEM courses on a number of different pedagogical grounds. Participants frequently reported a sense of disengagement in the classroom and frustration with the seemingly abstract content taught in introductory STEM courses. In addition, many participants were discouraged from continuing in their initial STEM majors by receiving disappointing grades and failing to understand course material.

As such, colleges and universities should consider offering professional development opportunities to both junior and senior STEM faculty members. These professional development opportunities should emphasize the more effective modes of instruction that have been demonstrated by the empirical research into teaching and learning. For instance, empirical evidence demonstrates the correlation between the use of active and collaborative instructional methods in the classroom and STEM learning and persistence (Freeman et al., 2014; Hake, 1998; Lyon and Lagowski, 2008; Mazur, 2009; Paulson, 1999; Springer, 1999). Furthermore, the utilization of problem-based learning, a specific curricular intervention that emphasizes collaborative problem-solving in small group settings, has been demonstrated to improve undergraduates’ evaluation of undergraduate STEM courses (Vernon & Blake, 1993).
Many colleges and universities already staff teaching and learning centers that offer such resources. For example, State University houses its own teaching and learning center that offers faculty free teaching consultations and workshops on effective pedagogy. But how many faculty avail themselves of these resources? STEM departments, if they are committed to improving undergraduate learning and reducing attrition, should encourage their faculty to take advantage of such resources by placing a greater emphasis on teaching quality in the tenure review process. Faculty should be encouraged to view teaching and research as two equally important components of their professorships. Anderson et al. (2011) write, “The continued vitality of research universities requires that we foster a culture in which teaching and research are no longer seen as being in competition, but as mutually beneficial activities that support two equally important enterprises: generation of new knowledge and education of our students” (p. 153).

**Balance students’ curricular commitments.** A major obstacle that participants encountered in their introductory STEM coursework was the demanding time commitment required by these courses, and the difficulty balancing this time commitment with the desire to lead a well-balanced college career. Administrators should acknowledge this very real struggle and design undergraduate curricula in such a way as to allow STEM majors to take more balanced course loads that include STEM and non-STEM classes during students’ first semesters in college. In this way, students might be able to lessen their workloads and lead more “typical” college lives, and thereby remain committed to their initial STEM majors. Furthermore, encouraging students to take more balanced course loads might offer the added benefit of allowing STEM majors to pursue a more traditional liberal arts education that can facilitate intellectual growth and instill positive habits of mind.
As Bok (2007) notes, college education should not simply offer students rigid vocational training and career preparation, but a broad based education that allows students to develop the intellectual skills critical for success for in 21st century globalized society. The abilities to reason intellectually and morally as well as familiarity and comfort with diverse peoples and ways of thinking are essential for 21st century college graduates (Bok, 2007). Therefore, requiring STEM majors to balance their curricular commitments and take a wide variety of courses during their first years of college can help students not only remain committed to their initial STEM majors but develop the intellectual and affective skills necessary for future success after graduation.

Offer systematic career counseling. STEM departments should consider implementing more systematic career counseling programs that help students understand the diversity of career opportunities that await undergraduates who graduate college with STEM baccalaureate degrees. Participants described becoming discouraged from continuing in their initial STEM majors when they began perceiving their desired future STEM careers as unappealing or taking too much time to achieve. However, participants often possessed rather limited understandings of future career opportunities. As Carnevale et al. (2011) note, a diversity of employment opportunities, within both STEM and non-STEM employment sectors, are available for STEM graduates. STEM undergraduates should be made aware of these opportunities.

The academic literature supports this recommendation. Empirical research has demonstrated that college students can benefit from receiving career counseling (Hughes et al., 2013; Mau et al., 1997; Mau, 1999). More specifically, Brown et al.’s (2003) meta-analyses found that career counseling that allows participants to explore different occupational opportunities during sessions can be particularly advantageous. This type of career counseling
might help STEM undergraduates taking introductory coursework better understand the multitude of career opportunities that are available for college graduates with STEM baccalaureate degrees.

Conclusion

By interviewing twenty participants and utilizing the conventional forms of grounded theory data analysis, I was able to produce a grounded theory of STEM attrition that describes and explains why participants decided to leave their initial STEM majors to pursue non-STEM courses of study. The rendered grounded theory consists of a central theoretical category, *locating alternative pathways*, as well as five theoretical phases that describe the “why” and “how” of STEM attrition. Ultimately, participants decided to discontinue in their initial STEM majors because they were able to locate alternative non-STEM pathways that allowed them to pursue intrinsic interests and extrinsic goals without having to face the same kinds of obstacles they encountered in their initial STEM majors.

