PERSISTENCE PATTERNS OF MATHEMATICS AND SCIENCE MAJORS:

A PROFILE OF HIGHLY MOTIVATED FRESHMEN

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Despite an increasing demand for college graduates skilled in science, technology, engineering, and mathematics (STEM) fields, a substantial number of students who choose these majors leave after taking their first-year "gateway" math and science coursework. Research has shown GPA to be a salient predictor of persistence in STEM majors: Students who earn high grades in gateway courses are more likely to continue, and those who earn low grades are more likely to leave. However, a small number of students defy that expectation: Despite a low gateway course GPA, they persist not just to the sophomore year but all the way to graduation. The purpose of this study was to determine what other experiences, motivations, or attributes aside from academic performance influence these students to persist.

A qualitative approach was taken with the use of semi-structured interviews, which provided a means for analysis based on insights directly from students. An invitation was sent to a cohort of graduating math and science majors at a large public institution, and 10 eligible volunteers were chosen to participate. A thematic analysis was conducted to seek common themes in the students' interviews regarding their experiences in their gateway coursework, their feelings towards their chosen major, their beliefs about their academic proficiency, their motivations for continuing in their major, and other prominent characteristics they attributed to their persistence. Five themes were found: Ambition, dedication, achievement, culture shock, and resilience.

Of the five themes, four are attributes of the students themselves: Ambition,

dedication, achievement, and resilience. The fifth, culture shock, is something that happened to them, although it does contain information about the students insofar as how they handled the situation. The end result was the identification of a specific group of students: High achievers majoring in math and science who are self-driven and independent, as well as confident in their abilities. A student fitting this profile is likely to persist in a math or science major despite any initial setbacks they may endure in the first year of coursework. In terms of application, institutions can implement initiatives for incoming freshmen to orient them to their STEM majors and guide them in understanding the attitudes, motivations, and practices that will help them succeed.

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CHAPTER 1

INTRODUCTION

In the higher education community, introductory mathematics and science courses are commonly reputed to be washout courses for students majoring in “STEM” fields: science, technology, engineering, and mathematics. Unlike the more rudimentary math and science courses taken by non-STEM majors, the more comprehensive introductory courses for majors are thought to be purposely difficult with the function of weeding out students who do not prove themselves proficient enough to major in math or science (Epstein, 2006). A more positive term is “gateway” courses, which depicts introductory math and science coursework as the first stop on the path to math and science degrees (Gainen, 1995). Regardless of what they are called, in these introductory courses STEM majors get their first experience with the subject of their major, which makes the courses key in the study of STEM major retention.

Despite an increasing need for workers in STEM careers, college students are leaving their STEM majors at a troubling rate (Higher Education Research Institute, 2010). There is evidence that students change their major as early as the first year, and many studies have explored possible reasons (Bean, 1985; Cabrera, Castaneda, Nora, & Hengstler, 1992; Herzog, 2005), but less research has been done to specifically link student persistence in math and science majors to their experience in introductory math and science coursework.

Statement of the Problem

In modern technological culture there is an increasing demand for workers skilled in STEM fields, but not enough students are pursuing those careers to keep up

(Heilbronner, 2011). Fewer students are opting into STEM majors upon entrance to college, and of those students, only a small percentage graduate in that field (Rask, 2010). Despite research in this area, results have not yet revealed all the factors that support or inhibit pursuit of a STEM field or the precise issues affecting student success and degree completion in those fields.

Much of the research that does exist has focused on women and minority students and the ways in which gateway math and science courses function as barriers to careers in STEM fields for those groups (Boli, Allen, & Payne, 1985; Cole & Espinoza, 2008; Oakes, 1990; Tai & Sadler, 2001). There is a great need to create more diversity in the sciences both to reflect more accurately the demographics of the population and to enrich the field with diverse perspectives. This is an issue important not just to STEM education but to the society at large, as race and gender equality continues to persist in the forefront of the country's public consciousness (Anderson, 1999). Increased diversity aids the quest for an open and just society (Healey, 2011), and with this goal in mind it is understandable that research on academic success in STEM fields would be focused on underrepresented students. However, in recent years lack of interest or success in STEM majors has become a large enough problem to warrant an examination of introductory courses from the broader perspective of all students initially interested in math and science majors, regardless of demographics (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011).The number of students completing STEM degrees has been trending downwards (Seymour & Hewitt, 1997), and it is not just underprivileged or minority groups who are leaving (Chen, 2009). The root of the problem that is causing students of all backgrounds to leave their majors and potential careers must be discovered. Based on enrollment data and theories of student persistence, it can be surmised that a large factor in student retention in STEM fields is based on early exposure to those subjects (Daempfle, 2002). However, it may be possible that it is not just the learning environment in introductory math and science courses that contributes to persistence; there may be other factors involved. An examination of student performance and experiences in this coursework from the perspective of established theory on persistence may shed light on the reasons behind the declining retention of STEM majors.

Theoretical Framework

The ultimate goal of this research is to retain students in math and science majors and produce successful graduates. The crux of the matter is persistence: what factors lead to student retention? There are decades of research devoted to the topic, but much of it relies on the early work of influential theorists such as Alexander Astin and Vincent Tinto. Astin founded his theory of persistence on the notion that both student characteristics and the college environment will have an effect on success. He developed an Input-Environment-Outcome model (Astin, 1991) as a conceptual guide for college persistence. With this model he proposed that the retention of students should be examined from multiple points: the preexisting characteristics of students prior to entering college, the environment they experience once in college, and the effects of college. The purpose is "to assess the impact of various environmental experiences by determining whether students grow or change differently under varying environmental conditions" (Astin, 1993, p. 7). Tinto is another notable researcher in this field, whose work focuses on student departure from college. Like Astin, he theorized that students enter college with existing characteristics that affect their ability to succeed and that many factors in the college environment itself can ultimately lead to either retention or dropout. In both Astin's and Tinto's research it is demonstrated that persistence is based on a large number of variables, a notable one being the experiences of students upon entering college.

In order to understand the persistence patterns of STEM students specifically, a theoretical framework needs to be employed that is designed to focus on STEM. Wang (2013) proposed such a model, illustrated in Figure 1. This model was tested on a nationally representative sample of students to examine factors influencing the decision to pursue STEM majors.

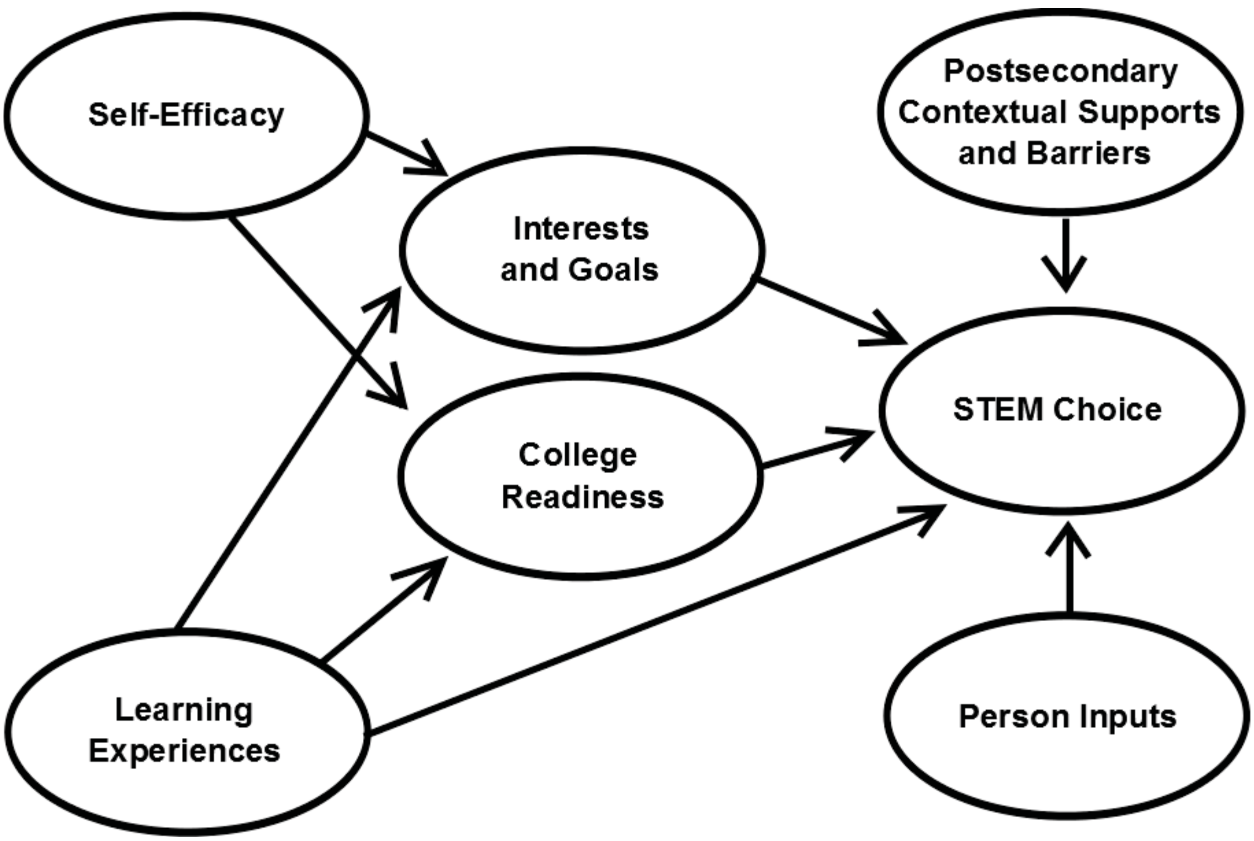

Figure 1. Conceptual framework of the factors influencing the choice to major in a STEM field, developed by Wang (2013).

Wang's model is based on social cognitive career theory (Lent, Brown, & Hackett, 2002), adapted from the general social cognitive theory established by Bandura (1986). Although developed for research on career choice, the authors of social cognitive career theory (SCCT) argue that it is applicable to an academic environment because choice, development, and success in both academic and career spheres share similar mechanisms: self-efficacy, outcome expectations, and personal goals. Various environmental factors, including supports and barriers alike, influence choice and success as well. In its academic applications, SCCT has been put to use in STEM research in recent years, particularly with the goal of expanding the STEM pipeline in K-12 education. However, only to a limited extent has this research been done in a baccalaureate setting, prompting Wang to create her framework. Although not a direct application of SCCT, her model draws from this theory to highlight the constructs most theoretically relevant to STEM education, basing the selection on prior literature on college student success in STEM fields. The core SCCT constructs incorporated into Wang's model are self-efficacy, interests and goals, contextual supports and barriers, and person inputs; to those she added learning experiences and college readiness.

Self-efficacy is essentially the central construct of Wang's theoretical model, with extensive prior research demonstrating its ability to influence academic major choice, long-term goals, and career interests (Porter & Umbach, 2006; Stupnisky, Renaud, Daniels, Haynes, & Perry, 2008). In STEM fields specifically, self-efficacy in regard to an individual's belief in his or her proficiency in math and science correlates to the decision whether or not to major in a STEM field (Scott & Mallinckrodt, 2005). To that end, self-efficacy is directly tied to another component of the model: students' interests and goals. A student's perception of his or her ability in math and science can directly impact interest in STEM subjects as well as long-term academic and career goals. High levels of self-efficacy lead to greater interest in math and science and potentially result in the goal of pursuing further education in STEM fields. Conversely, low levels of self-efficacy decrease a student's interest in math and science and can lead to apathy towards or even avoidance of further study in those subjects (Astin & Astin, 1992). Learning experiences and college readiness, the two components Wang added to the original SCCT model, also contribute to this flow of thought. As with self-efficacy beliefs, student's prior learning experiences can affect their academic trajectory in a number of ways (Lee, 2013; Lent, Brown, & Hackett, 2000). The learning environment, which provides students' early exposure to math and science and prepares them for future learning, can directly impact STEM major choice. However, it can also have an indirect impact via encouraging or discouraging student interest in math and science as well as their feelings about their college preparedness.

The final two components of the model have more of a direct impact on STEM major choice: person inputs and postsecondary contextual supports and barriers. For the former, education expectations are one sort of person input, but Wang places primary emphasis on student demographics. Many demographic variables such as gender, ethnicity, and socioeconomic status have been shown in research to influence STEM major choice and persistence (Carlone & Johnson, 2007; Crisp, Nora, & Taggard, 2009; Riegle-Crumb & King, 2010). Certain populations, such as white males, Asian Americans, and students from favorable socioeconomic backgrounds are overrepresented in STEM education, while other groups such as ethnic minorities and women are more likely to encounter challenges in the pursuit of STEM majors and careers. The remaining component, contextual supports and barriers, represents those issues that students face upon entering college that have positive or negative effects on their choice of major and persistence in that major. There are many possible contextual influences, but several involve the academic experience, such as academic integration into college, the learning environment of the coursework (especially gateway math and science courses), or rapport with instructors and peers (Chang, 2005; Church, Elliot, & Gable, 2001; Kuh, 2003). Other important influences include financial pressures and external personal and work responsibilities (Darolia, 2014; Jones-White, Radcliffe, Lorenz, & Soria, 2013). Depending on specific circumstances, these factors can either be supports that encourage students to succeed and persist or barriers that lead to discouragement and departure.

As a whole, all of the components of the theoretical framework act together to serve as a model of entrance and persistence in STEM majors. The educational trajectory of a student can be followed by taking into account each individual factor in the model and their interrelationships with each other. In summary, self-efficacy beliefs in math and science along with early learning experiences can determine students' interests and goals as well as their college readiness; these factors along with individual person inputs and contextual supports and barriers upon entering college influence students' decisions to major and persist in STEM fields.

Research Question

This study will address the following question:

1. What experiences, motivations, or attributes influence students majoring in math or science to persist to graduation after earning low grades in gateway math and science coursework?

The overall purpose of the study is to examine the connection between student experiences in introductory math and science coursework and retention in math and science majors. Research consistently demonstrates that academic performance is correlated to retention, both short- and long-term: students with high grades are more likely to persist, and students with low grades are more likely to drop out. However, some students who earn low grades do persist, so there must be other contributing factors. In this study, rather than examining general academic performance, the assessment was narrowed down to include gateway math and science courses only, which are taken during the freshman year. The data collected in the study are a product of insight from the students themselves. A total of 10 students were interviewed to discuss their experiences in the gateway courses in which they did poorly and the reasons they chose to persist in their major all the way to graduation. The end result of the study is intended to contribute to the understanding of the factors that influence persistence in math and science majors.

Definition of Terms

The following terms are defined according to their usage in the context of this study.

Major. There are several departments in the fields of math and science at this university and each has multiple bachelor's degree options. However, it will be sufficient enough for this study to group students by field into five major categories: biology, chemistry, geology, mathematics, and physics.

Persistence. This term is defined as the continued enrollment of a student without changing majors. For the purposes of this study, students must have been currently enrolled in their graduating semester and about to complete a degree in the major subject they declared upon entering the university as freshmen, regardless of the specific timeframe between those two points.

Science. This is a broad category representing four major fields: biology, chemistry, geology, and physics.

STEM. This is a widely-used acronym for "science, technology, engineering, and mathematics." This study focuses just on math and science, but STEM is a useful and relevant acronym when discussing literature on prior research and initiatives in these fields.

Significance of the Study

The research literature does not provide an examination of students who persist in their major despite poor academic performance, a gap that this study seeks to fill. It focuses on a small population of students—math and science majors—and first-year coursework is narrowed down to just math and science. The significance of this focused examination is its potential to provide a specific learning context and a specific point in time in which math and science majors decide to leave, giving practitioners and researchers a precise focal point to direct their efforts on student learning and success.

The reason the fields of math and science were chosen for study is their importance to society; there is a great need for STEM workers and researchers in the modern world (National Academy of Sciences, 2010). If students face insurmountable obstacles in their pursuit of a math or science degree, the number of graduates declines and society suffers. This study is important because it examines specific coursework that may be acting as barriers to student success and observes the qualities of students who persist beyond those barriers despite poor academic performance. The study's examination of experiences in gateway math and science courses will contribute to the understanding of STEM major attrition.

Limitations, Delimitations, Assumptions

One delimitation of the study is the measurement of persistence from the first semester of the freshman year to the final semester of graduation. With a timeframe of four or more years, this could diminish the measurable effect of gateway courses taken in the first year; i.e. other factors determining major change may have been involved after the first year. However, the datum most relevant to this study is that the students in question did not change their major immediately after the first year, which the literature demonstrates is a common departure point for students earning low grades; students are specifically asked to reflect back upon this time when discussing their decision to persist in their major. Another delimitation is the restriction of population to a single university, which limits the direct relevance of the results to this university only. However, as a large public university, an assumption is that the sample is still broad enough to include students from a variety of backgrounds and academic experiences, which research has shown can affect college grades and persistence.

CHAPTER 2

REVIEW OF THE LITERATURE

Following is a review of existing literature on topics relevant to the current study, including research on college student success and retention as well as issues in STEM education: major choice, student demographics, attrition, and mathematics and science gateway coursework.

Issues in Student Retention

Academic success is a major area of study in the field of higher education. As a means of gauging both student success and institutional effectiveness, institutions of higher education have placed a great emphasis on student retention (Schnell & Doetkott, 2003). Retention rates in American colleges and universities are very poor; although many students enroll in college, not all succeed and dropout rates have become excessive. Studies on students beginning college in the mid-1990s have reported that on average, just over half ultimately completed a baccalaureate degree (Berkner, He, & Cataldi, 2002; Kuh, Cruce, Shoup, Kinzie, & Gonvea, 2008). The more recently released 2004/09 Beginning Postsecondary Students Longitudinal Study found that in a nationally representative sample of students beginning postsecondary education for the first time in 2003-2004, by the end of six years 35% had not completed a certificate or degree and were not enrolled (Radford, Berkner, Wheeless, & Shepherd, 2010). Student departure can happen at any time, but a substantial number of students drop out of school before they have reached their sophomore year. Researchers therefore look to the experiences of the freshman year for potential predictors of student success.

Academic Success in the Freshman Year

When seeking ways to increase academic success and graduation rates, it is logical to begin with an examination of the freshman year. The first year is critical for college students as they transition from a secondary setting into a higher education one. Due to the changing characteristics and increasing numbers of college freshmen in the last several decades, institutions of higher education have begun to realize the importance of providing special attention to their freshman students (Gordon, 1989; Tinto, 2006; Turner & Thompson, 2014). Though specific dropout reasons vary, the characteristics of modern students compounded with the difficulties encountered when adjusting to college make freshmen particularly at risk for disengagement, poor grades, and withdrawal. Students may drop out due to issues they encounter and are unprepared to deal with during their first year of college. Noel, Levitz, and Saluri (1985) identified several themes of college student attrition such as adjustment difficulties, unrealistic expectations of college, and academic underpreparedness. The authors discussed the great amount of evidence that shows that the experiences of the freshman year are major predictors of student success.

One of the more salient predictors is GPA; research has shown that early academic performance consistently serves as a predictor of retention and future academic success. There is a strong correlation between first-year grades and persistence; the first-year college GPA plays a central role in predicting persistence and educational attainment, and it can affect both general persistence in college and persistence in a specific major (Pascarella & Terenzini, 2005). Allen and Robbins (2008) found that in a sample of nearly 90,000 freshmen, students with a higher first-year GPA were more likely to persist in their entering major. Allen, Robbins, Casillas, and Oh (2008) found first-year GPA to be a predictor of general college retention to the third year. In addition to GPA, they also found that freshman academic motivation and engagement directly affected retention. For these reasons, institutions have spent a great deal of time and resources the past several decades focusing on efforts to improve the freshman academic experience (Braxton et al., 2014).

Although previous research findings indicate there are correlations between first-year GPA and retention, they lack information about grades in specific courses (Allen et al., 2008; Murtaugh, Burns, & Schuster, 1999; Perkhounkova, McLaughlin, & Noble, 2006). One exception is the first-year seminar course or some variation thereof, which is designed specifically for the purpose of student success and whose effects on retention are intended to be studied (Noble, Flynn, Lee, & Hilton, 2007; Porter & Swing, 2006; Williford, Chapman, & Kahrig, 2001). It makes sense that individual courses would not be studied because freshmen take a variety of courses their first year depending on school, major, schedule, and interests. When studying freshmen in general, it would be too great an undertaking to narrow down academic performance to specific courses. However, when studying the retention of math and science majors specifically, it would be not only feasible but also appropriate to take a close look at the math and science courses that freshmen take in their first year of college.

Gateway Courses

In STEM fields, academic performance may perhaps be most critical in the introductory math and science courses of the freshman year. Students in more advanced coursework have the benefit of experience: they have already demonstrated the ability to succeed in their subject area, they are comfortable in the academic environment, and they have adapted to the style of instruction in their major field (Rigden & Tobias, 1991). By contrast, students in introductory courses are encountering their subject of interest for the first time with no idea what to expect. This is particularly difficult for freshmen, who are not only new to their subject, but are new to the college environment in general. They are still learning the academic ropes and the methods for succeeding as a student. Faced with the impersonal, competitive, and authoritarian environment of introductory math and science courses (discussed in depth in a later section), students may feel discouraged and doubt their ability to succeed (Baldwin, 2009).

Before discussing the impact of these courses on STEM majors, it should be noted that introductory math and science courses tend to have some measure of effect on students in all majors. Regardless of their chosen course of study, undergraduate students in traditional college settings are conventionally required to experience a breadth of content in a variety of foundational subjects in addition to a depth of content in their major field (Levine, 2006). Math and science are typically included among those foundational courses (Cheney, 1989); for example, the state in which the present study takes place requires a common undergraduate core curriculum for all its public institutions that must include at least one math course and two science courses. All undergraduate students in public institutions must therefore enroll in math and science courses whether or not they are competent (or feel they are competent) in the subject. Mandatory math and science enrollment policies such as this are not without evidenced-based justification; research has shown that success in math and science gateway courses is important for long-term success and retention, and not just among STEM majors. Adelman (2006) followed a cohort of students from high school through their postsecondary education. He found that 71% of the students who completed a college-level math course by the end of the second year of enrollment eventually completed their bachelor's degrees; only 38% of students who did not take math courses in their first two years ultimately completed their degrees. Looking at specific gateway courses, he found that the ratios of participation between students who eventually earned degrees and those who did not ran 4 to 1 in general chemistry and more than 3 to 1 in precalculus. In another study, Herzog (2005) found that after overall college GPA, performance in math coursework was the strongest retention predictor for new freshmen.

Despite their importance to success, college freshmen tend to perform more poorly in math and science courses than other subjects. In a study of longitudinal data from 1972 to 2000, Adelman (2004) reviewed the distribution of failing grades, withdrawals, and repeats in students' undergraduate coursework. He assembled a list of 20 courses with the highest percentage of failing grades and found that 12 of them were in STEM fields, e.g. precalculus, general chemistry, computer programming, and other related subjects. Another list of 20 courses with the highest percentages of withdrawals and repeats included 13 courses in STEM fields. Mathematics courses topped both lists. This brings to light an important challenge in recruiting students into STEM fields: math anxiety. It would not be unreasonable to expect that math ability and science ability would go hand in hand, yet students do not always have equal aptitude in math and science. Students are often comfortable with one area but have difficulty understanding the other, and therefore may pass their science courses but fail their math courses, or vice versa. However, on average, mathematics appears to cause more distress in students than other commonly-taken STEM courses such as biology or computer science (Tobias, 1993). Math anxiety has become prevalent in modern education, even among students interested in STEM fields (Jameson & Fusco, 2014; Sax, Kanny, Riggers-Piehl, Whang, & Paulson, 2015). This is problematic for a number of reasons, one of which is that students' beliefs both about mathematics and about their ability to comprehend mathematical concepts can actually hinder their ability to learn the subject (Mason, 2003). Students who want to pursue a science career but who suffer from math anxiety may end up altering their career aspirations because their success could partly depend on their math ability, or rather their perception of their math ability (Bong & Skaalvik, 2003; Moakler & Kim, 2014). Sax et al. (2015) conducted research on students' self-concept of mathematical ability and its relation to choosing a major in STEM. Rather than an aggregate study, they examined individual sub-groups of STEM majors based on the premise that different STEM fields place varying levels of emphasis on math ability. They found that while greater math confidence is a predictor of students' decisions to major in STEM in general, levels of confidence varied among the sub-fields, with students with the lowest math self-concept choosing to major in the biological sciences. Other sub-groups such as physical sciences have the potential to ward off students with low confidence in their mathematical ability. Both self-efficacy and actual ability in math are demonstrably important to STEM education and have a far greater presence in the research literature than science-based competence. However, self-efficacy in the sciences can have its own impact on students pursuing STEM-oriented majors and careers. Larose, Ratelle, Fuay, Senécal, and Harvey (2006) conducted a study of 411 entering college students to explore the associations between their self-efficacy beliefs regarding science and their academic and vocational pursuits in the sciences. Students with high or increasing self-efficacy towards science reported more positive academic and vocational outcomes than those with low or decreasing self-efficacy. Positive outcomes included science achievement, persistence in a science major, and decidedness to pursue a science career. Research on self-efficacy and performance in both math and science is important because both areas have been and will continue to be critical to college student persistence in STEM fields.

When students are unsuccessful in gateway courses, the traditional view is that they were ill-prepared or are simply not cut out for mathematics and science learning (Gainen, 1995). In this view, gateway courses serve as a trial run or test of ability to enter a STEM major: it is better for students to find out early on that they do not have the necessary skills to continue in their chosen majors. Instructors are accustomed to the competitive environment of introductory courses and may not see the need to alter instruction when they already have a system in place for acquiring students with innate talent (Baldwin, 2009; Willemsen, 1995). However, a more modern view challenges conventional wisdom by recognizing that students who choose STEM majors are in fact prepared enough to be successful, but the courses themselves are exceptionally difficult (Green, 1989). Tobias (1990) wrote that average-ability STEM majors are the ones most negatively affected by gateway courses. Her research focused on "second tier" students: those who are not top performers in math and science ability, but who have a decent enough aptitude and some level of interest that they could be successful in

STEM majors and careers if given the chance. She argued that introductory science coursework is designed to weed out all but the brightest top tier students. The reputation of these types of courses drives off potential majors in the second tier. Those who do take the courses find the extremely competitive environment intimidating and may end up being washed out of the major. These are students who could have gone on to be successful STEM majors had they been given more support in their early courses.

Students' experiences in introductory coursework may therefore have a significant effect on the entire course of their academic and career plans; in STEM fields, successful learning in math and science courses may lead to persistence in STEM majors and eventually to pursuit of STEM careers. Positive experiences in gateway courses increase students' confidence in their major and lead to improved retention and graduation rates (Byars-Winston & Fouad, 2008). In contrast, if students are not able to get through their introductory coursework, those negative experiences impede their ability to pursue their goals, and they may feel their only option is to find a new major (Tobias, 1990). The initial exposure to math and science can therefore reasonably be considered a determiner of long-term success.

STEM Major Attrition

A large number of students change their major at least once during the course of their academic career. In one study conducted by Kramer, Higley, and Olsen (1994), the researchers tracked multiple cohorts at a four-year institution and found that nearly 75% of the students changed their major at some point. STEM majors are particularly prone to changing their majors. Astin and Astin (1992) found in a longitudinal study of 27,065 students that the percentage majoring in STEM fields declined from 28.7% to 17.4% between the students' freshman and senior years. Chen (2009) pulled data from the 1995-1996 Beginning Postsecondary Students Longitudinal Study and found that 47% of the students who entered college in a STEM field had changed their major out of STEM sometime during the six-year study. In recent decades a great deal of attention has been paid to STEM education with various attempts at reform including transitions from teacher- to student-centered learning, curriculum restructuring, implementation of first-year experience courses, and more, yet students still leave (Kezar, Gehrke, & Elrod, 2015). The reasons students change their majors vary; some potential causes for STEM attrition as well as barriers to student success in STEM majors are discussed below.

As with any other major, students tend to opt into STEM majors with specific goals in mind: medical school, research, a professorship, engineering work, or some other STEM-related profession (Schoon, 2001). They were likely prepared academically in their secondary education to be able to handle the requirements of their preferred majors, taking more advanced levels of math and science courses than their peers. Math courses in particular serve as gatekeepers to college education, so a strong math background in secondary school that allows students to pass through the college-level gateway math courses will increase chances of overall success in college. The importance of secondary math achievement has been described as a "critical filter" (Sells, 1973). As discussed in the previous section, math ability can actually influence students' choice in major; Arcidiacono (2003) conducted a study of math achievement and major choice and found that students' math ability was directly correlated with choosing particular majors. Students who fall in a higher range of math ability and have greater math preparation are more likely to be initially interested in and then ultimately pursue a major in a STEM field (Astin & Astin, 1992). Beyond initial major selection, math ability can affect persistence in the major as well; students with greater math preparation are more likely to persist in their initial major choice than their peers. For example, Leuwerke, Robbins, Sawyer, and Hovland (2004) found that ACT Math scores of incoming engineering students predicted whether or not they persisted in their major. Astin and Astin (1992) encountered similar results when comparing SAT Math scores to STEM major persistence. Shapka, Domene, and Keating (2006) found that the critical filter of math achievement affects career choice and goal persistence as well. Their longitudinal study followed the trajectory of 218 students from grade nine to three years after high school, finding that secondary math achievement correlated with long-term career aspirations. Students who performed well in grade nine math chose to pursue more prestigious careers and were more likely to persist in that goal, while those who performed poorly aspired to careers of lower prestige and were less likely to continue their math education at the higher education level any further than necessary.

Although academic background can impact STEM major choice and correlate with persistence, it may or may not have any bearing on the experiences students encounter once they enroll in their first college-level math and science courses. In recent decades education proponents have been making an effort to provide as many programs and as much support as possible, particularly in the K-12 grade levels, to encourage students to pursue math and science (Wieman, 2012). However, once those students begin college-level math and science coursework, they could be faced with greater obstacles than they are prepared for. Gateway courses tend to have an inflated level of difficulty and are typically not taught in an engaging way (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012), so regardless of initial interest or preparation, students may find themselves losing interest in the subject or performing more poorly than expected. On the topic of math pedagogy, Pinker (2009) wrote that “mastery of mathematics is deeply satisfying, but it is a reward for hard work that is not itself always pleasurable” (p. 342). To spark more interest in STEM fields, gateway coursework would ideally need to be perceived as approachable. Rigden and Tobias (1991) wrote that introductory science should be accessible enough that it could serve as an advertisement for the discipline. As is, STEM coursework is viewed with dread by many college students who struggle through the required core introductory courses. Berland (2013) wrote that a curriculum must be developed that contextualizes student application of math and science content, influencing learners’ engagement with and attitude towards the subject. Pinker (2005) made an argument that these basic introductory courses do not do the field justice and that a better approach would be focusing on content as opposed to the discipline itself. Rather than just studying the biological fact of evolution, for example, students could study the evolution and development of human social structures, psychological and behavioral norms, morality, etc. When students learn based on a narrative, or “matrix,” weaving together the science facts along with the discussion of specific problems and various perspectives, the learning process is not only easier, but perhaps more enjoyable. Marder (2013) wrote that “we have to approach STEM more as an opportunity than a threat” (p. 150) and encourage new practices to decrease students' anxiety in their attitude towards STEM subjects.

Student experiences in the courses, positive or negative, contribute to their understanding of their own preferences regarding majors, and the grades they receive serve as feedback about their academic ability in that major (Arcidiacono, 2003). Poor academic performance in gateway math and science coursework may therefore lead to a reevaluation of major and career choice and ultimately result in the students leaving the STEM field.

Student Demographics in STEM Majors

In regard to STEM fields, much of the existing literature on math and science gateway courses and STEM majors has primarily focused on gender and ethnicity differences, which are certainly important topics of concern (Maple & Stage, 1991; Oakes, 1990; Riegle-Crumb & King, 2010). According to the National Science Foundation (2013), in the last decade, the number of bachelor's degrees in STEM fields awarded to underrepresented minorities has hovered around 12% in the fields of the physical sciences, engineering, and mathematics, and 14% in the field of the biological sciences. Consequently, minorities are underrepresented in the workforce as well, making up only about 13% of workers in STEM fields in 2010 (National Science Foundation, 2013). In terms of gender representation, the number of women pursuing STEM majors has been increasing, but still lags behind the number of men (Adebayo, 2008). Women who do graduate in a STEM field are underrepresented in the STEM workforce, making up approximately 37% of employed individuals (National Science Board, 2014). At this point in modern society there is a general need for more workers in STEM fields and not enough graduates to keep up (National Science Board, 2014), so it is critical to understand how students from varying backgrounds can be retained in STEM majors.

The relationship of student demographics to academic success in college can often be traced back as far as childhood (Blackhurst & Auger, 2008). Demographic differences can be found in academic performance and experiences in K-12 grades, which can impact the choices students make when thinking about majors and careers (Gainen, 1995). The result is different ethnicity and gender groups filtering into certain expected majors when they enter higher education. This may be especially true for the large number of first-generation students enrolling in college (Pascarella, Pierson, Wolniak, & Terenzini, 2004). As the first in their families to pursue higher education, their expectations and decisions upon entering college may be much different than students who had support and guidance from parents who completed a bachelor's degree (Nunez, Cuccaro-Alamin, & Carroll, 1998).

Once students are actually in college, their demographic background can have an effect on their academic performance and persistence (Adelman, 1999). Carlone and Johnson (2007) noted that "undergraduate science majors often must negotiate a culture characterized by white, masculine values and behavioral norms" (p. 1187) in which it can be more difficult for white women and students of color to thrive than their white male peers. Success in college does not necessarily rely completely on academic ability; students must be able to take on the role of "college student" and all it entails to successfully navigate the system (Collier & Morgan, 2008). They should be able to have rapport with their peers, understand their instructors' expectations, and generally assimilate into the college environment. Students unable to do this may struggle academically. In the math and science classroom climate, women and minority students may feel uncomfortable and out of place in courses filled with white males. In some cases it may just be perceived, but studies show there could actually be subtle but observable factors leading to exclusion. For example, Gainen (1995) found that men spoke longer than women in classroom discussion, and that professors had lower expectations for minority students. Gateway math and science courses designed to weed out lower-performing students create a competitive ethos that can be detrimental to women and minority students (Seymour & Hewitt, 1997). First-generation students, a large percentage of whom are members of underrepresented groups, can also face unique challenges in the higher education environment (Dika & D'Amico, 2015). Although background characteristics can account for disparity in STEM major persistence (Chang, Sharkness, Hurtado, & Newman, 2014), the above dissimilarities in classroom experience do not necessarily correlate to academic background or preparation; women and minority students who have secondary school grades and standardized test scores on par with their white male counterparts have reported feelings of anxiety and a lack of recognition by peers and faculty (Carlone & Johnson, 2007).

Self-efficacy in math and science may play a part in gender underrepresentation in STEM fields. Boli et al. (1985) conducted a study exploring the relationship between gender and math and science course performance. The resulting connection was weak, but there were strong indications that women perceived the courses as more difficult. Studies have found that gender differences in mathematics self-efficacy manifest at the elementary level and remain fairly consistent through secondary school, but tend to widen during the college years (Sax, 2008; Wigfield et al., 1997). Women have been shown to exhibit lower self-efficacy in math in comparison to same-ability male peers, ranking themselves lower in mathematical ability (Sax, 2008; Watt, 2006). Even those who do express interest in pursuing STEM majors and careers are at risk of abandoning those aspirations, despite their ability and interest. Frome, Alfeld, Eccles, and Barber (2006) analyzed data from a longitudinal study of a group of young women initially interested in STEM careers, tracking them from age 18 to 25. They found that perceived gender-based societal pressures such as the expectation of women to devote more time to home and family life and the view that women do not have a place in certain STEM fields ultimately wore down the women's aspirations towards working in male-dominated fields. The authors acknowledged the presence and impact of the women's movement and the increasing efforts of society to involve women in STEM, but that many of the women in this study were apparently unaffected by those efforts, or at least became less moved by them as they progressed from teenagers to young adults. Stereotypical gender roles can come into play even among those with initially high confidence levels (Shapiro & Williams, 2012). Of the female students who do persist in their STEM majors and have high levels of self-efficacy in their math and science ability, many could still have doubts about themselves in comparison to their male counterparts.

Stereotyping may also have an impact on minority students pursuing STEM majors (Baber, Pifer, Colbeck, & Furman, 2010). As with all students, a combination of factors influences dropout decisions among minority students. For example, studies on

African American and Hispanic students have shown that math and science competence at the secondary level, family and instructor support, personal motivation and ambition, the culture and learning environment of college, and other typical issues all directly impact STEM success and retention (Cole & Espinoza, 2008; Russell & Atwater, 2005; Torres & Solberg, 2001). However, as with female students, there are often additional issues present for minority students attempting to navigate the STEM education pipeline. The threat of stereotyping, whether real or perceived, can negatively affect academic performance and the self-efficacy of minority students (Chang, Eagan, Lin, & Hurtado, 2009). Established cultural environments and attitudes can be intimidating to them, leading them to perceive themselves in a position in which they must compete with their white male classmates for a place in their major programs (Wilson & Kittleson, 2013).

Though most demographic studies on STEM education focus on gender and ethnicity, a third demographic area worth exploring is age. There is little research on the relationship between student age and persistence; most studies specifically target "traditional aged" students, aged 17 to 24 (Donaldson & Townsend, 2007; Metzner & Bean, 1987). However, it is a worthwhile demographic to pursue; in the recent history of higher education, changes in the student body through the 20th century saw not just an increase in women and minority students, but older students as well (Bogue & Aper, 2000). Dey and Hurtado (2005) observed that around the turn of the 21st century, students over the age of 25 represented about 44% of all college students. These older students have different characteristics from traditional-age students, such as working full-time, attending school part-time, and consisting largely of women and minorities, and therefore have their own needs and expectations of higher education (Bogue & Aper, 2000). They may be more mature and have greater dedication to their coursework. Grosset (1991) found that students aged 25 and older had higher levels of self-efficacy in regard to their academic preparedness and ability, which in turn correlated to greater persistence rates. A more fully-developed self-concept and other internal factors give adult learners stronger motivations to succeed than traditional college students (Sachs, 2001). However, math is one area in which confidence is lessened; older learners actually fall behind younger students in math self-efficacy, partly due to academic inexperience in math. In a study of math beliefs of adult learners, Jameson and Fusco (2014) found an inverse relationship between the time since the last math course taken and math self-efficacy. Additionally, due to other responsibilities and pursuits in their lives, older students may not have as much time to devote to school as their younger counterparts (Deutsch & Schmertz, 2011; Ritt, 2008). This may be particularly true for women; while men who enter higher education at an older age typically cite personal motivation as their primary impetus, women often cite situational factors such as divorce or their children reaching school age, and tend to be providing for their families and working while attending school (Hostetler, Sweet, & Moen, 2007).

Persistence Theories

There are many theories in the literature regarding student persistence. Some prevalent themes are discussed below, with an emphasis on research in math and science persistence.

Students make their initial major decisions based on their long-term goals for the future (Arcidiacono, 2003). With a specific career in mind, students can choose the major most appropriate for preparing for that career. In their first and second year of enrollment, students will have the opportunity to reflect on their choice and determine whether or not it is in fact what they want to do. Stinebrickner and Stinebrickner (2012) wrote that once students enter their first year of college, they learn more about their own academic ability and reevaluate their interests in their chosen major and career; these changes in beliefs may result in dropout. This reflection will be based partly on the initial courses they take in the subject of their major; their experiences in those courses will affect the likelihood of continuing in the major. Students may discover a change in interests: having experienced the subject first-hand, they find that it was not what they expected. Research has shown that choosing a major congruent with a student's interests and skills can be a predictor of persistence in that major (Allen & Robbins, 2008). Students who end up in a major that does not align with their interests and skills will be less likely to continue. Tracey and Robbins (2006) examined longitudinal data on a large number of students and found a correlation between student/major compatibility and persistence at the university. In a similar study of nearly 50,000 students across 25 four-year institutions, Allen and Robbins (2008) determined that student/major compatibility was a predictor of whether or not a student would persist in his or her entering major. Students who are a good fit for their preferred major are therefore more likely to persist both in that major and generally in their pursuit of a degree. If students choose an initial major that ends up not being a good fit, attempting to remain in that major could lead to failure and dropout. Upon discovering incompatibility with a certain major, students reevaluate their goals and interests and seek out other majors that appeal to them. Student determination of whether or not they are a good fit for their chosen major can be based on a number of factors, such as academic performance, classroom environment, and academic self-efficacy.

In research on academic performance, student interest and compatibility with a major has been linked to first-year grades. In their freshman year, students discover their level of academic aptitude in their chosen subject (Arcidiacono, 2003). If students earn consistently high grades in their first few major courses, their determination of staying in that major will be strengthened. On the other hand, if they earn poor grades in their first major courses, they may begin to doubt their chances of success in the major. Their original interest in the subject might also be affected: students who do not succeed in their preferred major may lose interest in it. As interest in the subject matter is one of the more salient reasons for choosing and changing majors (Malgwi, Howe, & Burnaby, 2005), students who lose interest due to poor performance may seek out a new major that is a better match for their level of academic aptitude. As discussed in a previous section, first-year GPA is strongly correlated with persistence.

Other factors are of course at work in students' decisions to remain or withdraw, which may have influence on students even when their grades are low. One such predictor is the classroom environment; it is determined by several factors, but notably student engagement in the course and teaching and learning strategies. Students' interest in and preparation for STEM majors remain untapped potential if they are not in an environment that nurtures learning and development (Eagan, Garcia, Hurtado, & Gasiewski, 2012). Student engagement has been extensively researched. Wolf-Wendel, Ward, and Kinzie (2009) define it as a two-way relationship. On one side, students put forth a certain amount of effort into their academic and extracurricular lives that makes up their experiences in college, leading to varying levels of success depending on the effort put in. On the other side, the institution takes the responsibility of providing resources to promote and support student learning, encouraging students to take advantage of educationally purposeful activities and to benefit from them. Student learning is ultimately influenced by this engagement relationship (Coates, 2010). Tinto (1997) stressed the importance of student involvement in the first year to student persistence and retention: when students feel academically and socially integrated, they are more likely to persist. In more recent research as well, engagement has proven to be related to student retention, such as in a study by Hughes and Pace (2003). They examined freshman data from the National Survey of Student Engagement (NSSE) and found that the level of engagement was always lower for those students who withdrew from college. In a similar study, Kuh et al. (2008) analyzed NSSE data and found that engagement has a positive effect not just on persistence, but GPA as well. Schnell and Doetkott (2003) noted that “while many factors impact student retention, it is recognized that by actively engaging and supporting students upon entry we encourage them to strive for success” (p. 387). Tobias (1990) applied the theory to STEM fields, suggesting that lack of student engagement efforts on the part of faculty are a primary cause for poor performance in introductory coursework and consequently STEM major attrition. The review of gateway math and science coursework covered previously provides insight into the classroom environment of those courses. They are competitive in nature and serve as weed-out courses, which can have a negative impact on student persistence.

The classroom environment is facilitated by the faculty, who have a critical role not just in learning but in student persistence. Students sometimes shift the responsibility of their poor academic performance from themselves to the instructor, attributing their low grades and dissatisfaction to “bad teaching” (Gainen, 1995). Although those claims are subjective, students’ perception of faculty performance influences their engagement in and opinion of the course (Coates, 2010). With the knowledge of how their pedagogical practices can affect student learning, faculty could make an effort to focus on making a difference in their students’ experiences and outcomes (Umbach & Wawrzynski, 2005). There exist a multitude of pedagogical practices designed to increase student engagement and improve academic performance, but it is beyond the scope of this study to review them all. However, it should be noted that in regard to STEM fields, active learning is consistently found to be useful (Barrows, 1996; Bybee et al., 2006; Lord & Orkwiszewski, 2006; Zull, 2011). Popularized in the 1990s by Bonwell and Eison (1991), active learning shifts the focus from teacher to learner, giving a more active and responsible role to the student. Active learning is not a specifically prescribed method of approaching teaching and can in practice be implemented in a variety of ways, but the essential guiding principle is that students learn better and experience more long-term success when they have an active role in the learning process as opposed to passively listening to an instructor (Braxton, Milem, & Sullivan, 2000). A study conducted by Umbach and Wawrzynski (2005) discovered a positive relationship between student gains and faculty who use collaborative learning techniques and have high levels of interaction with students. Johnson, Spalding, Paden, and Ziffren (1989) wrote that “active inquiry, not passive absorption, is what engages students. It should pervade the curriculum" (p. 68). Math and science courses are not conducive to a lecture-only format. In a science classroom, a straightforward presentation might convey information from the instructor to the learners' minds, but research has shown that information received this way is not always retained (Haskell, 2001; Roediger & Karpicke, 2006; Zull, 2011). In typical introductory courses, students are meant to listen passively; when procedures are practiced, they lack the level of strenuousness and cognitive activity that are so important to learning (Wieman, 2012). To ensure knowledge retention and understanding, the information must be more actively processed in some way by the learner (Mastascusa, Snyder, & Hoyt, 2011). The areas of math and science deal with complex concepts that would benefit from a hands-on approach. However, despite being one of the most student-passive methods of teaching, many educators continue to use the lecture format (Bonwell & Eison, 1991). This may be due in part to the lack of formal pedagogical training among faculty; the coursework they took in preparation for their career in academia focused on their field of study rather than teaching that field to others (Baldwin, 2009). In STEM education particularly there is some evidence that math and science courses are generally taught differently from liberal arts and other courses at the university, taking a more authoritarian approach and discouraging student participation (Gasiewski et al., 2012). The failure of STEM instructors to maximize participation and encourage active learning techniques, particularly in gateway courses, may negatively affect student learning (Brint, Cantwell, & Saxena, 2012). Without an adequate foundation on which to base future learning, students may never fully grasp the complex and rigorous concepts in their field; success in one state of the learning process is typically required for success in the next stage (Schunk, 2012). This may be particularly true in STEM majors: while students in some fields expand their knowledge by studying a breadth of content that does not rely on previously-learned material, STEM majors are often unable to progress in their programs until they have mastered material in previous coursework. For example, Pinker (2009) observed that “mathematics is ruthlessly cumulative” (p. 341), with students in college-level calculus courses unable to comprehend the material without a solid grasp of algebraic operations. With such an emphasis placed on success in early coursework, implementation of active learning methodologies may have an effect on persistence (Braxton, Jones, Hirschy, & Hartley, 2008). Both a poor introductory academic experience in math and science and the anticipation of subsequent difficulties in future coursework may result in students becoming discouraged enough to leave their STEM major. Whatever the pedagogical environment of first-year math and science coursework may be, students will ultimately relate it positively or negatively to their interest and persistence in their major (Watkins & Mazur, 2013).

Another key issue, particularly in regard to STEM education, is self-efficacy. Perceived academic control can have a significant effect on academic achievement and persistence (Stupnisky et al., 2008). Elias and Loomis (2000) explored the relationship between self-efficacy, GPA, and major changes, finding that self-efficacy correlates positively with GPA and negatively with major changes. This means that students with high levels of self-efficacy earn higher grades and are more likely to persist in their majors, while students with low levels of self-efficacy earn lower grades and are more likely to change their major. There is extensive additional research on the relationships between academic self-efficacy, major choice, and academic success; self-efficacy is theorized to strongly influence students' decisions regarding their career and major (Porter & Umbach, 2006). Its importance to STEM education then is that self-efficacy specifically in math and science can influence students' choice to major in STEM fields (Scott & Mallinckrodt, 2005). When first enrolling in college, perceived self-efficacy expectations in math and science performance significantly correlate to choosing a major in a STEM field (Betz & Hackett, 1983; Scott & Mallinckrodt, 2005).