The road to participants’ *locating alternative pathways* began before they entered college. Participants entered college with *tenuous motivation* to pursue STEM majors that was often based on limited experience and a single impactful experience that contributed to their decision to initially major in STEM disciplines upon entering college. Once enrolled in college, participants began taking introductory STEM coursework that confronted them with numerous obstacles that demotivated them from continuing in STEM. Once demotivated from continuing in STEM, participants located and elected to pursue non-STEM pathways that fell into the following typological categories: *maintaining interest but switching majors; returning to earlier
interest; and following in family footsteps. Participants’ STEM attrition stories conclude with their achieving non-STEM satisfaction and success.

The value of this grounded theory analysis of STEM attrition lies in its ability to describe the multidimensional process of STEM attrition. Unlike extant literature that largely examines STEM attrition from quantitative methodological perspectives, this study embraced qualitative methods and described the theoretical process of STEM attrition directly from the perspective of participants who have experienced this phenomenon. As such, I was able to not only contribute to the academic literature on this important topic, but also offer a series of practical recommendations that can guide practitioners as they seek to reduce the number of undergraduates who abandon their initial STEM majors.
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APPENDIX A: Participant Recruitment E-Mail

Dear Students,

I am writing to tell you about a research study that I am conducting here at State University and request your participation in one 60-minute interview.

The purpose of this research study is to investigate STEM (science, technology, engineering, and math) attrition and why undergraduates discontinue in STEM majors.

You may be eligible for this study if you began your college career enrolled in the College of Science and are now enrolled in a different State University college where you major in a non-STEM field of study.

It is important to know that this letter is not to tell you to join this study. It is your decision. Your participation is voluntary. Whether or not you participate in this study will have no effect on your relationship with State University or your academic standing.

If you are interested in learning more or participating in an interview, please contact me via email at mfm191@stateuniversity.edu. I will then contact you to set up a convenient interview day and time.

All interviews will be conducted in a private office on campus and will be recorded and then transcribed. The information you present to me may be used in my dissertation and future scholarly papers that will be made public. However, your name will not be utilized in the data and you will be assigned a pseudonym. Research participants will be compensated $25.00 for their time.

You do not have to respond if you are not interested in this study. Thank you for your time and consideration. I look forward to hearing from you.

Sincerely,

Michael F. Minutello
Ph.D. Candidate, Higher Education
State University
APPENDIX B: Inclusion Criteria

**STEM**—Borrowing from Chen and Weko (2009), STEM academic disciplines refer to majors in the following content areas: Mathematics; Natural Sciences, Physical Sciences; Biological/Agricultural Sciences; Engineering; and Computer and Information Sciences.

**Inclusion Criteria:**

1. Entered College of Science during Fall 2011 or Fall 2012 semester
2. Spent at least one semester enrolled in the College of Science
3. Maintained above a 2.0 GPA in core STEM courses that are required of College of Science majors
4. Left STEM major in College of Science to major in non-STEM discipline
5. Currently majoring in non-STEM discipline

**State University STEM majors in College of Science:**

1. Mathematical Sciences (Mathematics): Actuarial Mathematics; Applied and Industrial Mathematics; Computational Mathematics; General Mathematics; Systems Analysis; Graduate Statistics
2. Statistics (Mathematics): Statistics and Computing; Applied Statistics; Biostatistics; Graduate Studies
3. Biology (Natural Sciences): Ecology; General Biology; Genetics and Developmental Biology; Neuroscience; Plant Biology; Vertebrate Physiology
4. Biochemistry and Molecular Biology (Natural Sciences): Biochemistry; Molecular and Cell Biology
5. Biotechnology (Natural Sciences): General Option; Clinical Laboratory Science Option
6. Microbiology (Natural Sciences): Microbiology
7. Astronomy and Astrophysics (Physical Sciences): Graduate Study Option; Computer Science Option
8. Chemistry (Physical Sciences): Chemistry
9. Physics (Physical Sciences): Physics
11. Forensic Science (Natural Sciences): Forensic Science
12. Premedicine (Natural Science): Premedicine and Premedical
13. Science: General Science; Life Science Option; Mathematical Science Option; Physical Science Option
State University Non-STEM Majors:

1. College of Arts and Architecture:
   - Architecture (BARCH)
   - Show Art (ARTBA)
   - Show Art Education (A ED)
   - Show Art History (ART H)
   - Show Graphic Design (GD)
   - Show Integrative Arts (INART)
   - Show Interdisciplinary Digital Studio (IDS)
   - Show Landscape Architecture (LARCH)
   - Show Music B.A. (MUSB)
   - Show Music B.M. (MUSBM)
   - Show Music Education (MU ED)
   - Show Musical Arts (MUBMA)
   - Show Musical Theatre (THRMT)
   - Show Theatre B.A. (THRBA)
   - Show Theatre B.F.A. (THRFA)

2. College of Communications:
   - Advertising & Public Relations (AD PR)
   - Show Communications (COMM)
   - Show Film and Video (FILM)
   - Show Journalism (JOURN)
   - Show Media Studies (MEDIA)
   - Show Telecommunications (TELCM)

3. College of Education:
   - Childhood and Early Adolescent Education (CEAED)
   - Show Education (undecided) (ED)
   - Show Education and Public Policy (EPP)
   - Show Rehabilitation and Human Services (RHS)
   - Show Secondary Education (SECED)
   - Show Special Education (SPLED)
   - Show Workforce Education and Development (WF ED)
   - Show World Languages Education (WL ED)

4. College of Health and Human Development:
5. College of the Liberal Arts:

- **African Studies (AFRST)**
- Show **Anthropology (ANTH)**
- Show **Archaeological Science (ARSCI)**
- Show **Asian Studies (ASIA)**
- Show **Biological Anthropology (BANTH)**
- Show **Chinese (CHNS)**
- Show **Classics and Ancient Mediterranean Studies (CAMS)**
- Show **Communication Arts and Sciences (CAS)**
- Show **Comparative Literature (CMLIT)**
- Show **Criminology B.A. (CRMBA)**
- Show **Criminology B.S. (CRMBS)**
- Show **Economics B.A. (ECLBA)**
- Show **Economics B.S. (ECLBS)**
- Show **English (ENGL)**
- Show **French and Francophone Studies B.A. (FR BA)**
- Show **French and Francophone Studies B.S. (FR BS)**
- Show **German B.A. (GERBA)**
- Show **German B.S. (GERBS)**
- Show **History (HIST)**
- Show **International Politics (INTPL)**
- Show **Italian B.A. (IT BA)**
- Show **Italian B.S. (IT BS)**
- Show **Japanese (JAPNS)**
- Show **Jewish Studies (J ST)**
- Show **Labor and Employment Relations B.A. (LBEBA)**
- Show **Labor and Employment Relations B.S. (LBEBS)**
- Show **Latin American Studies (LATAM)**
- Show **Law and Society (LAWSC)**
- Show **Letters, Arts, & Sciences (LAS)**
- Show **Liberal Arts (undecided) (LA)**
• Show Medieval Studies (MEDVL)
• Show Organizational Leadership B.A. (OL BA)
• Show Organizational Leadership B.S. (OL BS)
• Show Philosophy (PHIL)
• Show Political Science (PL SC)
• Show Psychology B.A. (PSYBA)
• Show Psychology B.S. (PSYBS)
• Show Russian (RUS)
• Show Russian Translation (RUS T)
• Show Sociology B.A. (SOCBA)
• Show Sociology B.S. (SOCBS)
• Show Spanish B.A. (SPNBA)
• Show Spanish B.S. (SPNBS)
• Show Women's Studies B.A. (WS BA)
• Show Women's Studies B.S. (WS BS)

6. Division of Undergraduate Studies (DUS):

• Division of Undergraduate Studies (D U S)
• Exploratory (division of Undergraduate Studies) (D U S)
• Undecided (division of Undergraduate Studies) (D U S)

7. College of Business:

• Accounting (ACCTG)
• Corporate Innovation and Entrepreneurship (CIENT)
• Finance (FIN)
• Management (MGMT)
• Management Information Systems (M I S)
• Marketing (MKTG)
• Risk Management (R M)
• Supply Chain and Information Systems (SC&IS)
APPENDIX C: Consent Form

SUMMARY EXPLANATION OF RESEARCH
State University

Title of Project: Why They Leave: A Grounded Theory Analysis of STEM Attrition at a Large Public Research University