Upon transitioning to college, students may experience negative thoughts about themselves, such as their sense of belonging and ability. When attempting to adjust to a new environment, students may have doubts about fitting in and integrating into the college experience. Their lack of a feeling of belonging serves to cause further retreat from positively engaging higher education (Tough, 2014). Some students may also have doubts about their ability, believing that their intelligence is a fixed quality that cannot be improved, what Dweck (1999) called an entity theory of intelligence. These students perceive failure as a natural lack of intelligence. This leads to a feeling of helplessness that may cause students to give up more easily or avoid challenging situations altogether.

It should be noted that the research emphasizes the correlation of high levels of self-efficacy, engagement, and other theories with not just persistence, but academic performance as well. In other words, even when the focus of the research is on some other issue, academic performance still has a connection with persistence; they typically go hand-in-hand. For example, research on self-efficacy in STEM majors focuses on the relationship between high self-efficacy with high math and science grades and persistence, and low self-efficacy with low grades and dropout. The literature does not cover the cases in which there are discrepancies, because the emphasis is on positive correlations. It would be interesting to explore what happens when academic performance does not go hand-in-hand with persistence; i.e. students earn low grades in math and science courses yet persist in their math or science major. With grades not acting as a determiner of persistence, other characteristics such as self-efficacy have greater prominence.

Concluding Thoughts

A review of the literature finds plenty of research on general college persistence, including academic performance and other factors in the freshman year that are linked to student retention. Additionally, with the increasing need to expand the STEM workforce, a large number of studies specifically address the persistence of STEM majors. However, most of these take a somewhat broad approach: they may look at general academic performance, precollege characteristics, or attitudes towards math and science, for example. Little research takes the very narrow approach of examining the impact of individual courses. There is a gap in the literature regarding experiences in early math and science gateway courses as a predictor of persisting in a STEM major, particularly in regard to students with poor academic performance. It is well established that secondary math and science preparation is a strong predictor of success at the college level (Gainen, 1995; Kokkelenberg & Sinha, 2010; Singh, 2009; Waits & Demana, 1988), but there is much less research on what happens after students begin college and take their first college-level math and science courses. When students earn low grades in their gateway math and science coursework, yet persist in their major not just to the sophomore year but all the way to graduation, what factors other than academic performance are present to lead them to make those decisions?

American culture is increasingly relying on STEM fields, becoming dependent on the prevalence of technology in our daily lives (Zull, 2011). STEM education has of late been in the public eye, but despite increasing demand for college graduates skilled in math and science, fewer students are opting into those majors (Astin & Astin, 1992). Of the ones who do begin a STEM degree, many change their majors before graduation. This study will not be concerned with the reasons students initially choose to pursue STEM majors; the purpose is only to observe their academic experiences after they have made that decision.

CHAPTER 3

METHODOLOGY

This study utilized a qualitative approach to address the following research question:

1. What experiences, motivations, or attributes influence students majoring in math or science to persist to graduation after earning low grades in gateway math and science coursework?

It is possible other institutions employ teaching practices, student support programs, or other initiatives targeted at math and science gateway coursework to improve the success and retention of students majoring in math and science. However, this university is relatively representative of large public four-year universities that rely on traditional methods of approaching math and science coursework with no special attention to their effect on persistence. This study can easily be replicated at other such institutions.

Sample Selection

The population of the study was undergraduate math and science students enrolled in their graduating semester at a large public four-year university in the south. Specifically, it consisted of students graduating in December 2015 with a bachelor's degree in biology, chemistry, geology, mathematics, or physics. This information was retrieved from the university's student database. The students in the target population were sent a recruitment e-mail with an invitation to participate in the study (see Appendix B). The e-mail described the study procedures and goals as well as the participant selection parameters in the following section. It was made clear that participation was voluntary and that a $10 gift card would be given as compensation. The e-mail directed students to contact the researcher if they were interested in participating in the study. When potential participants responded, their consent was obtained to view their transcripts, at which time their eligibility to participate could be confirmed. Because academic performance in the freshman year is a key part of the study, students' transcripts needed to be reviewed to calculate their first-year math and science GPA and determine if they met the required parameters for participation. The university's Office of Records and Registration gave authorization to review the academic transcripts of participating subjects for this purpose, so long as the subjects' consent was obtained. Once each student was deemed eligible, a meeting time and date was scheduled for the interview, which took place in my office on the university campus. At their interview, students were given a copy of the signed consent form (see Appendix C).

Before the sample selection began it was hoped that the resulting group would be a diverse assortment of students both to represent the makeup of the larger population and to provide breadth of input for data collection. A useful group would consist of students representing a blend of majors as well as various demographic attributes (gender, ethnicity, and even age), although it was not expected that every one of these possibilities would be present. However, a certain amount of diversity was needed. In regard to major, although a great number of the required first-year math and science courses overlap between the various math and science majors, each major places emphasis on the successful completion of different sets of specific courses during the freshman year. Students in different majors may therefore take different first-year courses, leading to potentially varying experiences based on the content and quality of coursework in those subjects (calculus versus chemistry, etc.). With more majors represented, there would be a broader spectrum of gateway courses discussed. In the overall population, the biology major contained the greatest percentage of students, followed by math, with a small percentage of students in chemistry, geology, and physics majors. It was anticipated that most of the 10 participants would be biology and math majors, but at least one or two students in the smaller majors should be included. In regard to demographics, the literature review chapter covers at length the reasons that demographics should be a key feature to examine in any study of STEM major persistence. The research has demonstrated important differences in the experiences of students of different genders and ethnicities. Age has been studied to a much lesser extent but would still be a worthwhile point of interest to consider. Differing results between various demographic characteristics may mean that those characteristics contribute to students' perceptions of their experiences as well as their academic motivations and willingness to persist in their major. Demographic diversity in the interview group is therefore important for obtaining feedback from the perspective of a variety of student backgrounds and experiences. With the demographic makeup of the overall population, it was assured that both genders would be represented, and there would be at least a few ethnic groups as well. Compared to other academic fields at the university, math and science have a high percentage of traditional-aged students, but ideally at least one older student would be included.

The intent was to use the first 10 eligible students who volunteered, and given the population's diversity, it was statistically likely that they would not be overly homogeneous. However, there was a small possibility that the first 10 volunteers would have too many factors in common; for example, the group could have primarily consisted of white males in the same age group and major. The study could have proceeded with an interview group based on that sample, but as just described, I believe it would not have been as fruitful as a more diverse sample. Therefore, in the event that occurred, I would go beyond the first 10 students until I had a reasonable mix of students. “A reasonable mix” is difficult to define, but at minimum I would have liked at least three of the five majors, both males and females, three or four ethnicity groups, and one or two non-traditional aged students represented. As a final aspect of the selection process, it was of critical importance that the participants provide meaningful data; those without much to say would not provide a significant contribution. To that end, after 10 students were selected to participate, an additional few would be selected as alternates. If during the interview process any of the initial 10 participants provided too little feedback, the alternates would be enlisted to either replace them or supplement the initial group.

Participant Eligibility

To participate in the study, interested students needed to meet the following subject criteria:

1. Declared in a major in biology, chemistry, geology, mathematics, or physics upon first entering college;
2. Completed coursework in both the fall and spring semesters of the freshman year, including at least one college-level math or science course each;

3. Earned a grade point average under 2.0 in the math and science courses taken the freshman year; and
4. Graduating in December 2015 with a degree in biology, chemistry, geology, mathematics, or physics.

These criteria guided the final selection of participants to ensure they met the conditions of the study. First, because the focus of this study is persistence in math and science majors from start to finish, students must have been initially declared in a math or science major as of the census date in their first semester of enrollment. At this university, the relevant majors are those in the departments of biology, chemistry, geology, mathematics, and physics. Undeclared students and those initially declared in a major from any other subject were excluded. Some of those students may have chosen to change their major to math or science very soon after starting school, but they were still excluded because the type of student under examination here was one who entered college already knowing he or she wanted to go into a math or science field.

Second, students must have enrolled in both the fall and spring of their freshman year and have taken at least one math or science course each semester. The university officially defines a freshman as a student with between 0 and 29 credit hours. However, many students participate in college preparatory programs in their high schools and may bring in credit earned through Advanced Placement exams or other means, getting them to the 30-credit hour mark early. For the purpose of this study, a freshman was defined as a student enrolled in his or her first year of college after graduating from high school; i.e. it was their first exposure to college-level math and science coursework. The criterion that they must have taken at least one math or science course each semester maximized their exposure to gateway math and science coursework, giving the students a full academic year to reflect on their chosen major and career path. Students who only took one math or science course had less experience on which to base an informed decision about their persistence in their major, so they were excluded.

Third, students must have had a low math and science GPA in the freshman year, reflecting low grades earned in their early coursework. This university requires a minimum GPA of 2.0 on a 4-point scale (a C average) to be considered in good academic standing. Poor academic performance in math and science coursework was therefore defined as a GPA of less than 2.0. The math and science GPA was calculated from all math and science coursework taken in the first full year of college: fall, spring, and summer. At this university, courses are evaluated using letter grades with the following grade point values: A = 4, B = 3, C = 2, D = 1, and F = 0. The equation used to calculate GPA is

$$\text{GPA} = \frac{\sum_{i=1}^{N} a_i b_i}{\sum_{i=1}^{N} b_i}$$

where *a* is the grade point value of a course, *b* is the number of credit hours in the course, and *N* is the number of courses included in the calculation. The GPA was calculated from all coursework with the catalog course number prefixes *BIOL*, *CHEM*, *GEOL*, *MATH*, and *PHYS*. The resulting values were numbers with a range from 0.0 to 4.0, which were rounded to the nearest thousandth. To be eligible, the students needed a first-year math and science GPA value between 0.0 and 1.999. Although there are plenty of students with GPAs above 2.0 who have failed one or more math and science courses, in order to have that higher GPA they would have had to balance the failing grades with higher grades. For the purpose of this study, I was more interested in students who consistently earned low grades in math and science during their first year of college.

Fourth, because the purpose of the study is to examine students who persisted to graduation, they must have still been declared in their math or science major and been in their graduating semester. It would have been acceptable for them to have switched specific degree plans and specializations; it is anticipated that students will refine their specific academic interests as they progress through their programs and change their plans accordingly. Because the focus is persistence in STEM, so long as they remained in their major subject, they were considered retained. At the time that the interviews took place, the current semester was fall 2015, which meant that eligible students would be graduating in December 2015. Students who had already graduated would not be used for practical reasons; having left the university, they would be more difficult to contact and perhaps not as able or inclined to schedule an on-campus interview. Additionally, they would have already moved on to other activities in their lives and the experiences of college may have been more difficult to recollect, especially as far back as the freshman year, which is critical to this study. Conversely, students still active at the university would be easier to contact and with more recent experiences they would likely have a greater quantity and accuracy of feedback to provide. Although they had not graduated yet, it could be verified that they would: when reviewing their academic record to determine eligibility, it could be confirmed that they were in good standing, were enrolled in the final required coursework on their degree plan, and would graduate so long as they successfully passed their fall courses. It should be noted that not all of the participants necessarily began college at the same time; it is quite common at this university, especially among math and science majors, for students to take longer than four years to complete a bachelor's degree. However, because the emphasis of the study is on the experiences of the freshman year in relation to students' persistence to graduation, rather than length of time to graduation, the number of intervening years is irrelevant in this context.

Participants

Information about the 10 participants is given in Table 1 on the next page, including their name, major, first-year mathematics and science GPA, demographic data, parents' level of college education, age at the start of their degree, and their timeframe to graduation.

As hoped, the first 10 volunteers represented a reasonable mix of students and gave informative, meaningful feedback, so no additional students were needed. The names provided in Table 1 and used hereafter are the pseudonyms assigned to each participant. In terms of major distribution, although mathematics was one of the largest groups in the overall population, a somewhat disproportionally large number of math majors were represented here. However, given that half of the participants were still science majors, and that four out of five possible majors were present, it was still a good assortment. The only missing major was geology, but geology was a very small group in the overall population, so this was unsurprising. Each participant's GPA was calculated from all the math and science coursework he or she took the freshman year (fall, spring, and in some cases summer).

Table 1

Interview Participants

Student	Major	GPA	Gender	Ethnicity	Parent Ed.	Age	Graduation
Cassie	Mathematics	1.750	Female	Hispanic	None	18	5.5 years
Charlotte	Biology	1.737	Female	Asian	Degree	18	4.5 years
Dean	Mathematics	1.000	Male	White	Some	18	5.5 years
Gabriel	Chemistry	0.800	Male	White	None	18	6 years
Kevin	Mathematics	1.667	Male	Black	Some	18	5.5 years
Mark	Biology	1.810	Male	Hispanic	None	18	4.5 years
Megan	Biology	1.667	Female	White	Some	20	6 years
Rebecca	Mathematics	1.857	Female	White	Degree	18	5.5 years
Robert	Physics	1.500	Male	Hispanic	None	18	5.5 years
Samuel	Mathematics	1.500	Male	White	Degree	36	5 years

The breakdown of demographics was fairly representative of the overall population: slightly more males than females, with White students making up the largest ethnicity group, followed by Hispanic students. The parents' college education is given as "None" if neither parent had any college coursework, "Some" if at least one parent completed any amount of college coursework, and "Degree" if at least one parent completed a bachelor's degree. I was initially surprised that only three of the participants had parents with degrees, but that fact actually ended up coming into play in the findings (discussed in the next chapter). There was one older student; the remaining nine were traditional-aged students, although one did have a short hiatus between high school and college. None of the participants graduated in the four-year timeframe traditionally expected for a bachelor's degree, but all 10 completed their degrees within six years, which is a current standard benchmark for measuring graduation rates (Kena et al., 2015).

Data Collection

The research question addresses issues such as student motivation, background, and self-efficacy. When examining human personalities, attitudes, and behaviors, direct interaction with subjects is advantageous; a qualitative approach was therefore taken to explore the research question. As a result, the data collected in the study was a product of insight from the students themselves; information that cannot be gleaned from numbers on a page. A total of 10 students were interviewed to discuss their experiences in the courses in which they earned low grades and the reasons they chose to persist in their major all the way to graduation. The end result of the study is intended to contribute to the understanding of the factors that influence persistence in math and science majors.

Each participant was interviewed individually, face-to-face. Notes were taken during the interviews and each interview was audio recorded and transcribed afterwards. Measures were taken to ensure participants' confidentiality. The audio recordings and transcripts were digital and stored on a password-protected computer. Signed consent forms and any written identification were kept in a locked drawer. Participants were assigned pseudonyms.

During the interviews, each participant was asked nine scripted questions (see the interview script in Appendix A). Thematically, the first eight questions were made up of four pairs of related questions. The first pair covered the meaning of their degree, asking them to identify the reasons they chose their specific major and what it meant to them personally to complete a degree in STEM. The next pair had to do with expectations versus reality: they were to reflect back on their time immediately prior to beginning college, describing any expectations they may have had going into their gateway math and science coursework, followed by how their actual experiences in their first year met or contradicted those expectations. That led into a pair of questions concerning the low grades the participants earned, asking them to identify what they attributed the grades to and how they were impacted by them. The last pair had them discuss their feelings about their major after having experienced their first year and share the factors contributing to their decision to stay in their major. The final question, rather than asking about their own experiences, asked participants to give advice to a hypothetical incoming freshman about to undertake the gateway math and science courses of a STEM major.

As participants were being interviewed, occasional probing questions were inserted to prompt them with direction for elaboration as necessary. The interviews were semi-structured and were therefore expected to be discursive and open-ended. Each interview included the nine pre-selected questions in order to guarantee that certain topics relevant to the study would be addressed, but the students being interviewed had the freedom to elaborate on an idea or go off-topic when responding. If the participants wandered too far away from the topic, they would be guided back to the pertinent issue being discussed. Leading questions were avoided in order to prevent influence on participants' answers, although exploratory questions not originally planned in the interview script were occasionally introduced in order to elicit more in-depth and informative responses.

Data Analysis

Once all the data were collected the analysis stage could begin. The qualitative approach utilized in this study consisted of thematic analysis. The 10 interviews were audio recorded and transcribed for review. Notes were taken during the interviews to supplement the transcriptions. When reviewing the transcriptions, relevant themes and patterns were sought regarding students' experiences in their gateway coursework, their feelings towards their chosen subject and major, their beliefs about their academic proficiency and ability to succeed, their internal and external motivations for continuing in their major, and other prominent characteristics they attributed to their persistence.

As a starting point, Wang's theoretical framework of the factors influencing STEM major choice was used as a guide to search for themes, with the individual components of the framework serving as a foundation on which to begin an analysis. Based on the interview questions and what I expected the students would want to discuss, I believed several of the framework components would manifest in the resulting data. I anticipated that self-efficacy would be particularly prominent as students discussed their academic performance and their motivations for continuing. Postsecondary contextual supports and barriers should be in evidence as they reflected on the teaching and learning environment of their first-year math and science coursework. Interests and goals would certainly come into play because some interview questions directly asked them to comment on their decision to initially choose and then to persist in their majors. College readiness seemed likely to factor into their responses to the interview questions regarding expectations versus reality of college math and science coursework. Similarly, I suspected that secondary learning experiences would come up indirectly as students discussed their gateway coursework, perhaps by using their secondary experiences as a reference point for comparison to their college experiences. The person inputs construct was the one I was most unsure of because I assumed participants would be less self-aware of how their personal characteristics and demographic attributes related to their persistence.

When the interview transcripts were reviewed, most of the framework components were in evidence as expected, though there were some unexpected results. During the course of the analysis some patterns were readily apparent, with certain themes appearing repeatedly across the participants' interviews in most or all of the transcriptions. Other emergent themes were discovered when comparing interviews, revealing underlying complexities shared among the participants. The goal was to identify approximately five to seven key themes for in-depth analysis. At the conclusion of the initial analysis, five themes were found, the results of which are discussed in depth in the next chapter.

Summary

The overarching purpose of the study was to determine student attributes, attitudes, and experiences that predict persistence in math and science majors. Interviews with students who persisted in their majors despite initial setbacks in their freshman year provided a means for an analysis based on insights directly from the students. The participants offered rich descriptions of their experiences, and a thematic analysis of their interview transcripts resulted in five key themes giving a comprehensive picture of the students' personal characteristics and motivations and their relationship both to their experiences in gateway math and science courses and their ability to persist in a math or science major.

CHAPTER 4

FINDINGS

In this chapter the results of the thematic analysis are presented, with ample supporting quotes from the interviews. First, some additional information is provided about the participants to supplement the data given in Table 1 in the previous chapter and provide context for the presentation of findings.

Gateway Course Grades

Table 2 lists the distribution of grades earned in all of the math and science courses taken by the participants in their freshman year, grouped by subject.

Table 2

Math and Science Grade Distribution

Subject	Course	A	B	C	D	F
Biology	Biology I	-	-	2	1	-
	Biology II	-	-	2	1	-
Chemistry	Chemistry I	-	-	4	2	3
Mathematics	College Algebra	-	2	-	-	-
	Precalculus I	-	1	-	-	1
	Precalculus II	-	1	-	-	-
	Calculus I	-	-	6	2	2
	Calculus II	-	1	1	2	-
	Calculus III	-	-	-	3	-
Physics	Physics I	-	1	2	-	1
	Physics II	-	-	1	-	-

In the previous chapter, Table 1 listed each participant's STEM GPA, which was calculated from all math and science courses taken in the freshman year. This GPA was used for determining eligibility, and it gives an important indication of the students' general first-year STEM performance. Breaking it down to list all the individual courses and grades that each student earned would not be practical; their courses will be mentioned as applicable in the findings presentation, which is a more appropriate context. However, an overall breakdown of all participants' grades is a useful visual reference in order to see in which courses the students were earning low grades; this is provided in Table 2.

At this university each science subject has two sets of introductory courses: basic-level courses for non-STEM majors and more advanced courses for STEM majors. All of the science courses taken by the participants in this study were the more rigorous STEM major versions. For math coursework, almost all of the STEM degrees require Calculus I or higher. However, some biology degrees only require lower-level math, which is the reason for the presence of College Algebra and Precalculus I and II grades. Grades of A and B are considered good, a grade of C is considered passing but low, and grades of D and F are considered failing. As seen in Table 2, no grades of A were earned in any first-year math or science courses. Four of the six grades of B were in lower-level math courses. Aside from two grades of B in Physics I and Calculus II, all of the rigorous math and science coursework required for STEM majors resulted in grades of C or lower.

When I first examined the data, I looked at the grade distribution within each major; e.g. all the math and science grades earned just by biology majors. The purpose was to determine if any specific courses had higher or lower grades when taken by students in certain majors. There is evidence in the literature that aptitude in math does not imply aptitude in science, or vice versa; many students do well in one area but fail in the other. For example, biology majors could have earned higher biology grades and lower calculus grades than math majors. However, the distribution ended up being extremely similar across the four represented majors and was not different enough to be notable. For example, Chemistry I was taken by at least one student in each of the four majors; within each major there was one failing grade and at least one grade of C in that course.

Interviews

The 10 interviews took place over the course of one week, and each interview lasted approximately one hour on average. Some of the participants were more forthcoming than others. I did not get the impression that any were hesitant to share their stories or opinions out of embarrassment; rather, they sometimes simply had trouble expressing themselves. On some occasions participants had difficulty verbalizing what they were thinking and feeling. However, they needed to be pushed to do so, because that was the intent of the study: getting the participants to express their feelings and motivations, and figure out what makes them different from their peers. Although sometimes I had to prompt the participants to elaborate or ask them probing questions to get them to open up, I avoided leading questions. For the most part I had no trouble eliciting responses, though. In fact, a few of the more loquacious participants provided an abundance of information. In those cases I allowed them to ramble a bit because it helped them to piece together their thoughts; they managed to stay on course without veering off topic.

The first eight questions on the interview script (see Appendix A) worked well, prompting the participants to reflect back on their first-year experiences and provide thorough responses that were beneficial to the study. The final interview question, however, required a slight modification. That question asked the participants what advice they would give to an incoming freshman, and its purpose was to give the participants a hypothetical scenario on which they could comment without direct reference to their personal experiences. Presumably the advice they offered would still in fact be based on their own experiences, but it was hoped that given the hypothetical context they would provide a response they might otherwise not, providing further insight into their feelings on the topic. The first of the 10 interviews was with Gabriel and his answer was not very insightful; the advice he gave was too vague. To prompt him further, the hypothetical scenario was extended: the incoming freshman has now finished his/her first year and earned low grades in math and science courses, so what advice would he give now? Gabriel then provided a more in-depth response about what characteristics he felt were needed for a student to be a successful science major, how to know whether or not the major was a good fit for the student, and more. Even though this response was not a direct description of his own experience, it was an excellent insight into his feelings on the topics of gateway coursework, academic success, and persistence, which being based on his own experiences provided an indirect look at his own first year. This follow-up question was therefore added to all the remaining participants' interviews.

Participant Summary

Following is a brief description of each participant's background, experiences, personality, etc. in order to establish a context for future references to them in the findings presentation.

Cassie had an optimistic outlook and an animated personality. She saw the positive side of every situation and even when discussing what could have been perceived as failures, she expressed no regrets or embarrassment. She had a strong desire to help others, and the experiences of her first year helped her choose her ultimate career goal of teaching secondary math. She spoke enthusiastically and expressively, giving thorough answers to all the interview questions. A key theme in her interview was overcoming her socioeconomic background.

Charlotte had a very introverted personality. She was somewhat shy in discussing her experiences, possibly stemming from embarrassment in discussing low grades, though her responses did not lack for detail. She clearly had a passion for science and worked hard to achieve her goals. However, she also shared that she suffered from bouts of anxiety and depression, which was a focal point in the discussion of her academic experiences. Her post-baccalaureate plan was to attend medical school.

Dean provided a unique view on learning in that he did not like certain traditional aspects of formal education such as homework assignments. His opinion was that if he could demonstrate he had learned, such as by passing exams, the rest was wasteful busy work. However, this was seemingly contradicted by his clear love of math and the acquisition of knowledge, as well as his desire to be an exemplar to his younger family members of the idea that hard work leads to success.

Gabriel was the participant with the lowest first-year math and science GPA, but he was also the most tenacious and, surprisingly, the least humble. His first attempt at each of the STEM courses required for his chemistry degree resulted in failing grades, yet he doggedly continued and ultimately made it to graduation. Of all the participants he appeared to be the one who struggled with content the most and therefore had the most academic hurdles to overcome; “not giving up” was the theme of his interview.

Kevin took the most coaxing to provide the level of detail necessary for a successful interview, but once he warmed up he gave some very useful responses to the questions. Much of what he said corroborated the experiences the other math majors had shared, but he also provided new anecdotes and insights of his own, particularly in regard to the learning environment of gateway math courses. Kevin was an introvert, but he cared a great deal about his academic success and intended to pursue graduate study.

Mark was the male counterpart to Cassie. He was incredibly enthusiastic about his major, his career aspirations, science in general, and what he wanted to do with his life. He was also another first-generation student who wanted to overcome his background; in his case, a small blue-collar town in which he was expected to work in the local factory. Mark held science and scientists in very high esteem and wanted very badly to join their prestigious ranks, while also pursuing a career that would allow him to help other people.

Megan was a traditional-aged student, but she took a year and a half off after high school to work before beginning college, and in the interim had a child. She was the only parent among the participants, which gave her a somewhat different perspective than the others. She has been pursuing the same goal since high school: earn a biology degree, go to medical school, and become a doctor. She was driven in personality and took a practical approach to solving problems and meeting her goals.

Rebecca was considering becoming a secondary math teacher upon completing her degree partly to help future generations lose their fear of math. Perhaps because it was something she wanted to do herself someday, she spent much of her interview talking about the teaching environments she experienced. She had one instructor in particular who epitomized the “weed-out” perspective, and her description of that class and others helped provide insight into that particular gateway course philosophy.

Robert had one of the highest academic aspirations, wanting to pursue a Ph.D. in Astrophysics, which was particularly meaningful given he was one of the first-generation participants. He was excited to be completing a physics degree and spoke about what a special achievement it was in comparison to easier majors he could have pursued; he had high expectations for himself and would have been unsatisfied with anything that lacked a challenge.

Samuel was the only older student in the group. This certainly was not his defining characteristic, but his age was admittedly relevant to certain aspects of his experiences. Another distinctive attribute of Samuel was his unequivocal passion for mathematics. Other participants spoke some about their love for their subjects, but Samuel was uniquely expressive. His interview was the longest because he had so much to say about his first-year experiences, meeting challenges, his math coursework, and math itself.

Themes Overview

The thematic analysis resulted in five themes: ambition, dedication, achievement, culture shock, and resilience. All five were abundantly evident in every participant's interview, providing a comprehensive picture of the characteristics and attributes that defined their experiences in math and science gateway coursework and their ability to overcome setbacks and persist to graduation. These commonalities of experience helped illuminate the specific defining features of each theme. In the following review, all discussion is taken directly from the interviews because the purpose of this research approach was to obtain insight from the students. However, rather than large blocks of text from the transcripts, I chose to paraphrase student responses in order to provide a narrative flow to the chapter. Great care was taken to accurately represent what was said, and at least one quotation is used in almost every reference for establishing direct context. Below is an outline of the themes and their defining features, followed by an in-depth description of each.

- Ambition
    - First-generation status
    - First-generation STEM
    - Parental influence
    - Overcoming background
    - Inspiring others
    - Unaided academic journey

- Dedication
    - Passion for subject
    - Driving motivations
    - Self-fulfillment
- Achievement
    - Prior academic achievement
    - Pursuit of prestige
    - Shock of low grades
    - Enjoying challenges
- Culture shock
    - Difficulty
    - Depth of content
    - Weed-out culture
    - Instructional style
    - Lecture format
    - Class size
- Resilience
    - Self-motivation
    - Academic responsibility
    - Self-reliance
    - Constructive reflection
    - Confidence

Ambition

All 10 of the participants were setting out to do something that nobody else in their family or their community had done before. They all were either the first person in their family to earn a bachelor's degree or at the very least the first to earn a bachelor's degree in a STEM field. At least two of them were breaking away from the status quo of the communities in which they were raised in order to pursue their dreams. Most of the participants wanted to achieve a goal that would both set an example for others and pave the way for those others to follow in their footsteps. The participants each had varying amounts of support from their families, but the primary motivation for embarking on their journeys came from within themselves. There were no specific interview questions requesting the participants to speak of these things, so it is telling that all 10 mentioned something along the lines of making their own path in life.

First-Generation Status

Of the many ways in which these students followed their own path, the most apparent is their first-generation status. Only three of the participants (Charlotte, Rebecca, and Samuel) had parents who had completed four-year bachelor's degrees. Of the remaining seven, three had parents with some college coursework and four had parents with no college coursework. Whether or not to classify all seven of these participants as first-generation students could be debated because there is currently no standard in higher education for the definition of first-generation status; each institution defines it differently depending on what is most beneficial to the institution and its students (Davis, 2010). Toutkoushian, Stollberg, and Slaton (2015) identified problematic variables such as whether one or both parents went to college; whether or not the parent completed a degree or took some courses without graduating; what type of degree the parent earned (associate's versus bachelor's); and the nature of the relationship of the parent to the child (e.g. biological, adopted, step, or other type of guardianship). All of these variations and combinations thereof result in a lack of consensus in what makes a first-generation student. In this study, the parents with some college experience did not complete an associate's degree (most completed just one to two semesters) and took general core classes with no STEM experience. For two of the participants, only the mother took coursework; for the third, both parents had some coursework. Many higher education institutions in the United States as well as organizations such as the federal TRIO program (whose mission is in part to provide assistance to first-generation students) consider first-generation students as those for whom neither parent holds a bachelor's degree (Engle & Tinto, 2008), in which case these participants would be considered first-generation. However, even if the parents' college experience is taken into consideration, it was not comparable to what their children eventually would experience as STEM majors at four-year institutions, and it is therefore still reasonable for the purposes of this study to consider the participants first-generation. It should also be noted that these students are either the eldest or only child in their families and have no older siblings who went to college before them who could impart advice.

Establishing these participants as first-generation students provides context for the personal significance of their pursuit of a bachelor's degree in a STEM field. When asked what earning a STEM degree meant to them, several responded that the most important thing was simply earning a degree, and only secondly did it matter what subject the degree was in. Dean, Gabriel, and Robert pointed out the significance of earning a bachelor's degree, attributing its importance in part to the fact that they were the first in their families to do so. Dean said that "earning a math degree implies that I'm earning a degree, period, that I've graduated from college," and that regardless of his major it would have been an achievement. He mentioned that his mother had done one semester of community college when he was a baby but had to drop out in order to care for him, and he had other older relatives who started courses but dropped out before completing them, so of all his immediate and extended family he was "the first to do the whole shebang." Gabriel believed that earning a degree would help set him apart, and that "everybody likes to feel special, or like they have a reason to stand on their own two feet when compared to someone else, and if I have a degree, that's something I can stand on." To Robert, earning a physics degree had "very powerful meaning." He said that he came from a poor, uneducated family, and that his parents were never able to go to college. Although earning a rigorous math or science degree was notable, as a first-generation student simply earning a degree would be impressive: "I just think by just finishing a college degree I'll be making not just my future better, but my kids and grandkids. I'd like to think that it will make my parents proud, too."

First-Generation STEM

For the three participants who were not first-generation students, the fact that they were pursuing STEM degrees still made them ambitious. Although students who have parents with bachelor's degrees have an advantage over first-generation students in regard to general college expectations and readiness, those parents will not necessarily be able to assist their children in their preparation for a STEM major. For example, Charlotte’s parents earned degrees in liberal arts and business fields; their only math and science coursework was designed for non-STEM majors. Even as a biology student, the lowest level math courses required for Charlotte’s degree were more advanced than the highest level math courses her parents took. With that lack of knowledge her parents were therefore personally unable to help prepare her for what was arguably the most important academic experience of her freshman year. The same was true for Rebecca; her parents’ degrees were not in math, and although they supported and encouraged her, they could not give her any specific advice in successfully navigating a math degree. Samuel mentioned a time that his father picked up one of his math notebooks: “he looked at it, and he looked at me, and said, ‘I have no idea what the hell you’re doing.’” He said that his parents fully supported him in his efforts, but that “there’s not really a way for us to communicate about math, or about the difficulties I’m having in math.”

Parental Influence

All of the participants spoke of their parents, with many expressing a desire to make them proud. Three in particular were inspired by one or both of their parents in their choice to go to college: Cassie, Dean, and Megan. Cassie was inspired to go to college partly because her parents were unable to do so; in fact, they did not even finish high school. Her parents were Mexican immigrants who came to the United States in part to give her and her siblings a better chance at life and education, and the lengths they went to in order to provide for her future meant a great deal to her. She did not necessarily feel obligated to go to college but was happy to have the opportunity to do so: “I guess what’s important about it to me is overcoming that background, and making my parents' efforts worth it, so I can go back and show them that the support they gave me meant something." She spoke a great deal about her parents and the sacrifices they made to secure her future. She wanted to make those sacrifices worth it and change her life, and in so doing make her parents proud. Dean talked at great length about his mother, who also made sacrifices for his future. She gave birth to him when she was 16, yet she continued high school and remained one of the top students in her class, and worked the whole time after she had him, forgoing higher education so that she could support her son. He said that "she gave up so much of her life for me, and I feel like I should give something to her. Not even to pay her back with money or with a degree, not that; just to make her proud." He continued on to say that as he was growing up, she would support him and push him to succeed, in a healthy rather than overbearing way, and that for her to invest so much into him and have it all be for nothing would be an incredible waste. So while he was pursuing his math degree for his own reasons, he wanted to do something for his mother as well and hoped to make her proud when he finished. Megan also found encouragement from her mother, saying "my mom is a major source of inspiration for me." However, hers is a sadder tale: Megan's mother passed away when she was still young, but she was old enough to remember her final years. Her mother did not go to college after high school, but after she had children she decided to begin a new career and enrolled at a community college. Not long after that she was diagnosed with cancer and was told she did not have much time. However, she continued taking courses, even when it got to the point that she was bed-ridden and taking them online. After she passed away and Megan grew older, her mother's determination and courage inspired her. She said that "if she could do that, then I feel like I would be letting her down if I didn't follow her example and do the best with what I have." Megan would be the first person in her family not just to become a doctor, but to earn a bachelor's degree. She believed "that's a rewarding path to take and I think it would honor my mom's memory."

The inspiration these students received from their parents was part of the original reason they chose to go to college, but perhaps more importantly, it was in their thoughts when they decided to remain in their major and not abandon their goals. Their parents did not have the opportunity to earn a college degree, but provided the means or support for their children to do so. The participants felt they could not let that go to waste. Other participants had less to say about their parents but did mention a desire to make them proud or to prove something to them. Kevin did not want to disappoint his parents by failing his courses or not completing his degree; he said that "having these low grades when they were expecting more of me, it was a bad feeling for me. I really wanted to make them proud, especially since I was doing something they hadn't done." Rebecca's parents had bachelor's degrees and expected her to follow in their footsteps, but she said it was not because they were forcing a certain lifestyle upon her but because they knew she was capable and wanted her to make the most out of her love for math. In any case, she wanted to do her best, finish, and make them proud.

One important observation to make is that none of the participants claimed to be completing their degrees directly because of their parents. They did not use language like "obligation," "repay a debt," or "had no choice." Their parents undeniably served as a source of inspiration, but the students' endeavor to continue was almost completely self-motived, which will be discussed in more detail below. When it came to their parents, it seemed more as though being able to make them proud, honor them, or prove something to them was a beneficial result of their completing their degrees, rather than the direct cause.

Overcoming Background

In addition to so many of the participants being first-generation students, another way in which they were ambitious was their longing to overcome their socioeconomic background. Cassie observed that some of her classmates had taken for granted the ability to go to college; these were students whose parents and even grandparents earned degrees, so it was expected that they would also. She believed those students "don't realize how lucky they are." Conversely, she also noted that her peers growing up took it for granted that they would not go to college. In fact, some of them considered it a waste of time; they were expected to begin working right after graduating from high school, or in many cases before. However, unlike them she did not see waste but opportunity, affirming that "education is basically like an escape from what's expected of a Hispanic woman from my neighborhood." She respected what her parents went through but did not want that life for herself or her future family. Like Cassie, a major motivation for Mark to become the first person in his family to attend college was to escape the life that was expected of him. He said that he came from a small town in which people were expected to work at the local factory or other low-paying blue collar jobs right after high school. He said that he understood the need for people in all kinds of jobs and that he meant no disrespect to those people, but that he was uncomfortable with the status quo and did not like that people had low expectations of him based on where he came from. One of his primary reasons for pursuing a degree in science was therefore "to prove that I could be beyond what people thought of me, as a first-generation college student who grew up in a very low-income town." As in Mark's hometown, people in Dean's community were expected to go into certain jobs after high school because it was the status quo. When describing his family, Dean said that "they just had to find a career and do it. But I'll have a degree, and I have options, and there's just so much I want to do." He said he had not decided for certain exactly what career he would pursue, and even said that he would likely choose to experience several types of careers before retirement. Being able to have choices in his life, unlike his family and community members before him, was a way for him to break away from his background; this served as a great motivator for him. Megan did not have a community to escape, but did have unusual life circumstances to overcome. Both of her parents died when she was young, after which she was raised by her grandparents. They lived on a very small income, so she had to begin working at an early age to help support the household. She had decided fairly early on that she wanted to go to college but could not afford it, so she took some time after high school to work two jobs and save money. However, during that time she accidentally became pregnant: "I love my daughter, and I don't for a second regret having her, but getting pregnant at 18 is probably the most irresponsible thing I've ever done." Her financial difficulties became even worse, but she did not want to let go of her dream, so she enrolled in college anyway and worked hard to support herself, her child, and her grandparents, all while attending school. She said that sometimes when people who were aware of her situation would look at her, she felt as if they were judging her, her lifestyle, her background, and what she was capable of doing with her life, and she wanted to prove them wrong.

Inspiring Others

As described to this point, all the participants were striving towards making new lives for themselves; particularly the first-generation students. However, one defining characteristic of these students was that in most cases, despite doing it for themselves rather than any external impetus, they were not selfish in the pursuit of their goals. On the contrary, they wanted to use their ambition as a means of helping others, or at the very least to set an example for others. One of the best examples may be Cassie, who had decided to become a teacher based on her experiences. Her parents were Mexican immigrants, she grew up poor, she was the only person in her family to attend college, and she had chosen a subject, math, which people from her community would consider completely impractical in life. She wanted to be a role model to children from backgrounds and neighborhoods like her own; she believed that becoming a mathematician and teacher would allow her to inspire the next generation to do the same because "I've lived their struggles." Megan had her own daughter to strive to be an inspiration to: "I'm proud I can be a role model for my daughter, and show her gender doesn't limit her and she doesn't have to fit into a mold society expects of her. She can be confident and do whatever she sets her mind to." Dean mentioned several times that "family's really important to me," which extended not just to his mother but to his younger siblings and cousins. He had two younger brothers, a younger sister, and almost 20 younger cousins whom he wanted to make an impression upon. Although he did want them to know that getting a degree is worthwhile, the main example he wanted to set was the value of hard work: "you really have to work to be successful. Whether that's college first, or going straight into some company... you need to be consistent and dedicated to whatever you do." Part of the reason he refused to give up is because he felt that he would be demonstrating to his young family members that it was ok to give up when things became difficult, when instead they needed to face their difficulties to succeed. Like Dean, Robert also sought to impart the value of hard work and persistence towards goals. He wanted to set an example to his younger siblings and cousins, but also to "other people from backgrounds like mine, show them that no matter where they come from they can achieve whatever they set out to do if they work hard." Mark is a final example, although his reasons were a bit different from the others. He felt that he would be letting down a lot of people if he did not complete his degree, especially considering the support they gave him through his endeavors, but notably this did not include his parents. He said "my family was definitely a motivator, but not in necessarily a positive way." Rather than wanting to make them proud, like the other participants wanted for their parents, he wanted to prove something to them; particularly his father. He said that when he was growing up "my dad would actually take my books away from me... because all I did was read instead of going outside and playing football and stuff." His father wanted him to be a "manly man" whereas Mark was a self-described "bookworm, nerdy, geeky kind of guy." Mark was unique in his small town and his parents worried there was something wrong with him. He wanted to prove to them that his bookish pursuits were perfectly normal and that as a scientist he would have a successful, well-respected career. At the same time, he would "show other kids like I was that they don't have to fit into a certain mold, they should be who they want to be, and they can be great." Like Megan, he also was concerned about perceived gender roles, saying that when people were expected to go into certain jobs in his hometown, "for the girls that was basically like secretaries and teachers, or else you were a housewife." He clarified that any career that a person wants to do is great, "but it was that they were forced into it, that's what made it bad." Even though he was not a female, he still felt he could set a general example by demonstrating that you can break tradition and do whatever you want to do.

Unaided Academic Journey

Embarking on a journey to make something of your life, to prove something to yourself, and to achieve prestigious milestones is a brave thing to do, but it comes with challenges. These students had no family or other people close to them who had been through the experience of pursuing a STEM degree, or even taking any advanced STEM courses, so they had to navigate the system on their own. The third interview question asked the participants what expectations they had going into their first-year math and science courses. Due to seven participants being first-generation students and the other three lacking familial guidance for college-level STEM coursework, they had no expectations whatsoever; at least no evidence-based expectations. Cassie said "I didn't really have many expectations. I didn't really think about it, honestly." Gabriel, Kevin, Rebecca, and Robert all said something essentially the same as Cassie. Samuel had no expectations either, but as an older student he was nervous because it had been almost 20 years since he had last taken his high school math courses. Dean took advanced math in high school, up to Calculus II, and assumed that college-level math would be more of the same.

Charlotte did not know what to expect either, though instead of assuming her science courses would be the same as high school, she actually feared the worst: "I think I psyched myself out a lot. I thought they'd be difficult. I guess I really didn't know what to expect." She said that part of that fear was based on "horror stories" she had heard from acquaintances in college about terrible classes and eccentric professors. Like Charlotte, Mark "was terrified." Because of the environment he grew up in and not knowing anyone who went to college, he had formed an image in his mind of "those that go to college as very elite, very educated individuals, the best of the best of sorts." Regarding college-level science he knew that not many people became scientists, so "that's actually where I expected the elite of the elite to be, was in the science majors." Because of those preconceived notions the only expectation he had going in was that he was going to have to work very hard to fit in. Otherwise all he had was a "fear of the unknown." Megan had no expectations, like the other participants. She did mention one thing the others did not, though, which is that her teachers in high school had talked to them some about college. However, she said "it was more about just getting us to go, like recruiting us for college, rather than telling us what it was actually like." She commented that there has been a push for a long time now to get young people to go to college, but that beyond being encouraged to go, she did not recall being given any specific information about what the courses would be like. As for her science classes, if anything she assumed that they would be like her high school science courses but more advanced. However, she said "at the time I wouldn't necessarily have thought 'more advanced' would mean 'harder.'" The same ambitious personality traits that led them to pursue this path despite having no idea what to expect also led them straight into some academic difficulty, as well as held them back from seeking help when needed or knowing the best course of action when events did not go as planned. This will be apparent in other themes discussed below.

Dedication

All of the participants had a clear love for the degrees they were pursuing and they were fully dedicated to seeing them through to the end. They provided candid explanations for the reasons they were devoted to their subjects, but their dedication was also expressed in other ways during their interviews, such as describing their degree and career goals and how they were motivated by them to succeed, as well as offering advice to future students about choosing a major that would be compatible with their goals and make them happy.

Passion for Subject

When they spoke of their feelings about their subjects, it was primarily in response to the first two interview questions: why they chose to major in math or science, and what earning a math or science degree meant to them. However, there were other opportunities for them to elaborate, such as when they spoke about why they chose to persist in their major. Before the interviews took place I thought there would be a good chance they would find it difficult to explain why they liked their field; it is often difficult for people to verbalize why they like a given thing. On occasion the participants would have to pause to think about their responses, but overall I was pleasantly surprised to find they had quite a bit to say on the matter. Their ability to talk at length about the reasons they found their subject so fascinating is evidence in and of itself that they truly did find their subject fascinating.

The science majors, especially the biology majors, were drawn to their subjects early. For example, Mark's favorite subjects in high school had always been science. He said he had inspirational teachers who encouraged him to explore the world around him, and he was awed by the mechanisms of life, how chemicals form, etc., leading him to ultimately decide to pursue a major in biology. The other two biology majors, Charlotte and Megan, both intended to pursue medicine as a career. Charlotte said that although she had only decided she wanted to pursue a career in medicine shortly before entering college, she had always loved science because "the world is just so interesting, I want to know as much as I can about it." Megan had come about it the other way, deciding to become a doctor and then choosing a biology major because it was the best fit. However, when asked if she would still major in biology if she ever changed her mind about medicine she said "absolutely. I love the subject, all the things we get to learn and do. It's fascinating." Robert was majoring in physics and had a great love for it starting in high school; he knew even before he entered college that he would want to continue on to graduate school and earn a Ph.D. He had a passion for the subject, but also wanted to inspire that passion in others, as well. Gabriel, a chemistry major, had a little more to say than the others. His first-year STEM grades were the lowest of all the participants, and in his major subject, he earned an F in Chemistry I, retaking it the following semester with a C. Simply looking at his transcript, one might assume that he did not have a great love for science and would perhaps wonder why he was pursuing it. However, to listen to him talk about science, there is no question of his love for it. Before he began college he would follow the works of certain popular physicists and chemists and participated in science-based nerd culture. At one point he said that “chemistry is like the magic of science” and proceeded to talk about interesting experiments he had conducted and remarkable things that can be done with chemistry. When prompted to discuss how his feeling for the subject related to his grades, he answered that “chemistry, the science itself, not necessarily the courses, keep me going,” and the reason for that is “because the coursework at this level is hard... there isn’t always a fun aspect when you get into the nitty gritty.” He said that he loved science and could live with the grades he was earning so long as he continued loving it.

The five math majors also loved their chosen subject. Cassie specifically mentioned having a passion for learning math, and said that her love for math never changed, even after her discouraging gateway course experience. In fact, she attributed her ability to recover from that experience to her passion for math: “even when I was messing up, I loved it. And I think that’s what got me through.” Dean also spoke of the satisfaction of the learning process in math. When discussing the new, more abstract concepts taught at the college level he said that it “was a little more conceptual, but the application was concrete. It was weird learning the ideas, but when you applied them, it was like ‘I get it.’” Working through problems and ultimately reaching conclusions was an extremely rewarding experience for him. When he originally had to choose a major, he had a wide variety of interests, but said that it always came back to math. For example, one of the reasons he decided against science was because there are not always answers, whereas “in math, we have theorems, and they’re proven. I really liked that there’s always an answer.” He explored architecture and thought he loved it because it allowed him to be creative, but it ended up being the underlying math found in the logic of the design process. Other areas he enjoyed such as programming and physics were all math-based, so he eventually realized there was really only one best option for him. Like Dean, Rebecca enjoyed math for the logic of it, but she also argued that math provided a creative outlet for her. She said that although most people think of math as logical, “it also gives you a lot of room to play with numbers and come up with solutions, and it really makes you think, makes you use your brain.” She enjoyed how problems could be solved in multiple ways and found the process of finding solutions to be “really fun.” Like other participants, she mentioned finding satisfaction in reaching successful conclusions, but she also said that “it’s comforting to me in a way,” and she did not understand how anybody could not enjoy the experience. Kevin had always had a strong interest in both math and the sciences, but like Dean, when it came to choosing a major he ultimately went with math because it was more universal: he found that in all of the various subjects in which he was interested, part of the reason he enjoyed them was because of their math applications. Of all the math majors, Samuel was the most expressively passionate about mathematics. He loved the logic, the puzzle-solving, and the satisfaction of finding a solution, but most importantly he loved what he called “chasing rabbits.” He described this as the winding process of attempting to find the solution to a problem: first you try one thing, and it may not work out, but while attempting it you think of another possibility that you explore, but then you find another route, and so on. He brought up “chasing rabbits” several times during the interview while explaining his love for the hunt. He shared that he had little interest in the applications of math; he simply enjoyed the math itself. Unlike any other participant in math or science, he at several points would describe actual concepts in his subject and would talk through them in an attempt to demonstrate the thought process it takes to solve problems or to illustrate a particular point he was making at the time. Like Cassie, he said "it was always fun. Even when failing... just because I didn't get it or get it in time doesn't mean that I didn't find it interesting."