Principal Investigator: Michael F. Minutello
Telephone Number: (516) 589-4634
Advisor: Dr. Dorie Evensen
Advisor Telephone Number: (814) 863-2691

You are being invited to volunteer to participate in a research study. This summary explains information about this research:

The purpose of this research study is to gather information regarding STEM attrition and better understand why undergraduate students discontinue in STEM majors. You (the participant) are being asked to participate in a single, 60-minute interview. You might also be asked to answer several follow-up questions via email. You will be asked questions pertaining to why you discontinued in your initial STEM pre-major. The interview will be recorded and then transcribed and analyzed. Ultimately, the information you present to me may be used in my dissertation and future scholarly papers that will be made public. However, your name will not be utilized in the data, and you will be assigned a pseudonym.

If you have questions or concerns, you should contact Michael Minutello at (516) 589-4634.
Your participation is voluntary and you may decide to stop at any time. You do not have to answer any questions that you do not want to answer.

I have read and understood the above, and give my consent to participate:

Participant’s Name: ___________________  Date: ______________

Participant’s Signature: ___________________  Date: ______________
APPENDIX D: Initial Interview Protocol

Why They Leave
Interview Questions
Protocol A

Getting started:

1. Thank person for willingness to participate.
2. Remind person that we are restricting ourselves to ONE HOUR (note time now).
3. Ask participant to read and sign letter of consent to participate in research project.
4. Ask if there are any questions about rights/procedures that you might address now.
   Remind them that if we publish, we will adhere to strict confidentiality – re name – we will also (if they wish) refrain from using name of employer or name of law school if they think this would lead to identifying them). We will run this by them again before we publish anything. Also, we will allow them to review excerpts from texts that relate to their stories before publishing (we call this a form of member checking).
5. Review “criteria for inclusion” in the study and use these as a jumping-off point to get some demographic info:
   a. Initially declared a STEM major upon entering college during Fall 2011 or Fall 2012 semester (Yes—which major? What year?)
   b. Spent at least one semester as a STEM major (Yes—how long were a STEM major?)
   c. Decided to change majors to another non-STEM major (Yes—when did you change and to what major?)
   d. What is your current major?

Opening questions:

1. Can you tell me the story of why you decided to select a STEM major upon entering college?
2. Can you please describe your experiences as a STEM major during college?
3. Can you please describe the factors that contributed to your decision to change majors to another non-STEM field of study?
4. Can you please tell me the story of how you decided to leave your STEM major?

Specific areas of interest:

1. Demographic characteristics
2. Pre-college academic preparation
3. Achievement motivation
4. Instructional methods utilized in STEM classrooms
5. Participation in co-curricula programming
Closing Questions:

1. Is there anything else you think I should know about your STEM attrition experience?
2. May I contact you if I have any follow-up questions or would like you to read a brief summary of my study’s results?
3. Thank you for your participation!

Be especially alert for (or prompt):

- WHEN participant realized he/she was ON TRACK for declaring a STEM major.
- WHEN participant began to question his or her decision to major in STEM discipline
- What OBSTACLES existed that contributed to their decision to leave their STEM major
APPENDIX E: Topical Interview Protocol B

Why They Leave
Interview Questions
Protocol B

Opening Remarks:

• Thank you for your willingness to participate.
• Ask participant to read and sign letter of consent to participate in research project.
• Do you have any questions or concerns regarding the consent form?
• OK, great, Let’s get started.

Opening Questions:

• What semester did you first enroll in college?
• What is your current class standing?
• Can you tell me what your initial pre-major was when you enrolled in college?
• Your major [insert name] is considered a STEM major by education scholars. Can you tell me the story of why you decided to select this STEM pre-major [insert name of specific pre-major] upon entering college?
• Who, if anyone, was involved in your decision to declare a STEM pre-major?
• Can you please describe your experiences as a STEM pre-major [insert name of specific pre-major] during college?
• Could you describe your typical academic day as a STEM major?
• How long did you spend as a STEM pre-major?
• Can you please tell me the story of how you decided to leave your STEM pre-major?
• Can you please describe any other factors that contributed to your decision to leave your STEM major? Could you describe the most important lessons you learned being a STEM pre-major?
• Can you please tell me the story of why you switched to your current major? Are you satisfied with your decision to switch majors from [initial STEM major] to [current non-STEM major]?
• Could you describe your typical academic day in your current major?