Driving Motivations

Simply having a passion for a particular subject is not always enough to motivate a student to continue; other factors are quite often present. The participants all had their own personal motivations supplementing their love for the major. Many of them were strongly motivated by the desire to be the first in their families to earn a bachelor's degree, an ambition discussed previously. However, while that ambition was a powerful motivator for many of them, it was something they were doing in part to establish themselves in others' eyes. In terms of more internal motivators, they all had their own personal goals and aspirations driving them. Kevin, Mark, Rebecca, and Cassie simply wanted to prove to themselves that they could complete a rigorous STEM degree; in other words, their driving force was to not give up or change their major to something they felt was easier, but to stay with it and accomplish something challenging. Kevin wanted to prove to himself that he could successfully finish a math degree, and earn high grades in his advanced math courses while he was at it. He believed that "doing well can give you that sense of accomplishment and pride, and that's a good feeling." Mark also wanted the satisfying feeling that would come with achieving a difficult-to-achieve science degree after years of hard work. He said "to break it down, why I would stick with a major, like a science major, is because it is prestigious. It is hard. It's, you know, the best of the best, you're part of the elite." He demonstrated his dedication to this goal when he shared something he started doing his second semester of college: "I wrote on a notecard that I kept on my person at all times, was what I wanted to see myself be doing," explaining that "you have to find something that keeps you going, and do it." Rebecca's primary motivation was to prove to herself that she could do it, and she wanted to finish simply for the sake of finishing. When she had trouble her first year, she said "I don't want to just fail and drop out, that's not me; I have to see things through." She attributed her success to "strong mental perseverance." Cassie strongly felt that completing her degree was an important step in her life. In explaining why, she said that "I know it sounds lame, but knowledge really is power," elaborating that the knowledge she gained from her math degree was something "no one can take away" and that it would allow her to have a future. The remaining six participants were motivated by career goals, though only three had a specific career in mind: Megan and Charlotte both wanted to go into medicine and Robert planned to pursue academia. It was very important to Megan for personal reasons to do something with her life that would challenge her but also benefit other people. She felt that medicine was a perfect blend of the two and once that was settled, she never wavered in her goal: "when I decided, I think I was just finishing my junior year of high school, and from then on becoming a doctor has been the only plan, nothing else mattered." Charlotte's internal motivation to stay in her biology major also stemmed from her desire to pursue a career in medicine: "I always wanted to be a doctor, and I felt that if I changed my major, it might have shut that door. And I really didn't want to shut that door." Robert ultimately intended to pursue a Ph.D. in Astrophysics and teach at a university. He was looking forward to the research he would be able to do in that role, but he was also excited about the teaching side as well: "I'll also get to have an impact on future students, and hopefully get them to love physics as much as I do." This goal helped keep him on his path as he struggled through his early coursework. The final three participants had not chosen a specific career yet, though they were all still driven to succeed by various career-related goals. In Gabriel's case, he knew that he would have worked in some sort of science-related career regardless of what he had done in college, but that by completing a chemistry degree he would be able to do something he believed was a worthwhile pursuit and a better use of his intellect than being limited to lower-level jobs. His high career aspirations were therefore a primary motivation for him, saying "if I was in this to become some grunt-level chemist, I would have dropped a long time ago. Because that is not what I want to do. This degree will help me get a job that I want, that I love." Samuel also knew that completing his degree would allow him to choose a career that he would love, but rather than having the ability to climb high on the career ladder, he was motivated by the desire to do good works. As a self-described liberal, he was of the opinion that "a lot of what math is used for is for destructive purposes," explaining that "the lucrative fields that math provides are for your chemical and oil corporations of the world, and those aren't things I want to be associated with." He refused to be a part of anything that had any moral ambiguity or in which he would not be fully aware of the consequences of the work he was contributing to. He said "I want to go into a career when I can just do math, and help other people, and know what I'm doing." For Dean, the fact that he had no specific career goals both excited him and frightened him. He said "I like a lot of things, and I'm pretty capable," and he saw himself moving around a lot after graduation. This was something that he was very happy to have the opportunity to do, explaining that "I've never had, like, a family member do that, have options with their degree, because they didn't have a degree." Unlike other participants, rather than striving towards a specific career goal, he was excited about the notion of the opposite scenario: having options. His driving motivation was to be able to have a choice in the path his life took. Although they were all different, all of these personal, self-driven motivations further exemplify the theme of dedication among the 10 participants. With this dedication, they would not let any setbacks stop them from reaching their goals.

Self-Fulfillment

The purpose of the final interview question, which asked what advice they would give to an incoming freshman beginning a STEM major, was to encourage participants to pinpoint what matters most in choosing a STEM major and persisting in it. A follow-up question asked them what advice they would give the freshman after completing the first year but earning low grades in math and science. How does a student move beyond that? How do freshmen know if a STEM major is right for them? An overwhelming response to this question was that students must examine their true motivations for pursuing their major to ensure they are doing it both for themselves and because they love it. Any other motivations would likely lead to failure or disappointment. Many participants said they would start out by asking the freshman his or her motivations for pursuing a STEM major to get to the true reason. For example, Charlotte said she would ask "ok, why are you a biology major? What do you want to do? Is it to get into some sort of school? If you're just in it because your parents want you to, what do you actually like to do?" Some common motivations the participants believed would not work were obligation to parents, societal pressure, monetary desire, or simply choosing to do an impressive-sounding degree simply because they thought it would make them look good.

Several participants shared anecdotes about classmates who had ended up leaving their majors because they had chosen it for the wrong reasons. Cassie spoke about classmates who had chosen their major because they felt an obligation to do so; she cited parental pressure and monetary benefit as two common reasons they would give for remaining in a major they did not have a passion for. Despite her great desire to encourage others to pursue math, she also felt that "you should find what makes you happy and do it;" if students are trying their hardest to succeed in math but derive no pleasure from the experience, it is not for them. Mark spoke about classmates who started at the same time as he did who eventually left because they were going into very hard fields but could not handle the difficulty and left. He was of the opinion that they were not truly passionate enough about the subject and were going into it for the wrong reasons. He said that "if you're going into it for a monetary reason, it's gonna be a lot harder. You have to love what you do, and you have to relish in the challenge of it." In giving advice to the hypothetical freshman, he would first determine their motivations, and make sure it is "not what their parents are telling them to do, or society is telling them to do," but instead have them answer the questions "What would it take for you to be happy? What would you need to do to get to that point?" Robert shared that he had known classmates who had tried to force themselves to continue liking physics when they clearly had lost the passion they had once had, and because they were no longer enjoying it they were earning low grades; by the time they realized they needed to change their major they had lost several credit hours and brought down their GPA. He stressed that freshmen should explore their options their first year: “don’t lock yourself into a major right at the beginning unless you know for absolute sure that this is what you want to do with your life.” He said that even if they think they are confident in their choice of major, college will inevitably surprise them. As the other participants suggested, Robert’s advice included making sure that they truly love the subject they choose: “you should definitely do what you love; don’t pick a major because you think you should do it, but because you want to do it.”

Gabriel shared a story about his own choice to major in chemistry. He had originally intended to major in music, but before he began college he took some time to think it through and realized that his primary motivation was his father’s plans for him. He said “once I realized that my motivation to do music was mostly my dad, and when it came down to just me and music, I didn’t really want to do it anymore.” Once he accepted that reality and thought about what he wanted for himself, he realized chemistry was the degree he needed to do. In giving advice to a hypothetical freshman earning low grades, he said the most important thing to do is to ask yourself questions and make sure you are in it for the right reasons: “is this going to get me to the career I want? How much do I like this stuff? Do I want to learn this stuff?” Kevin strongly believed that although students should respect their parents, they should not let their parents dictate the long-term course of their lives. He explained that “if you’re gonna do anything well, first of all you should do it for yourself, and secondly for other people.” Samuel, the older participant, felt very strongly about this point, because he saw many of his peers either staying in a major they were unhappy with or leaving a major they wanted because they felt pressure to do something else. He said “with my younger classmates some of them have really intrusive parents... [but] unless your parents are math majors, they really don't understand what you're doing." Later in the interview he said that when students earn low grades in their gateway courses, they need to ask themselves whether or not they truly like what they are doing, because the struggle will not necessarily go away. He remained in math because he enjoyed the struggle; just because something does not come easily does not mean that it cannot be done, but you must enjoy it.

When some of the participants spoke about the importance of choosing a degree that you love, they notably identified a correlation between having a passion for a subject and performing well in that subject. Robert was one of them; when talking about students needing to have a passion for physics, he commented that "if they love it, hopefully they'll do well in it." Rebecca made a similar comment about math: "first you have to like it... if you really like it, you will make it work." Cassie expanded on this, saying "if you really love it, and of course put in the effort, you'll make it. But if you don't love it, or find yourself not wanting to put in the effort, then maybe it's not for you. And that's ok." Dean made this point as well, saying that math "doesn't click for some people, and that's fine." In short, the participants felt strongly that any other motivations are meaningless if students do not love the subject and are not pursuing it for personal satisfaction and fulfillment. If they do not truly love their subject, and that passion is not their driving motivation to want to succeed, then they should find something else to pursue. This belief reflected their own love for their subjects and their dedication to completing their degrees.

Achievement

The participants were all high achievers, and not solely in an academic sense. They did come from strong academic backgrounds and they were interested in earning prestigious degrees, but not because they thought it would be easy; because they thought it would be hard. These were the type of people who enjoyed a challenge; any unexpected setbacks would simply be learning experiences that gave them an opportunity to improve themselves. Being accustomed to achievement, their low first-year grades were shocking to them, but this only increased their determination. Rather than giving up, they chose to rise to meet the challenge; some out of pride, some to prove to themselves that they could do it.

Prior Academic Achievement

Academically speaking, one commonality among the participants was the high level of aptitude in their secondary studies. Participants recounted earning high grades in their high school math and science courses, with several having taken advanced coursework or having participated in college preparatory programs. For example, Dean, Mark, and Robert all mentioned taking Advanced Placement coursework; Cassie, Dean, Kevin, and Rebecca all reached the level of calculus; and seven participants said they earned almost no grades below B. One very important aspect of all the participants' academic history was not just that they took advanced courses and earned high grades, but they did not have to put much effort into doing so. Several made statements along the lines of “physics kind of came naturally in high school” (Robert) and “math was straightforward for me. Easy” (Dean). At least half of them claimed that they rarely had to study in high school for their math or science courses. A few participants also mentioned that the ease with which they learned math and science in high school in part helped them select a major when they went to college; their degree was a natural choice given how well they had always done in the subject (likewise how much they loved it, as discussed previously). This aptitude was self-reported, and no official secondary GPAs or grades were provided. However, given the participants' openness and frank discussions regarding the struggles of their freshman year, there was no apparent cause to question the validity of their reported academic history, so their accounts were taken at face value.

Pursuit of Prestige

Prestige was very important to the participants; not necessarily for the sake of external recognition (although that was a perk for some), but for the personal fulfillment and a sense of accomplishment. This makes sense given their academic background and desire to perform their best; high achieving students could likely want to put their abilities to good use and work towards the most distinguished degree possible out of the subjects that interested them. All 10 participants were pursuing their chosen field because they loved it, but at the same time, all 10 mentioned that the fact that a STEM degree comes with a certain prestige was a nice bonus to solidify their decision. For example, Kevin had the opportunity early on to participate in mathematics research; he said the experience allowed him to explore advanced concepts and applications of mathematics that challenged his prior thinking and learning. Although he had felt from the beginning a certain pride in pursuing a math degree, as he did this research he realized that he had a unique ability and that "being able to do that sort of thing sets me apart from other people." Rebecca pointed out that everybody uses math to some extent in their daily lives, but the math involved in the pursuit of a math degree is many times more advanced, and being able to do it "gives you some weight, some importance. Being able to say you have a math degree is automatic prestige, and for good reason, because it's a difficult degree to complete." The sense of accomplishment and prestige for Megan was particularly heightened because she had to overcome a great deal to reach that point: "my parents both died when I was a kid, I had a kid at 19, and I'm a single mom, but I'm getting a biology degree and I'm going to medical school,.. and yes, I'm going to toot my own horn here, but I think I did great." As mentioned previously, one of Mark's primary driving motivations was the prestige associated with completing a rigorous science degree. It would be a major personal accomplishment that he could be proud of because "scientists are impressive people." He believed it was ok to be a bit selfish about wanting the prestige because "if you're good at what you do and you're making good contributions, then it's a good thing." He did say that now that he has done some work in the scientific community and has met some prestigious scientists, he has seen that "they have some big egos," so "it's important to know your motivations, to be honest with yourself," so that you can put the good of the work ahead of your ego.

For several participants, the prestige of their degree was particularly appealing when compared to other "easier" majors; some students had interests in other subjects that they could have pursued in lieu of math or science, but those majors would not have satisfied them in the same way. Coincidentally, Charlotte, Robert, and Samuel all had an interest in English. When Charlotte first began earning low grades in science and worried that her GPA would prevent her from getting into medical school, she briefly considered English, which appealed to her interest in reading and writing, but she felt that it would not satisfy her intellectual curiosity. She believed she would gain more knowledge with a science degree because “with English, to a certain extent I can teach myself, but with science, it’s harder.” She was aware that medical schools in her state would accept students who held degrees in fields other than science so long as they had completed the requisite science coursework, but it was important to her to complete a biology degree for the sense of personal accomplishment it would provide. Robert felt the same about physics, claiming there was great prestige and accomplishment in earning a physics degree. He likened it to being part of a “secret club” due to the specialized knowledge involved. He said that although he also had an interest in English, he felt that was a subject that anybody could have an appreciation for and study on their own, whereas “you can’t just pick up a book and teach yourself differential equations, or aerospace engineering, or quantum mechanics.” He acknowledged that English majors have their own specialized knowledge, but he considered it more “accessible” knowledge, not involving the intense study that advanced physics requires. Samuel also made this point, saying that he did not understand how people could struggle in English: “if you can’t read or write very well, I don’t understand, I can’t empathize with you.” He said that as he watched his peers change to easier majors he was never tempted to do so because “one I wanted to learn the math, and two I wanted the prestige.” He said that those other students may finish with a better GPA and have an easier time of completing their degree, but that he will be able to say he has a math degree, and “that means something to people... it has more distinction than a lot of other common degrees.” Dean had a wide range of interests, but after exploring his options and giving serious thought to what he wanted out of life, he decided that "I need to be able to do the most with my abilities," and that in the end, "it's always been math. It'll always be math." He knew that people considered it a very rigorous degree and that it would be the most impressive and worthwhile option to pursue. Cassie was quick to add that there was nothing wrong with other fields and students should major in whatever makes them happy, but that because she had a talent for math, she should take advantage of it. In her case there was also a different sort of prestige in that she was going above and beyond the expectations of individuals with her particular background, as mentioned previously; in her neighborhood "the kids were expected to grow up and work, not go to college, so school and learning wasn't really that important." In light of that, she said she felt proud to be someone who can comprehend math at a high level.

On a related note, a few participants directly correlated the difficulty of the coursework with prestige, explaining that a degree difficult enough to deter potential majors would be an impressive degree to earn. Gabriel had fully intended to pursue music but realized that it would be too easy; the skills he had in music were natural talent and ability, nothing he had to work for. He wanted a degree that would require him to think and work hard, and with chemistry he said "I'm using my full brain." If he had made good grades in music it would have been because he would have breezed through it, but with chemistry "I learn, I discuss, I feel like I'm actually earning the good grades, when I get them anyway." He also knew that earning a chemistry degree would allow him to attach himself to a prestigious group of people: "I already knew I was really smart, so I wanted to go to a place where I felt everybody was smart." Mark said that “science is hard; it’s why not a lot of people do it.” He of course felt differently; he made reference several times during his interview to a life principle he was taught by his father: “if it’s hard to achieve, it’s worth doing.” Rebecca enjoyed having “to work very hard to get through very challenging courses” because she knew that as a result she would have an accomplishment to be proud of as opposed to “coasting through an easier degree.” Although Cassie said that she would like to think anybody could excel in math given the proper motivation and training, she did admit the possibility that not everyone is able to complete a math degree, and that she was proud of herself for being able to do so. To varying degrees and in different manners, all 10 participants desired the prestige associated with their respective STEM degrees, a desire that reflects the importance of achievement to each of them.

Shock of Low Grades

Despite their history of academic achievement and their desire for further accomplishment, the reason these students were part of this study was the fact that they earned low grades upon entering college. Because the participants were accustomed not just to earning high grades in math and science, but for the courses to come easily to them, they were shocked when they enrolled in their first college-level courses and suddenly found themselves struggling. The initial reactions varied by participant, but they general felt a mixture of confusion, despair, and frustration. Four of them said they felt lost and confused. Cassie was initially discouraged and shared that “my first year here everything went wrong... I didn’t know what was going on, I didn’t understand the material, I didn’t know what I was doing, I was just- I felt pretty helpless.” When Gabriel failed both Chemistry I and Calculus I his first semester, he said he initially felt lost and unsure of where to go from there. Megan lamented that "I pretty much bombed my first year," calling her science courses "a slap in the face, especially chemistry." She said that her whole world was turned upside-down, and that she had to shake herself to understand what had happened. Kevin suddenly found himself experiencing some anxiety, particularly in regard to test-taking, which was a new and confusing feeling for him. He remarked that "I don't know if it's something that can develop over time, 'cause in high school I was always excited to take tests, and I always did well on them." He had always done so well that the shock of earning low grades had a detrimental effect on his confidence.

Charlotte and Mark both felt despair and anxiety. Charlotte was the participant who had gone in anticipating college courses to be extremely difficult, so she was the least surprised at the difficulty of the courses. However, despite the courses not living up to the "horror stories" reputation she had heard, they were still different enough from her prior secondary experiences that she felt great anxiety about her academic ability and performance. She described earning low grades as "terrible, it was really bad." This was a completely new and unwelcome experience for her, having grown up in a household "where grades were everything." These feelings eventually led her into an anxiety-induced depression, which she did not fully realize was happening until after she was well into it. Mark had also come in somewhat fearful of what to expect, though on the first day of class he started to feel more confident. He had reviewed the syllabi of his math and science classes and seen a lot of material that looked similar to what he had covered in his AP courses in high school, and therefore assumed the courses would be easy: "I thought I was gonna be hot stuff." However, when he got his first chemistry exam back with a grade of 43, he very quickly realized this would be much more difficult than he thought. As the semester went on he continued earning low grades, and by the time his final grades posted he had become depressed, saying "it can really get you down, when you encounter something you're not used to." He was already prone to test anxiety and it became worse, complete with physical symptoms. He became distrustful of feeling too confident in himself: "overconfidence was something to avoid, the hubris of it could end up hurting me."

Three participants described feeling frustration and disappointment. Rebecca was frustrated because she had always been good at math and did not understand why that would change; she said "I felt dumb, like I didn't get it at all," even though rationally she knew that it should not be the case. Samuel felt frustrated and disheartened, for a brief time thinking that it had been too long since he had taken math coursework and that he would not be able to handle it. Robert said he was disappointed because he thought he could have done better. Although he knew he would not change his major, he had some brief doubts about his career choice and whether or not he had enough aptitude to pursue graduate work in physics. Only one participant did not comment on this point: Dean mentioned being surprised at how different the courses were from what he was expecting, but did not bring up any particular feelings he had on the matter. Perhaps he did not wish to share how he felt, or at the time he simply accepted it and moved on.

Enjoying Challenges

Although the participants suffered an initial shock, they were ultimately able to overcome it. This will be discussed more in-depth in subsequent themes, but one last important aspect of high achieving students to point out is that an encounter with a difficult situation did not result in them abandoning their pursuits. In fact it had the opposite effect of motivating them to want even more strongly to continue. As with the desire for prestige, the need to pursue something precisely because it was difficult appeared to be a characteristic of these high achievers: they sought out and enjoyed challenges. The participants felt that pursuing an easier degree would be a waste of their talents and that anyone who truly loved their subject should stay with it even if it turned out to be more difficult than expected. As an example of that, Charlotte mentioned a few times that many of her peers chose a biology degree to get into professional school, and that pursuing that goal was more important to them than the degree itself. She remembered classmates who had begun the biology major at the same time as her but left, mostly due to failing grades. She called those students "one-track, [because] they're trying to get into med school, or dental school, or PA school, or whatever. And even one bad grade can look bad on a transcript, so they'll just change their major instead of going through it." She commented that this was a sign that they were not truly passionate about their major itself but simply completing a necessary step for professional school; she suggested that attitude towards their major may have played a part in their inability to succeed. Basically, it was harder than they expected, and instead of pushing onward or rising to meet the challenge, they simply gave up.

Several of the participants described what it meant to want to pursue a challenge. Gabriel was very interested in music and had considered a major in music theory, but he knew that it would be an easy path, whereas his other love, science, would be more difficult and rewarding in the end. He said that "a chemistry degree is me pushing myself to my limits, as far as I- like how well I can think and do things. And that to me is very special, because I'm able to say that I went there, I tried, and I did it." Rebecca knew that her math degree was more rigorous than other options she could have chosen, but she said "I like the challenge, and I feel like I'm putting my abilities and energies to good use." She felt her talents would have been wasted elsewhere. When talking about his biology degree, Mark said that "I like the challenge. I like the fact that it's hard." He needed it to be a challenge in order to feel that it was worth the pursuit. He joked that "I could have majored in basket-weaving and have been done a long time ago!" When asked to elaborate why he would choose to pursue a degree specifically because it was hard, he replied that it was primarily to prove something to himself, but also "sort of for my own self-interest, self gain, a little egotistical... it's a strong motivator, to be one of the top, to be able to do something." Almost all of the participants admitted to experiencing some trouble with the content of their courses due to the unexpected difficulty of college-level coursework. Prior to college, though, most said that one of the reasons they initially chose their major was because the subject had previously always come easily to them. Samuel was an exception; math had never come easily to him, but he loved it regardless. He said "while I've always enjoyed math, it's always been something I've had to work at; it never came extraordinarily easy to me." Of all the participants, Samuel gave the impression that he was the one who most truly enjoyed a challenge. He likened learning new material to playing a video game: "you go through a hard level and you fail, but it's fun, and 'I know I can get through this,' and you start over, and you go through it with the new knowledge, and you try something different." In giving advice to other students, he said "it's trying to decide when you’re having just a setback versus when it really is an insurmountable, unenjoyable struggle.”

In addition to enjoying the challenge itself, quite a few participants took the setbacks of their freshman year and made learning experiences out of them. Kevin began college as a confident math major but ended up failing Calculus I his first semester. However, he said that rather than causing him to doubt his choice in major, it actually strengthened his desire to complete a math degree. He said that the failing grade helped him realize he was less prepared than he thought, and consequently “I resolved to do better, ‘cause I know I could. And basically it was that resolve that kind of solidified my desire for math, proving to myself that I could do it.” His final comment of the interview was that “perseverance is vital. You can do it. You just have to stick with it.” Although earning low grades was initially upsetting, Robert also decided to view the situation in a positive light: “I thought about how it could be a good thing, that retaking these classes gives me more of an opportunity to learn, to get it right. Don’t give up, do better the second time around. It’s a second chance.” Gabriel was also glad for the second chance, but he had an interesting view of the part the gateway courses played in it. He considered them to be intentionally difficult, but he believed that they were designed not to force unskilled students to leave, but to toughen up the students who really wanted to stay. He said that “calculus and chemistry, these hard courses, like condition me to be better in school.” As a final example, Cassie actually found a career out of her gateway course setback. Although she joked that “those grades will always be on my transcript, haunting me,” she actually found a career out of her experience. Her struggles and eventual success motivated her to want to help others get through their own struggles with math, so she decided to become a teacher. The fact that these students would not only seek challenge, but enjoy it and learn from it, demonstrates the achievement that they both strive for and embody.

Culture Shock

The shock of earning low grades was covered in the achievement theme, but this theme deals with the causes behind and the aftermath of the low grades. All 10 participants experienced some level of culture shock upon entering their gateway math and science courses; Mark observed that "it was a whole bunch of new stuff all going on at once." The students found the coursework to be much more challenging and demanding than they could have possibly anticipated, and they were taken aback by the learning environment, which was much different than their secondary school experiences.

Difficulty

With the lack of expectations of what their first-year courses would be like, the participants found themselves surprised by the unexpected difficulty and rigor of the gateway coursework. Many of them had something to say on this point, particularly regarding the differences they discovered between their high school and college courses. Going from experts in math and science to suddenly earning failing grades would naturally cause them to look to the courses themselves to see what changed. Robert was shocked by the differences between high school and college physics. He had anticipated that his advanced physics courses would be challenging, but he had no such expectations for the introductory coursework. What he found, though, was that "your freshman year you're jumping straight into technical, calculus-based concepts...

it's complex and intimidating and difficult, right from the beginning." After a brief hope that his biology courses would be easier than he feared, Mark discovered that his initial fears were true: in his words, "you do have to be the best of the best... you have to be almost perfect." That may have been an exaggeration, but from his perspective he was making a huge leap from never studying but still earning high grades in AP classes to failing college courses that he thought were going to cover similar material. He wondered, "it's something I was great at in high school, why wouldn't I be good at it in college?"

Some participants believed that their high school experiences did not prepare them for college-level math and science. Gabriel said he went into his freshman year with no expectations, but the only courses in which he experienced trouble were his science courses, saying "the courses I took in high school sadly to say did not prepare me at all for college-based science courses." Megan had never earned anything but grades of A and B in high school, so earning grades of C and D during her first year was a new and unwelcome experience. She said that her high school math and science, even though they were advanced, did not prepare her for college-level work. She said "when I came here I was so determined that I would make it to medical school, but my freshman year was- well, it showed me just how hard I'd have to work to make it." She admitted that she had not studied as much as she should have because she was used to earning grades of A without studying at all. Cassie was used to math coming easily to her and was "shocked" at finding out how "intense" her first college-level classes were. Like Megan, she underestimated the time and dedication they would require. Rebecca said that "in high school I took calculus, but it was different somehow, not quite as in-depth and intense as here." Another surprising difference she discovered was in the level of responsibility that college professors place on students for their own learning of the material, regardless of how difficult it is; in comparison in high school more effort is made to ensure each student understands.

Many participants referenced the lack of effort they had to put into their high school coursework and by comparison said that the expectations of them were much higher in their college courses. Their professors demanded a larger quantity and quality of work from them, resulting in the students having to learn how to study properly; for some, learning how to study at all. For example, Charlotte noted that a large factor in the difficulty she experienced in her introductory science courses was the approach she took to them. Her prior methods of learning and absorbing knowledge were no longer applicable in this more rigorous setting, but it took her time to realize that and to adjust. Commenting on this struggle, she said "when you've built a habit of over like 12 years of education, learning how to study a certain way, learning how to do things a certain way, it's hard to break out of that." In answer to the question about giving advice to an incoming freshman, her immediate response was to say "make sure they know how to study. Like I would tell them, 'the way that you're studying now is going to be totally different a year from now.'" Kevin gave similar advice in response to that question; specifically, to "study as much as possible." Despite taking fairly advanced courses in high school, Kevin found Calculus I to be a "jarring" experience and found he had to make significant changes to his study habits. He said that in high school, he actually rarely had to study for math at all; it came very easily to him. However, once he began his college level coursework and realized how much more difficult it was, he knew he would have to begin studying, "and I did, especially after I got my first two tests back and didn't pass them." He also found that he had to make adjustments to accommodate an unexpected workload; he "didn't know just how much work would be involved. Mostly studying of course, but just the sheer amount of work you have to put into these classes." Mark also spoke of study habits and time allocation, saying that in high school he rarely had to study and he would often wait until the last minute to complete assignments or prepare for tests because he knew they would be easy. In his gateway courses he quickly found out that "you cannot procrastinate because as soon as you do that you will fall behind and fail." In regard to suddenly having to learn how to study, he discovered as Charlotte did that "it's kind of hard to build that habit when you don't have a basis for it."

Depth of Content

In terms of the actual content covered in the coursework, several participants noted that the concepts were given deeper perspective and students were expected to approach the subject very differently than they had in high school. Cassie recalled that high school math involved working with numbers themselves and solving equations, but that at the college level the focus was more on reasoning and critical thinking. "I learned that math is more than just solving for *x*... It's like the equivalent of learning another language and you- it's like you have to be able to communicate and reason through numbers the same way people do with words." She specifically pointed out that she was not talking just about her advanced math courses, but the lower-level courses taken her first year: right from the start, in her gateway math courses she was introduced to "all these new and advanced concepts I wasn't prepared for." Dean shared a similar observation as Cassie in that “math up until then had been math and formulas, but with these we wrote a lot of proofs... I was used to numbers and concrete ideas and this was more abstract.” He noted that the logic he loved about math was still there, but in a different way. Rebecca also found that college-level math covered content in a much deeper fashion and explored the root of problems rather than simply solving them. For example, she said that in high school they would simply learn formulas and how to plug numbers into them, but in college they would be asked to probe more deeply into the reasons the formulas work, where they came from, etc. She explained that “in college you have to go into everything in incredible depth and detail. You really have to think about things and sometimes it’s hard to wrap your head around the new concepts that are being introduced.” Samuel did not realize how difficult it would be; he said he experienced some sleepless nights studying and worrying before falling into a routine. In his advice to incoming freshmen, he told them that it will take more work than they think it will, but that more importantly, they need to “realize that you don’t know what math is.” He said “all that you’ve done up through high school is learn to recognize a problem and follow a process and an algorithm, just finding an answer to that problem.” However, as other participants found, college math is not about plugging in numbers but about asking questions. Unlike the other participants, Samuel provided demonstrations for many of his responses, and at this point walked me through an exercise. He asked me to define an even number; I answered “divisible by two.” He pointed out that 1 would be an even number by my definition because 1 divided by 2 is 0.5. I expanded my answer to “any number divisible by 2 that results in a whole number.” He then continued the thought process until he reached the mathematical proof for an even number, demonstrating that college math is “figuring out what’s true, and why it’s true, or why would you follow this process, and if that’s true, what are some universal truths for all the numbers, and so on.” He then returned to his original point, which was that for an entering freshman, “what you think of as math is not math.” Robert discovered that college physics is much different from high school physics, and much more difficult than he could have anticipated. He said “I came into this feeling so confident, and then I found out there’s actually so much I don’t know.” As the participants majoring in math also noted, one of the key differences is that in high school the subject is taught at a surface level; with physics he simply learned the basic foundations of the science. However, in college much deeper concepts are introduced: “you’re not just learning the science, but you’re learning critical thinking and problem solving skills, and making applications.”

Notably, none of the three biology majors commented directly on this, at least in terms of their biology coursework. It was the students taking math and math-based courses who agreed that the content of their coursework was very different than their high school experiences. For example, although Charlotte earned grades of C in her first two biology courses, which distressed her because she loved biology, she actually failed calculus and chemistry. She said she was not entirely surprised because they both required a strong mathematical foundation and math had always been the one subject she struggled with; on chemistry, she said “since chemistry has math in it, I was so worried I was gonna fail, and it just got to me, so then of course I did.” Charlotte did not offer a reason why she earned her grades of C in biology; she simply said she was taken off guard by the level of difficulty in a subject she had always done well in. It is possible the approach to biology was essentially the same as her high school experiences in science, but the content itself was just more advanced. However, Mark did make one relevant observation about the difficulty of college-level biology coursework. While he was speaking on an unrelated topic, he happened to say that "one of the major problems I had coming into college, especially as a science major, was how to study. And how to express that information once I knew it." He clarified by explaining that "I could easily memorize a fact, but using it- that was the hard part... making an idea out of it. I never really had to do that before." In an indirect way, he appeared to be observing that rather than simply acquiring knowledge, as was done in high school, he now had to apply the knowledge he learned and adopt critical thinking skills.

Weed-Out Culture

None of the participants had heard of the phrase "weed-out course" before beginning college, and given their limited knowledge of what to expect from college regardless, they likely would not have fully realized the implications of what it meant until actually experiencing it. Once they did enroll in their gateway math and science coursework they heard classmates talking about weed-out courses and professors, and learned what it meant. All of the participants acknowledged that their first-year math and science coursework was unexpectedly difficult, as discussed in the previous sections. They may have held somewhat different views on what makes a weed-out course, but the general consensus was that their gateway courses were purposefully and excessively difficult. While speaking of the quality of her first few math courses, Cassie said it was a "completely new and scary environment" and felt as though they may have intentionally been designed that way. She was particularly suspicious of one the intentions of one of her instructors, saying “I thought she was grading too harshly, like she was trying to scare people away and get them to drop.” Kevin agreed, saying that Calculus I in particular “was really, purposely hard I think.” He said that he did not necessarily get that vibe when he retook the course, or in the science course he took concurrently, but acknowledged that he was working harder that semester so it might not have affected him as much. Regardless, he did say that “thinking on it, yeah, there was definitely a hard quality to it that I didn’t get from my other non-math classes.” He also shared that some of his peers who took other sections of Calculus I and II believed they were designed to weed out students. Samuel said the same thing: “Calculus and Calculus II are unnecessarily difficult... the only reason I can see is to weed out people who aren’t willing to do it.” He called calculus meticulous, precise, and intentionally hard. Megan thought that the gateway courses in science were “hard on purpose” and that “it can be intimidating, especially if you’re in one of those classes with 200 students, it’s easy to feel like the prof doesn’t know you exist and nobody wants to help you.” Rebecca actually experienced this; she shared a story about an upsetting experience with a calculus professor who gave her the impression that he did not feel she deserved to be there. When she was struggling with the material and went to him outside of class to discuss it, she said “he made me feel stupid... he was basically like, ‘I explained everything in class already so you should have gotten it there, and if you didn’t you should just read the book,’ and I just felt like he didn’t want me there.” The impression she left with was that if she was struggling enough to have to go to him, then she was not capable enough to succeed in calculus. This also had the unfortunate side effect of further making Rebecca wary of asking instructors for help. Although her experience was terrible, it was more or less unique among the participants. They agreed that the courses were intentionally difficult, but overall did not get the impression that their instructors did not want them to be there. Gabriel held the most positive view of weed-out courses. He knew that his gateway science courses were designed to identify students who could not succeed and have them leave their major. However, he felt that on the bright side, this allowed students to realize early whether or not the major they had chosen was a good fit for them.

Instructional Style

Apart from the courses themselves, the learning environment of the math and science gateway courses contributed to the participants' culture shock. As with the coursework difficulty and content, this was partially due to significant differences between high school and college; the college learning environment consisted of instructional methods and philosophies completely unlike what they had been accustomed to in secondary school. Three aspects of the gateway math and science course learning environment particularly stood out in the interviews: instructional style, lecture format, and class size.

When the participants spoke about instructional style, one of their primary concerns was actually the lack of attention professors gave to instruction, at least when compared to high school instructors. As a point of reference, when asked why they initially chose to major in their field, Cassie, Charlotte, and Mark all cited inspiring teachers they had at the secondary level. These teachers went out of their way to help them learn and encourage their interest in the subject. Cassie said that her teacher was the first one who “showed me that teachers can really care about their students. She changed my life and she changed my view of math.” Charlotte and Mark each had a science teacher who inspired them to want to emulate them: Charlotte by becoming an amazing scientist and Mark by helping other people come to love science. In college they encountered instructors very unlike their role models. Cassie commented that although she generally liked her professors, she got the impression that a few of them were more focused on their research and only taught classes because they had to. Additionally, she found that some professors simply lacked the ability to teach well: “they’re really, really smart, they’re like geniuses when it comes to math, but they can’t really explain it to other people.” Gabriel had a similar observation: “the professors are researchers, they’re held to this high standard, they’re really extremely smart but honestly don’t always know how to teach.” Dean did not have too much to say about the teaching environment of his coursework, but did say that sometimes his classmates would have trouble and dislike the way the instructors would teach, so he would end up having to help them. As mentioned previously, Rebecca probably had the worst experience of all the participants when it came to an instructor. According to her report, “when I failed calculus, I have no clue, I didn’t understand anything. And in the class, I don’t want to blame the professor, but he didn’t explain anything well and we would get so lost.” When she asked for help she received little: “I didn’t know what to do, and he didn’t work through it with me to help me understand.” Based on her lengthy description, he seemed the sort of instructor who felt that a presentation of information is all that is needed and the students who are bright enough to be math majors will understand, and those who are not are unlikely to have potential and are not worth his time. When

Rebecca retook the course she had a much better experience: “I retook it, and had a new professor, and she explained much better,” helping Rebecca work through her problem areas.

Kevin had also had instructors his first year who did not teach as well as he would have hoped, and he felt very strongly that this should not be the case. He believed that instructional quality should be a critical consideration in first-year math courses because in his experience the difficulty level of a course “mostly depends on the type of teacher you have, how well they teach it, and how well they get the concepts across.” His first year he failed and retook Calculus I: the content and structure of the course was identical because the syllabus was set by the department, but he claimed that “the second time around I had a really awesome teacher who explained things a lot better than the first time around.” He acknowledged that students often have little choice in the matter, but that being fortunate enough to have an excellent instructor can make a significant difference in the outcome of a course. In giving advice to a hypothetical incoming freshman, Charlotte suggests the freshman “learn to be flexible, because each class, each professor can be so different.” She elaborated that this is particularly true given that college students change courses and professors every semester rather than every year like in high school, so there is less time to acquaint oneself with the particular nuances of a professor’s teaching style before moving on to the next one. She did say that “students talk all the time about professors, so you kind of know what you’re getting into as you go into the class, but it’s not the same as actually getting to know them.” She recalled that she never had the same professor twice, despite taking so many biology courses. Like Charlotte, Samuel commented on the variety of teaching styles reflected in the faculty, and that students cannot always know what the teaching environment of the class is going to be like until they're in it. He said "if you're lucky enough to find a teacher that works well for you then you'll do better for it."

Sometimes universities utilize graduate teaching assistants (GTAs) to teach freshman-level coursework, freeing up seasoned faculty for the fully-committed students who have reached more advanced coursework. Only two participants mentioned that they had taken gateway courses with GTAs, and they had different opinions. Cassie commented that GTAs "have their own thing going on and they don't have a lot of experience teaching." She mentioned this in the context of being newly exposed to intimidating college-level math, and felt that it would be more helpful to students to have more experienced teachers working with freshmen. Gabriel, on the other hand, felt that GTAs could relate better to the undergraduate students because they had been through the experience not long ago themselves. He said that "the faculty here, I believe are- I don't want to say conceited, they have this really high level of math," and that "they expect you to come in with a certain level of knowledge yourself, and if you don't have it, they don't seem to want to go back and teach you." GTAs, however, were more willing to work with you.

Lecture Format

Many participants in both math and science majors mentioned the prevalence of the lecture format in their gateway coursework. Most simply mentioned it in passing without specific comment on their opinion of such a teaching method, although certain inferences could be drawn based on their description. For example, although Cassie did not have any negative feedback specifically aimed at the lecture format, she did comment that when she had trouble with a concept she knew it would be better to contact the professor during his or her office hours rather than in class, because "you can't exactly stop the whole class while he's on a roll in his lecture to ask him to clarify something." This could simply be Cassie's personality being reflected; perhaps a feeling that it would be inappropriate to interrupt or wishing to avoid the embarrassment of admitting that she was having difficulty. However, the way she worded it could imply that active participation was discouraged in that professor's classroom. One piece of evidence for that possibility is that Cassie explicitly stated that she felt an enthusiastic instructor would have a greater impact on students, adding that "I've always liked those teachers that are so excited about what they're teaching and they want you to be a part of it, and it kind of makes you excited about it too." She did not know whether or not that would have a direct impact on performance but speculated that increased student interest and engagement in the class "could only be a good thing." Gabriel spoke of the lecture format when discussing his math courses, critiquing this method as an ineffective approach to teaching. He said that his first attempt at calculus was taught this way; the instructor "would just stand up there and talk, his lessons were pretty much, 'here is this type of problem, you solve it like this, ok go home and do the homework.'" At home Gabriel would invariably encounter issues that had not come up in the lecture, and that, compounded with his general trouble comprehending the material, helped lead to his failing grade in the course. In his second attempt under a different instructor, the class would work through problems together, allowing students to see the process in a hands-on fashion and ask any questions that arose while still in the classroom with the instructor. He said as a result, "when you would go home and do your homework, you had all the tools necessary to actually work from the easy problems all the way through the hard ones all on your own, which is how math is supposed to work."

Some students spoke about instructional methods that did work for them, such as more hands-on approaches or engaging classroom activities. When Megan retook Biology II she had a different instructor, one she said may have been the best she ever had. She apparently made the course more entertaining while still covering all the necessary content. Megan's opinion was that "I think with science it's really helpful to have a hands-on approach and let us actually do stuff instead of just sit there and listen." She acknowledged that this was the purpose of labs, but that lecture can get boring and that actually getting to participate in a more direct way made it more engaging. She suggested that students who do not like science could also potentially benefit from this; perhaps it would help them like it more, and lessen their fear of the subject. Perhaps because she had anticipated the possibility of callous, eccentric professors, Charlotte was the most forgiving of the gateway course instruction she experienced because it was less dreadful than she expected. She did comment on the format, mentioning that the instructors preferred to lecture with extremely little classroom interaction. She also mentioned that this was not her preferred means of obtaining knowledge, explaining that she was more of a visual learning and that "lectures don't help me so much as reading over my notes of the lectures." Similarly, when talking about his learning style, Kevin said that he could not learn well simply by watching; he needed to walk through math problems himself. He said this was often problematic because sometimes his instructors would "just stand up there and work through problems and say ‘ok put this here, and then do this,’ and so on, but unless I actually get to walk through it too and interact with it I have trouble getting it on the first go.” In these cases he said he would have to go through it again on his own later to avoid getting lost or confused later. Samuel felt the same, saying that in a math classroom “it helps to do things with your hands, to see things visually, to connect the dots,” because “math seems so arbitrary sometimes.” Rebecca had a few professors rely solely on lecture, including one “just presented it and we were supposed to follow along and just get it.” Rebecca said that her learning style is incompatible with the lecture format: “I need to be able to actually interact with the professors and work through problems together instead of just being shown.” When she retook the class, she had a different instructor who encouraged classroom interaction and working in groups, which helped her significantly.

Class Size

The third most discussed topic related to the learning environment was class size. Most of the participants mentioned having experienced at least one class of well over 100 students during their freshman year, which made learning difficult for some of them. One of the biggest surprises to Charlotte was the immense size of her gateway science courses. In particular, she lamented the inability to interact more with her professors: “you really don’t know your professors that well. Especially coming in, when you’re taking like Biology I, and you’re in a class of, I don’t even know, like 300 or something.” She contrasted this experience to high school, where students get to know their teachers better due to smaller class sizes. She said the same was true for classmates; “since there’s so many it’s kind of hard, because you’ll get to know someone through the course of the semester, and then you may never see them again." She said she became used to it after a while, but it was initially disconcerting not knowing every person in her class or being able to have any meaningful in-class interaction with either the instructor or her classmates. In the context of how the course structure impacted her academic performance, she said, "I think if I could change anything in that sort of regard it would be to have smaller class sizes." Megan suggested that a potential benefit of reducing the class size of the gateway biology courses would be to allow more interaction among the faculty and students, with more hands-on lessons instead of a room of hundreds of students "just sitting there listening to the professor." Even though more students take biology than any other science, Gabriel noted that the first-year chemistry and physics courses also have very large class sizes: "you're in a room with like a hundred some-odd people." He suggested that cutting the courses down to a quarter of the size would make it more reasonable, because "being in a small classroom you're able to ask more questions, you're able to keep everybody on the same page." Math courses at this university tended to be much smaller in size than science courses, but given that students in many majors needed calculus, those courses tended to run larger than the advanced courses. Samuel commented that the calculus sections he enrolled in, while not nearly as large as his science courses, "were generally really big, just too big for there to be any meaningful interaction."

Resilience

The participants had been through a great deal: they struck out on their own to make their own path in life, they chose a rigorous degree in a subjected they loved in the pursuit of prestige and self-fulfillment, and when they finally arrived they encountered shockingly difficult coursework and a demanding learning environment for which they were unprepared. There were many points at which they could have given up, yet they persisted. What is more, they persisted under their own volition; they had no external pressures or obligations to continue, they took responsibility for their academic performance, and generally acted independently. At the critical point between their freshman and sophomore years, they chose to continue and were confident they would be able to overcome their setbacks. These were resilient students.

Self-Motivation

As mentioned previously, these students were primarily driven by self-motivation. Although many participants were influenced by external factors, such as a desire to make their parents proud or to set an example for younger family members, the motivation itself was driven internally: it was the students who wanted to make an impact on the other people in their lives, rather than a feeling of obligation from those people to do so. Cassie was perhaps the participant most strongly influenced by her parents, and spoke at length about the effort her parents made to give her the opportunity to go to college. She expressed gratitude for their sacrifices and wanted to make them proud, but never mentioned that she felt pressure or obligation from them; she only spoke of her own desire to succeed. Several other participants had their parents' support, but like Cassie, did not receive any pressure from them. Charlotte's parents encouraged her to finish her degree, but only because they knew she was an intelligent person and they wanted her to have the opportunity to live up to her fullest potential. Ultimately, though, her happiness was their primary concern, and Charlotte said she did not feel any pressure from them, especially in regard to her choice of major: “I don’t know that they’re particularly invested in me being a science major, so long as I have a goal and a plan to finish, and I make the most out of what I do.” She said they would have been just as pleased and supportive if she had chosen to pursue her other interest, English, and became a writer. Ultimately it was Charlotte herself who provided the motivation to complete her biology degree and pursue a career in medicine. When Kevin left for college his father wanted to be supportive, but the only guidance he could think to give was to suggest Kevin not take so many math and science courses because it would be too much to handle his freshman year. However, that was advice that Kevin could not follow if he wanted to be a successful math major and graduate in a timely manner, so after that they realized it would be best to leave the advice to the experts at the university. Samuel said that his parents supported him and were proud of him for going back to school, but that his journey has been completely self-motivated. Rebecca stated that “I’m doing this because I want to, not because I have to.” She said that she wanted to make her parents proud, but that she was finishing her math degree for herself.