Specific areas of interest:

• Demographic characteristics
• Pre-college academic preparation
• Achievement motivation
• Instructional methods utilized in STEM classrooms
• Participation in co-curricula programming

Closing Questions:
• Is there anything else you think I should know about your STEM attrition experience?
• May I contact you if I have any follow-up questions or would like you to read a brief summary of my study’s results?
• Thank you for your participation!

Types of Follow-Up Questions:
• Can you say something more about that?
• Can you give another example of that?
• What did you do when you felt [diminishing motivation/mounting anxiety]?
• Is it correct that you feel [x]?

Be especially alert for (or prompt):
• WHEN participant realized he/she was ON TRACK for declaring a STEM major.
• WHEN participant began to question his or her decision to major in STEM discipline
• What OBSTACLES existed that contributed to their decision to leave their STEM major
APPENDIX F: Topical Interview Protocol C

Why They Leave
Interview Questions
Protocol C

Opening Remarks:

• Thank you for your willingness to participate.
• Ask participant to read and sign letter of consent to participate in research project.
• Do you have any questions or concerns regarding the consent form?
• OK, great, Let’s get started.

Opening Questions:

• What semester did you first enroll in college?
• What is your current class standing?
• Can you tell me what your initial pre-major was when you enrolled in college?
• Your major [insert name] is considered a STEM major by education scholars. Can you tell me the story of why you decided to select this STEM pre-major [insert name of specific pre-major] upon entering college?
• Who, if anyone, was involved in your decision to declare a STEM pre-major?
• Can you please describe your experiences as a STEM pre-major [insert name of specific pre-major] during college?
• Could you describe your typical academic day as a STEM major?
• How long did you spend as a STEM pre-major?
• Can you please tell me the story of how you decided to leave your STEM pre-major?
• Can you please describe any other factors that contributed to your decision to leave your STEM major? Could you describe the most important lessons you learned being a STEM pre-major?
• Can you please tell me the story of why you switched to your current major? Are you satisfied with your decision to switch majors from [initial STEM major] to [current non-STEM major]?
• Could you describe your typical academic day in your current major?

Specific areas of interest:

• Demographic characteristics
• Pre-college academic preparation
• Achievement motivation
• Instructional methods utilized in STEM classrooms
• Participation in co-curricula programming
• Time
• STEM grades

Selective Coding: Testing Hypotheses

• Following Path of Least Resistance
• Cost-Benefit Analysis

Closing Questions:

• Is there anything else you think I should know about your STEM attrition experience?
• May I contact you if I have any follow-up questions or would like you to read a brief summary of my study’s results?
• Thank you for your participation!

Types of Follow-Up Questions:

• Can you say something more about that?
• Can you give another example of that?
• What did you do when you felt [diminishing motivation/mounting anxiety]?
• Is it correct that you feel [x]?

Be especially alert for (or prompt):

• WHEN participant realized he/she was ON TRACK for declaring a STEM major.
• WHEN participant began to question his or her decision to major in STEM discipline
• What OBSTACLES existed that contributed to their decision to leave their STEM major
## APPENDIX G: List of Participants

<table>
<thead>
<tr>
<th>Alias</th>
<th>Gender</th>
<th>Minority Status</th>
<th>Enrollment</th>
<th>Initial Major</th>
<th>STEM Grades</th>
<th>Time in STEM</th>
<th>Current Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mary</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Freshman Year: 3.5 GPA</td>
<td>2 semesters</td>
<td>Sociology</td>
</tr>
<tr>
<td>Sarah</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology</td>
<td>Chem 100: B-</td>
<td>2 semesters</td>
<td>Elementary Education w/ Minor in Special Education and Dance</td>
</tr>
<tr>
<td>Scott</td>
<td>Male</td>
<td>No</td>
<td>Senior</td>
<td>Physics</td>
<td>First semester: 2.92 GPA Chem 100: C+ Physics: B</td>
<td>1 semester</td>
<td>Risk Management w/ Option in Actuarial Science</td>
</tr>
<tr>
<td>Jane</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Forensic Science w/ Focus on Biology</td>
<td>Chem 100: B+ Freshman year: 3.8 GPA <strong>Chem 102: D</strong> Microbiology: dropped</td>
<td>3 semesters</td>
<td>Criminology and Art History</td>
</tr>
<tr>
<td>Eric</td>
<td>Male</td>
<td>No</td>
<td>Senior</td>
<td>Chemistry</td>
<td>N/A</td>
<td>3 semesters</td>
<td>Finance</td>
</tr>
<tr>
<td>Kate</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Forensic Science w/ Chemistry Option</td>
<td>First semester: 3.22 <strong>Chemistry: D’s</strong></td>
<td>2 semesters</td>
<td>Criminology Spanish Global and International Studies</td>
</tr>
<tr>
<td>Cynthia</td>
<td>Female</td>
<td>Yes</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Bio 100: B+ Math 100: B Math 102: B First semester: 3.2 GPA <strong>Chem 100: F; D</strong></td>
<td>2 semesters</td>
<td>Psychology w/ Focus on Neuroscience</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Chemistry</td>
<td>N/A</td>
<td>1 semester</td>
<td>Chemistry Education</td>
</tr>
</tbody>
</table>