Other participants had even less parental involvement. Robert’s parents never pushed him to go to college, but he said it was not because they did not think it was a good idea, but simply because they had not done it so it was not something they necessarily thought about. He believed they would be proud regardless of what he did, so long as he was happy; his choice to pursue a physics degree was completely his own. Megan’s parents had died when she was young, and although she wanted to honor their memory (and make her grandparents proud) but doing the most she could with her life, it was her decision to do so. Although Mark did say that he wanted to prove something to his family, he also wanted to prove something to himself and not let himself down. He said that he had been raised his entire life to understand that "you've got to work hard for something if you want it," and he firmly believed it to be true. He had joked before about how he could have graduated by now with an easier degree, but that it was important to him to do a challenging one: "the reason I push myself is, if I don't, who will?" He needed no external motivation; he would not have let himself give up on his goals. Dean said that "there's nobody pushing me, asking how school is going. Nobody. Even when I was younger. This is just something I need to do, I tell myself to get it done, so I do." Gabriel knew that there were plenty of external motivations that he had relied on. However, he ultimately determined that self-motivation was the most important when completing a rigorous science degree: "I found that there is that barrier point where things get really really hard, and you need some kind of internal motivation to keep going." Later on he added that "when it boils down to it I'm doing this for me," because when he left for college he was on his own: "when the bad grades happened, somebody could have come along and said 'you can do this, remember the end goal,' but there wasn't anyone."

In the end, all 10 participants mentioned in some way that their decision to go to college, to pursue a STEM degree, and to persist to graduation was fully motivated by their own desires and ambitions. Many of them felt a certain gratitude or debt to others, or wanted to make them proud, but were not obligated in any way by those individuals to make the choices they had made. What this demonstrates is that when facing challenges and making decisions, these participants are resilient enough to handle things on their own.

Academic Responsibility

The participants generally had a strong sense of responsibility. When they first encountered their gateway math and science courses and began earning low grades, they felt shock at what was happening, but did not externalize blame. Cassie mentioned a few factors that contributed to her first-year struggles, such as unexpected course difficulty and troubles at home, but rather than place blame she took responsibility for her actions and her grades: “I did mess up, yeah, there’s no denying that.” When reflecting on her feelings regarding her own low grades, Charlotte pointed out, “I internalize a lot of things,” expressing the belief that her grades were her responsibility and her problems were her own to deal with. Unfortunately, her intense personal desire to succeed and to hold herself accountable led to problems with anxiety and depression. Gabriel internalized as well, saying “I do beat myself up sometimes, thinking I should be working harder.” According to everything he said in his interview, he already worked extremely hard, and he did mention some issues he had with instructors and troubles at home and work that interfered with his learning, but when it came to his grades he took full responsibility. Megan admitted that “I screwed up at the beginning because I wasn’t prepared and I took on too much at once.” She was not as hard on herself as Charlotte and Gabriel; she did not feel that she was to blame for each and every circumstance that caused events to unfurl the way they did. However, she did not place blame on anybody else, either, and acknowledged that she would need to be the one to make the effort to recover. Mark also recognized that regardless of how difficult his courses were, it was up to him to take the initiative to pull through: "it was eye-opening. It was an epiphany moment, saying, you know what, this is really hard, I have to change what I'm doing." Rebecca said that even though she believed instruction can make a huge difference in how well students perform in a class, she did not blame her professors for the grades she earned. Kevin also mentioned trouble with the instructor during his first attempt at Calculus I, but did not blame the instructor for his grade. He merely observed that it may have been easier for him to comprehend the material if instruction had been clearer with a more hands-on approach, but that ultimately is was the shock at the difficulty of the course and his lack of studying that led to his failing grade. He acknowledged his responsibility multiple times when he referred to wanting to raise his grades back up to the high standards he normally held himself to. Samuel took full responsibility for his grades, but did mention that one factor somewhat out of his control was his age. He said he never had a problem learning the material in his math courses, but that it took him a much longer time than his younger peers; had he gone to college soon after high school he might not have had difficulty keeping up.

The participants took initiative to correct their own problems; they were not coerced into doing so by anybody else. Though few said as much directly, the wording of their responses indicated they made changes of their own volition: they did not mention other people telling them to change, but simply referred to their own actions and decisions regarding turning things around. Resilience in the face of challenges is all the more meaningful when done of one's own volition.

Self-Reliance

Another characteristic related to the participants' self-driven goals and their lack of external motivation was their preference for academic independence. Many of the participants excelled in math and science at the secondary level either without much effort or without assistance, and were therefore uncomfortable with the idea that they may need help at the college level. Eventually they learned that sometimes in order to be successful, they would have to discuss their difficulties with their instructors or seek out other supplemental academic resources at the university, but when they first began their coursework they stuck to their previous independent-minded habits. Charlotte did so simply because she knew no other way of doing things: "throughout high school I've always been one of the top students, and then when suddenly I wasn't, I didn't know what to do, and I didn't know how to ask for help." However, other participants did not want to ask for help because they felt it would be an admission of failure, or would lessen others' opinions of them. Cassie had never liked asking for help because she thought it "would make me look stupid." She said "I know this sounds arrogant, but I didn't want to have to be one of those people, the ones who don't understand and have to go to the teacher for every little thing." Samuel felt that asking for help was an acknowledgement of his own incompetence: "to go to the professor and talk to him was admitting failure; it was weakness." Kevin had never liked asking for help, explaining that "I've always been afraid to ask questions because- well not because it shows weakness per se but because it looks like I don't understand the material." He said that in his memory he had never asked a professor a question in front of classmates, and only rarely had he gone to a professor during office hours to follow up on something he did not understand. Rebecca also indicated pride and embarrassment as reasons for not wanting to seek help: “I was scared to go to the professor because this had never happened before, and I didn’t want him to think I was the kind of student who doesn’t get math and doesn’t belong there.” Gabriel lacked some humility in his interview; several times he pointed out how intelligent he was, although this did not seem to be for the purpose of bragging so much as insisting that his grades were not a reflection of his intellect. This same pride kept him from asking for help when he was struggling in his courses; his preference was to attempt stubbornly to solve his own problems rather than risk anyone thinking he was not smart. Similarly, these students were used to working on their own. Because in the past they did not need help and were confident in their abilities, they were not used to having to work with others. As Charlotte shared, “I tried study groups, especially my first year, but they didn’t really work for me... I pretty much keep to myself.” Kevin had also attempted working with classmates when he felt it was necessary to get through a class, but stated “I definitely prefer to work on my own.” Dean described himself as a very independent learner and claimed he never went to his instructors or peers for help on anything, which he admitted may have played a part in one or two of the grades he earned his first year. Mark was the exception in this area. Although he said he never felt the need to ask for help in his gateway courses, he would not have been opposed to the idea at all. He said that “I have always been a firm believer that if you need help, to seek it out.” The stubbornness most of the participants displayed during their freshman year reflected their resilience in that they wanted to succeed on their own terms, but in this case it may not have been a beneficial attitude to take.

Constructive Reflection

The struggles the participants experienced in their math and science gateway coursework, as well as the courses themselves, have been discussed in previous themes. In this theme of resilience, the ability of the participants to move beyond those experiences is described. One important aspect of moving on is the view students take of their gateway courses after the fact. The participants already spoke of how they felt about the courses while they were in them, but what happened afterwards? Surprisingly, many of the participants looked back on their gateway courses and were glad for the experience. The primary reason was they believed the initial shock helped them realize just how difficult their chosen major was going to be, and that they would need to work very hard if they wanted to succeed.

When several of the participants were discussing the concept of weed-out courses, they did say they were excessively difficult, and that at the time it was frustrating and disheartening, but in the end it may have been worth it. As they progressed through their more advanced courses they discovered that those courses relied heavily on what was taught in the gateway courses. Samuel said that his advanced math courses were very in-depth and built on what was learned in calculus, so even though he personally felt the calculus courses at this institution were causing too many students to leave the math major, it was important to have an intense experience at the beginning to be better prepared going forward. He described a time in his Introduction to Proofs course when he had a eureka moment in which he saw and understood the connections to his previous math courses, all the way back to basic algebra. He described it as “a moment where it crystalizes and you realize what proofs are actually doing. You learn how it relates to everything. And you just discover how neat it all really is." Dean emphasized the importance of getting a good start in math: "make sure you connect the dots. If you can connect the dots, you can connect future dots... You'll really mess up in your upper-level classes if you don't get down the basics first." Cassie also referenced the cumulative nature of mathematics: "maybe there's one little piece you don't quite understand, and it screws up everything else you try to learn after that." Kevin began noticing the cumulative nature of his math coursework fairly early. After he failed Calculus I and retook it, and then took his next two math classes, he said he noticed how all the classes fit together: "I started to see these links that really helped connect it all together and make sense. And then the whole major just sort of clicked for me."

Megan understood that the gateway science courses were hard, but said "I think people give up too easily" and felt that changing their major was the easy way out. She shared that "I definitely saw classmates do it, all the time. We'd be sitting in class, going over some concept, and they'd complain about how they don't understand... and then next semester they're majoring in history." If students entered their major truly wanting to succeed, then they should seek help and find a way to get through their first year. She stressed the importance of the gateway coursework, and said that in retrospect it was good that it was difficult. If students could just bear with it then they would get to the more interesting advanced courses, "and then you'll have a science degree, and it was really hard, but look how impressive you are! Just get through that first year and you can make it to the end." Gabriel also felt that students gave up too easily. He believed that if you initially fail a weed-out course, it does not mean you are incapable; just that you need to try harder. His view of gateway courses was that “if you get this, then continue. If you don’t get this, then you’ll need to work a little bit harder than most to continue.” In other words, if at first you do not succeed, try until you do; do not immediately give up. He said that learning how to do this in the gateway courses was critical for success in a chemistry major, because “chemistry never gets easier.” He explained that even beyond the gateway courses, success in one course was required for success in the next; therefore, chemistry was a highly cumulative, structured experience. Samuel made a similar observation for math: the early content taught in calculus is "hard and the ones who can’t do it get cut. But then you keep going and it keeps just being hard, so it’s almost like every class is a weed-out class, people just keep falling by the wayside as you go along.” The students in this study, however, had the resilience to continue.

Confidence

After the participants earned low grades in their gateway math and science courses, they took responsibility for those grades and took the initiative to learn from their setbacks and find a means of moving forward. Because of the ordeal they had been through, one which would have caused most of their peers to change their majors, they must have had courage and confidence in their attempt to recover.

Some participants mentioned that part of what helped them recover was recognizing that nobody is perfect, and that as discussed in a previous section, they could learn from their setbacks. Cassie admitted that she went through a “rough patch,” but knew that she could get through it. Despite initial discouragement after first encountering her unexpectedly difficult gateway math courses, she “got over it” because she knew she could do it. She told a story about a time in her secondary education in which she was struggling, but with the help of an inspiring teacher she was able to overcome it and succeed; with that memory she “realized it wasn’t always going to come easily,” but that if she persevered she could succeed. Rebecca also acknowledged that perfection is not always possible, and that “it’s ok to not do fabulously every once and a while... you just learn from it and move on.” She stressed that it would have made no sense for her to stop, and she never considered changing her major, because “I know I’m not stupid. I’m smart, I love math, and I can do this.” She referenced classmates in her calculus class who failed with her, but who must have changed their major because she never saw them again. She said “they just got tired, and frustrated, and couldn’t deal with it... but I didn’t want to do that, I didn’t want to give up so quickly.” Although Samuel had different anxieties than his younger peers coming into his college-level math coursework, his decisions and actions going forward were very similar to theirs. After initially earning low grades, he made the decision to persevere and took the necessary steps to correct the issues at hand so that he could successfully move forward. One difference was in perspective; other participants admitted feeling some initial doubt about their ability, but Samuel recognized that feeling as self-pity. He explained that years of earning high grades in secondary school builds up a confidence, sometimes even arrogance, in a student’s self-perception of ability, and when that perception is challenged, he felt that it is less likely that the student suddenly feels they lack ability, and more likely that they subconsciously feel depressed that their record has been tarnished. In either case, he realized that it was all about “getting the right perspective and realizing it’s not the end of the world. Feeling like you can get yourself back on track, and knowing you can.”

Other participants remembered the high standards they had always had for themselves, and held on to that as motivation for continuing. Kevin said he had always been the kind of student who earned high grades and would hold himself to certain standards. However, in high school that had been much easier because the courses themselves were easier. Despite that, when he earned his first low grades in college, his old instincts kicked in: “getting those low grades here helped me want to get back up to those high standards I had before.” As a direct result of earning low grades, instead of losing confidence or morale, it gave him back his motivation and he began “relearning how to study and stuff, getting through the slumps I had in those classes.” Charlotte still had a certain amount of pride after her first year, commenting that “I didn’t give up just because I’m stubborn. I didn’t want to fail, basically, like in a large-term sense.” She suffered from anxiety and depression for a time, due to earning low grades and having high expectations for herself, but it was precisely those high expectations that helped her pull through and feel confident enough to tackle her obstacles. She had a dream of completing a biology degree and going to medical school and she could not abandon it, despite the trials of her freshman year. Her final comment in the interview was “I think I just wanted to prove to myself that I could do it, more than anything.” Like Charlotte, Gabriel was also very hard on himself; he claimed to always hold himself to high standards and beat himself up when he did not meet them. He admitted that “these classes are hard for me, and I’m pushing myself to perform at the level that I am.” However, he had confidence in his ability to pull himself out of academic troubles, saying that “what kept me going in school was knowing that I was smart enough to do it and finish.”

Many of the participants simply cited a determination to continue, attributing their motivation to a straightforward stubbornness. Dean was completely confident in his ability to recover, saying “I knew it was still something I could do. When I came back the next semester I said ‘let’s do this.’” Several times Gabriel claimed that for him, overcoming obstacles was simply a matter of persistence and will power. At one point he used the metaphor of hitting a brick wall: “once you get to a brick wall on that road... you literally get either around the wall, over the wall, or through the wall. And for me, calculus was one of those deals where you’re just gonna sit up against this wall until you figure it out.” When asked to elaborate on what it means to not give up, he responded that “I didn’t want to say I couldn’t do this or I need to start over. I wanted to stay where I was and keep pushing forward and not restart or go backwards, not take a step back.” Robert claimed his feelings about his physics major never wavered. As other participants shared, he “got over it and just kept going,” attributing his perseverance partially to stubborn determination. He figured out how to correct his mistakes going forward and improved, choosing to keep a positive outlook. He said that “being the first person to go to college in my family, I set such high expectations for myself... I wasn’t about to give up.” Mark went through a mild depression after his first semester but said he recovered fairly quickly. He generally had a very positive outlook on life and his work and had a strong sense of self-motivation and determination. He said “I always look at it and say, ‘you know what, I might not have done my best this time, but that does not mean I give up. Because if I keep going, I’ll be fine.’” He felt that he had to believe in himself because not doing so could result in a self-fulfilling prophecy: “you have to believe that you can keep going, because if you falter in that, then it’s not going to happen.” He also described himself as “incredibly stubborn,” so even in the times when he started to feel despair, he would doggedly continue until he met whatever challenge he was facing. His philosophy on setbacks was that they can sometimes be unavoidable, and although they can be terrible and several in a row can be disheartening, it could never be so bad that he could not find a way to get through it. Megan had initially been discouraged because she had never earned grades so low, but she was confident in her ability to overcome the situation and get back on track. She said “I changed some things, lightened my load, and life got better after that.” She said she even took a little extra time to graduate, both to better focus on school and to make room for some additional science courses that she took both to raise her GPA and to “show the med schools that my freshman year was just a fluke, that I’m perfectly capable, but just needed to get myself put together.”

At the conclusion of his interview, Gabriel had an insightful comment regarding students with high expectations for themselves. Students like Gabriel and Charlotte push themselves to anxiety in their efforts to do as well as possible and they constantly second-guess their actions and abilities. However, Gabriel said that even though he was guilty of doing those things, it was not worth it “because what you did is what you could at the time. If you had the discipline to have worked a different way to have gotten a better grade than you did, then that’s what you would have been doing from the beginning.” In other words, the type of person who worries about doing their best is very likely already doing their best, “so it’s not fair to beat yourself up... it’s not about being better, it’s about getting through it and recognizing you’re already doing what you can.”

Summary

This presentation of the five themes has been somewhat sequential in a way, as the themes each cover an aspect of the participants’ personalities or experiences that guided them through their freshman year. Ambition describes the participants’ aspiration to goals above and beyond expectations as they set out on their own to overcome their backgrounds and serve as an inspiration to others from similar backgrounds. Dedication comprises both a dedication to their subject as well as to their goals, represented by the driving personal motivations compelling them to continue. Achievement consists of their prior academic achievement, their pursuit of further achievement, and their desire not to come by this achievement easily; there must be a challenge in the pursuit. Culture shock is what happens when students with these characteristics enter gateway math and science courses; the difficult courses, weed-out culture, and various aspects of the learning environment are all new and challenge their prior preconceptions of learning. Resilience is what gets them through the culture shock and back on the path to achievement; they are self-motivated and self-reliant and use their setbacks as learning experiences, with the confidence to move onward to success.

CHAPTER 5

DISCUSSION

The purpose of this study was to answer the research question: what experiences, motivations, or attributes influence students majoring in math or science to persist to graduation after earning low grades in gateway math and science coursework? A thematic analysis of 10 student interviews resulted in five themes answering this question: ambition, dedication, achievement, culture shock, and resilience. Each theme is multifaceted, being made up of several defining features. Ambition represents the students' desire to reach beyond expectations; they wanted to overcome their backgrounds and inspire others to do the same. All of them were the first in their families to pursue STEM degrees and careers, and most were first-generation college students. Dedication is the unwavering pursuit of their goals. They were driven by a passion for their subject, their future careers, and other powerful personal motivations. Achievement consists of both their history of academic achievement and their intense desire to succeed, but they did not want easy success; the journey must be challenging for the accomplishment to be fulfilling. Culture shock is what happens when students with these attributes encounter the academic environment of gateway math and science courses. They were unexpectedly difficult and the learning environment was uncomfortable, both of which were a shock enough to contribute to the students' poor academic performance. However, resilience is the reason they pulled through in the end. They took responsibility for their grades, took initiative to adjust and improve, used the setback as a learning experience rather than seeing it as a failure, and had confidence in their ability to recover and persist.

In this chapter these five themes are related back to the theoretical framework at the foundation of the research, the meaning of the findings is discussed in more depth, the significance of the results is presented, and directions for future research are proposed.

Themes and Theory

The starting point of this research as well as the thematic analysis itself was the theoretical framework proposed by Wang (see Figure 1 in the first chapter). Her model proposes multiple constructs and relationships that are theoretically relevant to STEM major choice. Students' self-efficacy and learning experiences affect their interests and goals as well as their college readiness, which in turn influence their choice to major in STEM. Additionally, STEM choice is affected by supports and barriers found in the college environment and the individual characteristics of the student. These constructs were used as a starting point in the thematic analysis of the data, and the resulting themes did end up having a foundation in the framework.

Self-efficacy was a key element in this study. Research has shown that self-efficacy in math and science proficiency directly relates to STEM major choice, persistence, and long-term goals. Based on the results of this study, students in STEM majors must have confidence both in their existing capabilities and in their ability to learn. It is also essential for freshmen to realize that mistakes can be overcome and that they have the ability to recover from setbacks, learn from them, and move forward. A defeatist attitude is counter-productive and will decrease chances of long-term success. Self-efficacy is evident in several themes. Ambition requires students to have high enough self-efficacy levels in math and science ability to strike out on their own to pursue academic paths previously untaken by anyone in their families. Dedication involves self-efficacy as a driving force for maintaining motivation to continue. Achievement shows that students are accustomed to academic accomplishment, which goes hand in hand with self-efficacy. Resilience includes confidence, which is powered by self-efficacy.

The construct of interests and goals also played a significant role in the findings. Self-efficacy often directly contributes to interests and goals: high levels of self-efficacy in math and science naturally lead to interest in math and science and the desire to pursue related goals. Because of this relationship, interests and goals appeared in the same themes as self-efficacy. Ambition involves setting and pursuing goals, which are defined by students' interests. Dedication requires students to maintain their interests and believe strongly enough in their goals that they will not abandon them. Achievement is a goal in and of itself, as is the related prestige, and students must have very keen interests in order to want to be challenged in pursuing their goals.

In Wang's framework, the two constructs of learning experiences and college readiness have to do with students' secondary education. High school learning experiences can impact college major choice, and college readiness can affect postsecondary academic performance. Because the focus of this study was college-level experiences, pre-college experiences were not directly brought up in the interview questions, but the students ended up speaking about them anyway because of their relevance to the events of their first year. These two constructs therefore appeared in a few themes. Ambition partly arises from prior learning experiences; students have a positive experience in their secondary math and science courses and feel they can pursue it further. Achievement relates to learning experiences in a similar way; the positive secondary experiences conditioned them to success in STEM and led to a desire for more advanced accomplishments. Culture shock shows the negative side of college readiness; students believed based on their secondary experiences that they were experts in math and science only to find out that the college STEM environment is quite different.

In regard to person inputs, Wang primarily intended demographic variables to be the relevant factors in STEM choice and persistence. Unfortunately this data set is entirely too small to make any statistical inferences about the demographic relevance. However, there are observations worth noting. The ethnicity and gender breakdown was representative of the population, from which it could be inferred that anyone of any ethnicity or gender is capable of possessing the attributes and motivations of this student model. Put another way, if the sample had been made up of a greater percentage of white males than the population, it could be possible that white males were more likely to fit this model. Additionally, a greater than expected percentage of the participants were first-generation, which could mean that students with a socioeconomic background they wish to overcome are more likely to have enough ambition, dedication, and resilience to persist in this context.

Postsecondary contextual supports and barriers include factors such as academic integration, the learning environment, and rapport with instructors. Unfortunately in the case of the participants in this study, this construct consisted more of barriers than supports. Culture shock embodied this construct. Academic integration was challenging for the students because they found the gateway math and science coursework to be much more difficult than anticipated, and in many cases they felt as if they were intentionally being weeded out. The learning environment was similarly challenging as the students faced instructional methods and philosophies they were unaccustomed to, as well as class sizes significantly larger than their secondary courses. Rapport with instructors varied, but generally was poor or infrequent due to the large class sizes and distant instructional approach.

In the first chapter, Wang's framework was referred to as a means of following the academic trajectory of a student. I had assumed that the themes I found would follow a similar trajectory, perhaps even aligning more or less with the framework constructs. The five themes did end up having a somewhat logical flow to them in the discussion of the findings, but they did not make up a step-by-step trajectory. Instead, each theme represented multiple framework constructs, and each construct was found in multiple themes. In the end the model turned into more of a web than a trajectory, but the interconnectedness was still there and made logical sense.

Discussion

This study has identified and analyzed a specific group of students: high achievers majoring in math and science who are self-driven and independent, as well as confident in their abilities. However, this confidence is in part what led to their problems in their gateway coursework. Because they were used to earning high grades without much work, the increased difficulty of college-level coursework shocked them to such a degree that that they did not know what to do. Their confidence also meant that they were unused to asking for help, and because they were used to working independently and did not want to appear weak, they initially did not seek help, which worsened the problem. After the experiences of their first year, though, resilience helped them pull through. Of the five themes that were found among these students' interviews, four are attributes of the students themselves: ambition, dedication, achievement, and resilience. The fifth, culture shock, is something that happened to them, although it does contain information about the students insofar as how they handled the situation. With all of these themes and attributes taken into account, the result is a specific profile; a student fitting this profile is likely to persist in a math or science major despite initial setbacks they may endure in the first year of coursework.

The original aim of this study was to determine what led to the ultimate success of these students; how were they able to persist? That question has been answered, and specific attributes and characteristics have been identified as being relevant to their persistence. In terms of application, practitioners can explore ways of using this knowledge to accomplish several goals: they can redesign their gateway courses and improve instruction to enrich the introductory math and science experience; they can identify students who fit the profile found in this study and help them to succeed; and they can also attempt to improve persistence opportunities for students who lack the attributes of this particular profile. However, in this last goal, one significant issue that would need to be addressed first is the possibility that these attributes are inherent in students and not adoptable.

Given that all 10 participants met all five themes in some way, it is very unlikely that persistence is based solely on just one or two of the attributes. Instead, it is more likely that they work in conjunction, giving the student everything he or she needs to be successful. Based on the analysis of the participants in this study, the details involved in any given attribute are not critical to fitting the profile. For example, a student does not have to come from a specific background: although a surprising majority were first-generation students, the three whose parents held bachelor's degrees demonstrated that this is not requisite. The 10 students represented a mix of ethnicities, genders, and ages, so no demographic variables or combination thereof are specifically required. Some students came from socioeconomically disadvantaged backgrounds that they wanted to overcome; others had more privileged families with no desire to escape. They all had different academic and career goals and different reasons for pursuing them. In short, the details, although of vital importance to each individual student, are irrelevant to the broader implications of the model. What matters are the thematic categories in which the details fall. Students who have ambition, dedication, achievement, and resilience fit the profile. Certain sub-categories are important as well. For example, in dedication, it is important that students have some personal motivation driving them to reach their goals, but it does not necessarily matter what that specific motivation is, so long as it is powerful enough to keep them going. In achievement, students must have a history of high academic achievement and a desire to continue working towards accomplishments, but it does not necessarily matter what specific types of classes they took or where they went to school. In these sorts of categories, the student can fit the mold in a variety of ways.

Significance of Results

The ultimate question is, of course, how does all of this help? The goal is to understand persistence in math and science and to find ways of increasing that persistence. In terms of application, then, the results of this study can be used in a few ways. Four areas are addressed in this section: proposed changes to the gateway courses, means of assisting students who match the profile discovered in this study, means of assisting students who do not match the profile, and suggestions for institutional practice in implementing change.

Gateway Courses

As mentioned previously, only four of the five themes are attributes of the students themselves. The fifth, culture shock, is something they experienced. However, this theme is just as important to the study results and the pursuit of persistence. A certain profile of student has been found based on the discovery of the four other themes, but the ways in which they acted during their experiences in their gateway courses supplemented those themes. The participants' attribute themes of ambition, dedication, achievement, and resilience helped get them through their culture shock and influenced their interpretation of events. For example, the academic responsibility found in resilience meant that they took responsibility for their academic performance and did not place external blame on anything else, including the courses and teachers. This helped them to provide a more objective analysis of what occurred in the gateway courses. The enjoyment of challenges found in achievement and the constructive reflection found in resilience meant that they understood why the gateway courses need to be challenging and did not unfairly criticize the content. Based on their experiences and observations, there are certain applications that can be made to gateway math and science coursework.

As evidenced by research on postsecondary academic fields, coursework in math and science consists of quantitatively challenging and tightly structured content with closely related concepts. This contrasts with the non-quantitative fields of liberal arts and social sciences, which are characterized by a looser and more open course structure with emphasis on broader knowledge. Several of the participants commented on this nature of math and science course content. Students in math and science majors must master the content in their gateway coursework before proceeding to higher level coursework, which in turn must be mastered before progressing further; the material at each stage is vital for mastery in the next. This means it is critical for students to have a solid foundation of success in their gateway coursework.

What this also means is that the courses should not be made easier so that more students will pass. It is true that there is a great need for more people in STEM fields; that is one of the premises of this research. To enter a STEM field, people must be able to complete STEM degrees, and to do that, they must successfully pass the introductory gateway coursework. However, easier coursework will not help the situation. All it will serve to do is put out less qualified graduates, defeating the purpose. Despite all 10 of the participants failing gateway math and science coursework, hence appearing in this study, they would agree with this assessment. Being interviewed in their graduating semester, they had the benefit of hindsight: despite their initial struggles resulting in disappointment, retaken courses, and delayed graduation, they knew that they needed a solid foundation if they were to have any chance of being successful in their advanced coursework. Their opinions on this point were given in the "constructive reflection" section in the previous chapter.

Instead of reducing the academic rigor of the gateway courses, a different approach could be taken based on insight from the students in this study that would lead to a more beneficial course structure, content presentation, and learning environment. It is possible for the gateway courses to maintain their challenging and complex nature yet still be taught in a more engaging and meaningful way. According to the participants, this ultimately comes down to instructional quality and style. Teachers of all grades can greatly impact their students' lives, but these students observed marked differences in the teaching environment of their secondary experiences versus their college-level education. K-12 teachers are trained to teach and education is their primary goal; college instructors tend to have other pursuits such as research and rarely have formal training in teaching. Although the participants did not comment on the lack of teacher training, as that is something they would not necessarily be aware of, several of them did observe that their professors were not always effective teachers and provided specific examples as evidence.

Prior research shows that the academic culture of STEM fields is one that promotes student responsibility for mastery of challenging concepts rather than an emphasis on teaching as a means of successful knowledge transfer (Epstein, 2006; Gasiewski et al., 2012). From some instructors' perspective, their job is to provide information to the students via lecture, and once they have done that, the students will do what they will with it (Wieman, 2012). As discussed in the literature review, student participation and active learning techniques greatly enhance student learning, but despite this the sciences have a much lower rate of class participation than the humanities. Math and science instructors are predisposed to lecture, are unlikely to utilize cooperative learning strategies, and generally do not adopt a student-centered attitude to pedagogy. All of these points were made by at least one participant in both math and science fields.

If instruction were to change, it would not have to be the level of K-12 education, with extensive educator training provided. College students should not have their hands held; they do need to learn how to take responsibility for their own learning. However, many of the participants did wish that at the very least there was more classroom interaction; if the instructors engaged with the students more, they would be able to learn more effectively for several reasons. According to the participants, a more engaged instructor is more likely to make students feel comfortable asking questions, so they will be more likely to actually do so rather than remaining silent and end up misunderstanding the material. They also said that in a more engaged classroom there would be more hands-on approaches to learning in which students would get to actively work through problems and experiments with each other and guided by the instructor, rather than being left to work things out on their own at home. None of the participants gave any inclination that they liked the lecture format that characterized their gateway courses; several specifically said that they felt their learning style needs were not met in the courses.

Some basic teacher training could be provided to professors, potentially as a university-wide initiative, although handling it at the college or department level may be better because different instructional methods may be better suited to different subjects. Providing basic training at the department level would potentially also increase consistency across the departments' courses. Several students mentioned that when they retook a course, their second instructor was markedly different from the first, and one student specifically pointed out that an incoming freshman would need to be flexible because all the instructors conduct their classes differently.

One last change that could be made to the gateway courses themselves would be a decrease in class size. Several participants commented on the large number of students in their freshman-level courses, which they noted was not conducive to the learning environment. However, large class sizes tend to be more of a resource allocation issue than a decision made by choice on the part of the institution. That said, if university administrators could find a means to decrease class sizes, the results may be worth the effort. Some participants said they would appreciate the opportunity to get to know their classmates, which smaller class sizes would allow, because establishing those peer relationships is beneficial to them as they progress through their programs. Additionally, smaller class sizes would make it easier for instructors to engage with the students and do more interactive activities, which the participants said would be beneficial to their learning.

Students Matching Profile

One application of the results of this study should be to help those students who already fit the profile. They already have the necessary characteristics for success: ambition, dedication, achievement, and resilience. As this study has shown, they are capable on their own of recovering from setbacks. However, the purpose of initiating change would be to prevent that from happening to begin with; essentially, focusing on the culture shock theme.

During the interviews, two questions asked what the participants' expectations were going into their first-year math and science coursework and how their actual experiences met or contradicted expectations. The overwhelming consensus was actually a lack of expectations: they had no idea what to expect, which for many of them is partly what led to their culture shock and academic difficulties. Even students who had completed college preparatory coursework reported being taken by surprise in their college math and science coursework. Steps must be taken to correct this so that future students have the best chance to succeed. One possibility would be for institutions to work closely with their feeder secondary schools to ensure students are getting the content necessary in high school to be prepared for college. However, that would not solve all problems, partly because it does not catch all the students who will be attending the university, and partly because the issue is less about preparation and more about the shock of completely different learning environments. It would be more practical and directly useful to address the issue in some direct way once students have decided to attend the university.

At this institution, when students are admitted to the university they are required to attend a two-day freshman orientation. One hour of this orientation is devoted to academic college sessions; students attend the session of their major college in order to learn more about academic life in the college, available student resources, etc. In the college housing math and science majors, incoming freshmen are given a warning that their introductory coursework will be more difficult than anything they have encountered before, and that even straight-A students will have trouble. The problem is that those straight-A students, the high achievers profiled in this study, do not believe the warning. Each individual believes he or she is the one who will defy expectations, because they have no reason to believe otherwise; math and science have always come easily to them, and they have the grades to show for it. Charlotte is an excellent example. She knew going in that she wanted to be a doctor, and also that medical schools require extremely high GPAs. She knew that in order to accomplish her goals, she would need to aim for grades of A in all of her classes, especially math and science. However, despite warnings she received, she felt extremely confident that grades would not be a problem for her based on her prior academic history, and therefore made no special effort that first semester in her approach to learning. She soon discovered that she would need to make significant changes to her study habits in order to succeed in college-level math and science.

Because of this disparity between student expectations and reality, I believe the first step in attempting to help students who fit the profile is to get them to believe that they will need to put in some serious effort if they want to succeed, and that their overconfidence will hurt them. Samuel actually referenced this in his interview when talking about the types of students he encountered on the first day of Calculus I: "there's the kid who's like, 'well I know all this 'cause I took AP Calculus in high school so this is gonna be no problem...' he doesn't really know what he's talking about, what he's getting into." Students somehow need to be oriented to the STEM major in such a way that they will understand what they are getting into. Admittedly it is not feasible for them to fully understand until they are actually immersed in the courses themselves, but there still may be better ways to prepare them so they are not taken completely off guard.

Many institutions offer first-year seminar courses to acquaint students to college life and teach them skills for academic success; these have indeed been shown to increase first-year grades and retention. However, applying this approach to STEM education is not entirely practical. The gateway courses are intense and fast-paced enough that if students were to take the preparatory course alongside their first math or science courses, by the time they learned anything useful it may be too late. On the other hand, requiring them to complete the preparatory course before taking any STEM major courses could potentially delay graduation by a semester, given the extensive course sequencing involved in many of the majors.

Perhaps an orientation devoted solely to STEM majors would be a good compromise. As-is, with only an hour to talk about a great number of important issues, the warning about the gateway course difficulty (and the rigor of the degrees in general) is squeezed into about five minutes. The students are in the middle of a two-day orientation, being bombarded with information, and might not even remember being given the warning. An orientation just for STEM majors would allow the college to provide specialized preparation to their students, giving them time to implement various strategies and tactics designed to convince the incoming freshmen what they are facing. Depending on the institution's rules regarding the use of data, perhaps students could be shown hard evidence in the form of previous grade distributions in the courses they are about to enroll in. Additionally, they could specifically be shown the grade distributions solely of students who had high GPAs in high school. Having one or more peers come in to talk at the STEM orientation may be especially helpful. Students may be more inclined to listen to someone like themselves: fellow students, perhaps some who have only just finished their freshman year, who had an excellent GPA in high school. In all of these orientation activities it may also help to divide students by major;

that way math students would get detailed information about the Calculus I and II experience, for example.

Students Not Matching Profile

In this study students were found who persisted in their math or science major to graduation, despite earning low grades in their first math and science courses. Themes were discovered describing the attributes of these students that led to their success, and a certain profile of student was identified. Discovering those themes was the primary goal of the study, but they must be applied in order to be of any use. Other students who fit the profile can be helped based on these findings, as just discussed, but what of those students who do not fit the profile?

It is not enough to say that it is simply the profiled students' personalities and histories that led them to succeed. We must be able to replicate their success in other students, or at least attempt to. However, personalities tend to be static, and each student's life circumstances have already occurred; how can either of these things be changed? A college recruiter or counselor can only share stories to incoming students, not give them the experience of living through them. Even if it were simply a matter of taking a profiled student's story and applying it directly to another student, which profiled student should be used? Although they all conform to certain themes and general attributes, the details differ; which would be most applicable to the new student in question?

In the end, this is the wrong approach to take. The first thing we must realize is the fact that each and every student is unique and broad strokes can only be taken so far. Additionally, potential problem areas exist in attributes such as self-motivation, independence, and confidence; these are very personal, defining characteristics that may or may not be teachable. Some of the participants may have even taken on certain attributes subconsciously. Megan, for example, watched her mother persevere through her cancer to continue her education by taking community college courses. Cassie was with her own mother as she moved from Mexico and worked multiple jobs, making many sacrifices so that her children could have a brighter future. Without these experiences, Megan and Cassie may have ended up becoming completely different people. The circumstances under which they learned how to be strong, motivated people were extremely personal.

As a starting point, the new student could be told the themes and general attributes of the model. Rather than sharing an individual profiled student's life story, examples could be provided from several students to show the new student that every person derives strength from different sources. All of the students in this study were driven by something: they were working towards a goal, wanted to be a positive influence, desired to prove something to themselves, or simply could not stand the thought of failure. Students could be encouraged to search their own feelings and motivations to find something to work towards; something to cling to. Mark commented on this when giving advice to the hypothetical freshman in the final interview question: "I know I keep saying, 'just stick with it, just work hard,' but to motivate someone to do that, I mean, everyone has their own motivations... a lot of the motivation to continue has to do with long-term goals and what you love." Also, as the participants themselves said, it is not just a matter of finding the motivation to continue, but wanting to do so; while they are searching their beliefs and desires, they need to decide if math or science is truly what they want to dedicate themselves to. Once students have found their own personal, meaningful motivations, they can be guided in how to apply it to their academic lives.

Institutional Practice

The previous two sections addressed the significance of this study as it relates to students; in other words, how students could use the knowledge gained from the research directly. However, the results of the study may be best suited for university administrators and academic support staff, who could learn from and apply the research as applicable to their student success initiatives, adapting and molding it to fit their needs. This section addresses ways in which institutions or individual academic departments could apply this research to improve the academic success and persistence of their students.

When seeking to help freshmen STEM majors succeed in their gateway math and science coursework, one of the first and most important issues to address is how to identify whom to help and when to intervene. For example, an institution could establish a preemptive initiative for all incoming STEM majors, such as the STEM freshman orientation mentioned previously. Alternatively, only at-risk students could be identified and monitored, but reliable selection criteria would need to be chosen, and a timeframe for intervention determined. Should this be done on a one-on-one basis, small to large groups, or whole cohorts of incoming students? Who should work with the students: counselors, academic advisors, faculty, peers, or some combination thereof?

There are many possibilities, but after reflecting on the thematic analysis results and brainstorming the most effective ways to identify and help new students, I believe the role of academic advisor is thoroughly suited to the task. It would be nearly impossible to make broad, sweeping reforms at the institution or even department level and expect to be able to have a positive impact on all students. There are too many variables to consider, as each student is unique. That is not to say that large-scale implementations would be ineffective; certain ideas, such as the STEM orientation discussed previously, would be a means of reaching out to a large group of students simultaneously to emphasize the importance of the freshman year, the differences students can expect between high school and college, the intense challenge of math and science gateway coursework, etc. However, the goals, backgrounds, life circumstances, personalities, driving motivations, and myriad other factors that guide the path of any given student will be completely unique. Any attempt to create a matrix of student "types" would either be an impossibly immense task or result in broad enough categories as to be useless. One-on-one meetings would be ideal, and in fact already exist in the context of academic advising.

At most universities, a student's academic advisor is one person at the institution whom he or she will almost certainly meet with on multiple occasions on a one-on-one basis. In those meetings, the advisor is already speaking with the student about educational and career goals, degree and coursework options, academic standing and grades, and often non-academic circumstances. For incoming and freshman STEM majors, these meetings could be adapted to learn more about the student in the context of the themes fitting the profile found in this study, and subsequently advise and assist the student accordingly. By having purposeful conversations with students, academic advisors could collect relevant information such as the students' background, college expectations, dispositions, motivations, parents' education, etc., while also imparting relevant needed advice such as how best to prepare for the particular courses the student is about to undertake, what resources to take advantage of in their particular circumstances, and so on. For the best effectiveness, the student and advisor should meet at least twice over the course of the freshman year, perhaps even three times if resources allow: before the year begins, in the middle, and finally when the year ends. In each visit the advisor can use previously-collected information as a guide while also adding new information as the student learns and grows. One of the particular advantages of this approach is that the student profile discovered in this study is in part defined by an aversion to seeking help; by requiring them to come in to discuss their progress, thoughts, actions taken, etc., students can be given the help they need without having to ask for it.

This proposal seems time-consuming, but with proper training, advisors can incorporate these conversations into preexisting advising session formats without adding too much time. Even just a few extra minutes per student does add up, though, so more advising staff may be required to reduce each advisor's caseload to allow more time per student. Ultimately, individual institutions and academic departments would need to decide what approach would be best for their students based on the staff and resources they have available. Multiple approaches might be tested and assessed to determine which proves to have the best outcomes. However, given the importance of retaining STEM majors and the uniqueness of students, some sort of approach that allows individualized attention may prove most effective and worthy of the cost and resources necessary to support such an endeavor.

Future Research

As with any study conducted on a small scale, it would be beneficial to widen the research to include more students at multiple universities to establish reliability. That said, the results of this study do align with the framework on which it was based, and therefore is supported by prior research. There is supplemental and expansive research that could be conducted. One possibility would be to test the application suggestions described in the previous section, such as implementing a specially designed freshman STEM academic advising program on a trial basis with results carefully monitored over several years. In regard to helping students recognize their personal ambitions and driving motivations, different strategies could be taken in identifying which students to help and deciding when to intervene in order to determine the most beneficial implementation. For gateway math and science courses, pilot programs for instructor teacher training could be tested to determine if they have any effect on student performance and persistence.

I had thought there would be a possibility that different gateway courses would have different impacts on students, but that turned out not to be the case here. However, I believe it would be a worthwhile effort to investigate this on a larger scale. Are there specific courses in which students earn significantly lower or higher grades than others, or which have uniquely different learning environments? Do students' grades or experiences in certain subjects differ depending on their major? I suspect the answers to these questions may depend on institutional culture, so if this study were expanded, multiple institutions should be included.

Conclusions

It is unfortunate that students make the decision to leave their STEM majors after having experienced only the gateway math and science courses of the freshman year. When they leave their major after just one year, they do not get the opportunity to experience the more discipline-specific coursework of their major that could have provided the intellectual stimulus needed for them to find satisfaction and apply their talents (Hughes, Hurtado, & Eagan, 2014). The retention of math and science majors at the earliest stage of their academic program is a crucial step in reversing the downward trend in STEM career interest.

It is not too far-fetched to say that the future of STEM can be directly linked to gateway math and science coursework. As demonstrated, this is a critical point at which potential STEM majors will decide to either continue or withdraw. Understanding what occurs in these courses, the backgrounds and experiences of the students, and their cognitive processes all contribute to a better understanding of what causes those students to persevere and be successful, allowing faculty and staff to better guide and assist students in their endeavors.

Ultimately there are many factors that influence student retention in college; departure from STEM majors is not based on a single experience or influencing factor but a composite set of events. An individual student's success is the result of the sum of a multitude of factors including academic preparation, personal will and aspirations, social and demographic background, learning environments, and more. No single attribute or experience can determine whether or not a student will persist in a STEM major. However, the thematic analysis conducted in this study resulted in the discovery of five themes common to a particular profile of student who is ambitious, dedicated, achieving, and resilient, and is able to overcome the culture shock of intense gateway math and science courses. In applying these themes, the study identified certain attitudes students can adopt, motivations they can be encouraged to try, and approaches to gateway coursework they should take to improve their chances of success and persistence. Reforms can be made to the coursework, but ultimately it is the students who must be given primary focus. Institutions can implement special programs for incoming freshmen to help orient them to STEM degrees and help them navigate their freshman year, but ultimately it is critical to recognize that each student is different. Broad, sweeping reforms can be implemented, but the more specialized attention an institution or academic department can spend on its students, the better they will be able to understand and assist those students, which will ultimately lead to the results they want achieve.

As a final insight from a participant: Samuel recognized that he was lucky he was given the opportunity to continue after his first year, because he knew many academic advisors would have removed him from his math major upon seeing his failing grades. When asked why they would be wrong in doing so, he responded "because they'd be doing what math people do; they'd be looking at the numbers instead of the person." His final comment of the interview encompassed all the themes: "It's a challenge, but one I know I can beat. You think you can keep me down with that D? No. No, I can do this. You just watch and see."

APPENDIX A

INTERVIEW SCRIPT

1. What were your initial reasons for choosing to major in math or science?
2. What does earning a math or science degree mean to you?
3. What expectations, if any, did you have going into your first-year math and science courses?
4. How did your actual experiences in the courses meet or contradict those expectations?
5. To what do you attribute your grades in the courses?
6. What impact, if any, did earning those grades have on you?
7. In what ways, if any, did your feelings about your major change over the course of your freshman year?
8. What factors contributed to your decision to remain in your major?
9. What advice would you give an incoming freshman about to undertake these courses?

APPENDIX B

RECRUITMENT LETTER

Graduating math and science majors,

My name is Erin Gonzales and I am a doctoral student at the University of North Texas. I would like to invite you to participate in my research study on math and science major retention.

The objective of the study is to explore students' motivations and experiences during their freshman year that influence their decision to persist in their major despite initially receiving low grades in math and science.

You all meet the first criterion for participation: you persisted in your major all the way to graduation. The second criterion is you must have earned low grades in math and/or science courses your freshman year. If you volunteer, I will request your consent to review your transcript and confirm you meet the second criterion.

If you decide to participate in this study, I will do an interview with you, taking approximately one hour of your time. It will be audio-recorded, but your confidentiality will be maintained. No identifying information will be included when publishing the results of the study.

Participants will receive a $10 gift card at the conclusion of their interview.

If you are interested, please e-mail me at egonzales@uta.edu and we can schedule a time to meet.

Thank you!

Erin Gonzales
PhD Candidate
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APPENDIX C

INFORMED CONSENT FORM

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose, benefits, and risks of the study and how it will be conducted.

Title of Study: Persistence Patterns of Undergraduate Students in Mathematics and Science Majors Overcoming Poor Academic Performance in Gateway Mathematics and Science Coursework

Student Investigator: Erin Gonzales, University of North Texas (UNT) Department of Counseling & Higher Education

Supervising Investigator: Dr. Marc Cutright

Purpose of the Study: You are being asked to participate in a research study that involves interviewing graduating math and science majors who received low grades in math and science courses in their freshman year. The purpose is to examine the connection between your experiences in those courses and your decision to persist in your major.

Study Procedures: You will be asked to participate in an interview with the student investigator that will take about one hour of your time. The interview will be audio recorded.

Participant Eligibility: To be eligible for the study, participants must have received low grades in freshman-year math or science coursework and be graduating with a bachelor's degree in math or science. Your academic transcript is required to confirm eligibility. By signing this form, you give your consent for the student investigator to access and review your University of Texas at Arlington transcript.

Foreseeable Risks: No foreseeable risks are involved in this study.

Benefits to Subjects or Others: This study is not expected to be of direct benefit to you, but we hope to learn more about math and science major persistence from the perspective of students.

Compensation for Participants: You will receive a $10 gift card at the conclusion of the interview as compensation for your participation.

Procedure for Maintaining Confidentiality of Research Records: The audio recording and transcript of your interview will be stored on a password-protected computer. The confidentiality of your individual information will be maintained in any publications or presentations regarding this study via the use of a pseudonym. No participant will be individually identified.

Questions about the Study: If you have any questions about the study, you may contact Erin Gonzales at eringonzales@my.unt.edu or Dr. Marc Cutright at marc.cutright@unt.edu.

Review for the Protection of Participants: This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at 940-565-4643 with any questions regarding the rights of research subjects.

Research Participants' Rights:

Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

- Erin Gonzales has explained the study to you and answered all of your questions. You have been told the possible benefits and potential risks and/or discomforts of the study.
- You understand that you do not have to take part in this study, and your refusal to participate or your decision to withdraw will involve no penalty or loss of rights or benefits. The study personnel may choose to stop your participation at any time.
- You understand why the study is being conducted and how it will be performed.
- You give your consent for your academic transcript to be accessed and reviewed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You have been told you will receive a copy of this form.

Printed Name of Participant	Signature of Participant	Date

For the Student Investigator:

I certify that I have reviewed the contents of this form with the subject signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

Signature of Student Investigator	Date

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