**Note:** Bold text indicates a major change or update in the student's current major.
<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Marital Status</th>
<th>Year</th>
<th>Major</th>
<th>Courses</th>
<th>GPA Length</th>
<th>Concentration/Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madison</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Pre-Med</td>
<td>Bio 100: B+ Chem 100: B+ Math: C’s</td>
<td>3 semesters</td>
<td>Rehabilitation and Human Services</td>
</tr>
<tr>
<td>Charlotte</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biochemistry</td>
<td>Physics: C Chem 102: B+ First semester: 3.7 GPA</td>
<td>3 semesters</td>
<td>Psychology</td>
</tr>
<tr>
<td>Heather</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Biology</td>
<td>Bio 100: A</td>
<td>1 semester</td>
<td>Human Development and Family Studies</td>
</tr>
<tr>
<td>Sophia</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Chemistry</td>
<td>Math 100: B+</td>
<td>1 semester</td>
<td>Psychology</td>
</tr>
<tr>
<td>Robert</td>
<td>Male</td>
<td>No</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Bio 100: B Math 100: C+ Bio 200: C+ Chem 100: dropped Chem 101: C First semester: 2.7 GPA</td>
<td>2 semesters</td>
<td>Risk Management w/ Real Estate Option and Concentration in Finance</td>
</tr>
<tr>
<td>Evelyn</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology</td>
<td>Bio 100: B+ Chem 100: dropped</td>
<td>1 semester</td>
<td>Secondary Education w/ Focus on English Communications and English Minor</td>
</tr>
<tr>
<td>Christina</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology</td>
<td>Chem 100: A- Bio 100: B Math 100: D</td>
<td>1 semester</td>
<td>Enterprise Risk Management</td>
</tr>
<tr>
<td>Alexandra</td>
<td>Female</td>
<td>No</td>
<td>Senior</td>
<td>Pre-Med</td>
<td>Math 100: C Bio 100: A Chem 100: B Chem 101: B+</td>
<td>3 semesters</td>
<td>Psychology w/ Neuroscience Focus</td>
</tr>
<tr>
<td>Danielle</td>
<td>Female</td>
<td>No</td>
<td>Junior</td>
<td>Biology w/ Neuroscience specialty</td>
<td>Chem 100: A- Bio 100: A- Math 100: B</td>
<td>1 semester</td>
<td>Human Development w/ Minor in Psychology</td>
</tr>
<tr>
<td>Name</td>
<td>Gender</td>
<td>International</td>
<td>Year</td>
<td>Major</td>
<td>Courses</td>
<td>Semesters</td>
<td>Minor</td>
</tr>
<tr>
<td>-------</td>
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<td>-------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Brian</td>
<td>Male</td>
<td>Yes (international)</td>
<td>Junior</td>
<td>Math w/ Actuarial Science</td>
<td>Math 101: A-&lt;br&gt;Math seminar: A</td>
<td>1 semester</td>
<td>Accounting</td>
</tr>
</tbody>
</table>
Curriculum Vita for Michael F. Minutello

EDUCATION

Doctor of Philosophy in Higher Education, Educational Psychology minor. The Pennsylvania State University (2016)

SELECTED PROFESSIONAL EXPERIENCE

Academic Specialist, Quinnipiac University. North Haven, CT (2016-present)
Graduate Assistant, Penn State Learning, The Pennsylvania State University. University Park, PA (2014-15)
Tutor, Huntington Learning Center. Long Island, NY (2004-08)
Theology Teacher, Fairfield Preparatory School. Fairfield, CT (2000-01)

SELECTED RESEARCH EXPERIENCE


AWARDS & HONORS