EXPERIENCES OF FRESHMEN ENROLLED IN MATH-INTENSIVE STEM MAJORS

A Dissertation

by

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ABSTRACT

Undergraduate retention in STEM majors has been a longstanding concern with educators. By virtue of the curriculum, mathematics is more prominent in some STEM majors such as Physical science, Computer science, Engineering, and Chemistry. First, using a meta-analytic approach, the role of SAT math score, first college math course, and first college math grade in predicting STEM undergraduate retention was investigated. Next, a qualitative narrative inquiry was conducted to understand the role of mathematics in freshmen year engineering in the broader context of academic and non-academic factors influencing retention. Finally, given that facing academic difficulties was common among engineering freshmen, students' reactions to negative feedback was observed in a lab setting. The role of individual personality traits in reacting to academic feedback was investigated.

The results suggested that first year mathematics course-taking experiences influenced student retention. Specifically, students who received lower than a C grade in first semester math were highly likely to drop out of their STEM majors. Participants considered mathematics, chemistry and coding as the most challenging courses during freshmen year. Being academically underprepared for these courses was a drawback for freshmen engineering students. While better high school preparation helped students perform, psychological factors such as motivation and personality were important factors in overcoming academic challenges. The personality trait closely related to academic performance, conscientiousness, was not predictive of effectively responding to negative feedback. However, other personality traits such as emotional stability, and openness, played an important role in navigating academic challenges. Understanding students' reactions to academic challenges is a vastly under explored area of research, especially in the context of undergraduate STEM majors.

DEDICATION

"Success is not final; failure is not fatal: it's the courage to continue that counts."

-Winston Churchill

This dissertation is dedicated to everyone who has encountered failure. No matter how devastating it may seem at first, it changes you for the better.

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Contributors

This work was supervised by a dissertation committee consisting of Dr. Mary Margaret Capraro [Chair] and Dr. Dianne Goldsby of the Department of Teaching, Learning and Culture, and Dr. Steven Woltering [Co-chair] and Dr. Victor Wilson of the Department of Educational Psychology.

The experimental design described in Chapters 3 and 4 was developed collaboratively with Dr. Steven Woltering and Trang Nguyen (graduate student in the Department of Educational Psychology) at the Neurobiological lab for Learning and Development in the Department of Educational Psychology. The task was programmed on ePrime software by Yajun Jia (graduate student in the Department of Educational Psychology). All other work conducted for the dissertation was completed by the student independently.

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TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER 1

INTRODUCTION

In a world with increasing technical sophistication, there is an increasing need for a well-educated science, technology, engineering and mathematics (STEM) workforce (President's Council on Jobs and Competitiveness, 2011). However, a high dropout rate among undergraduate STEM majors has been observed (Pal, 2012). Low retention rates have been a constant theme for several years, in spite of rigorous academic screening for admission into the program (Tinto, 2006). Improving recruitment and retention of STEM undergraduates is crucial to sustain the high demand for STEM professionals (Augustine, 2005). There is a need to better understand the causes for the low persistence rates in STEM majors.

Statement of the Problem

STEM (Science, Technology, Engineering and Mathematics) includes a wide variety of majors at the undergraduate level. Some of the STEM majors such as Physical science, and Engineering which require mathematics courses beyond calculus are classified as math-intensive majors (Bressoud, 2011; Musu-Gillette, Wigfield, Harring, & Eccles, 2015). Due to the structure of the curriculum, mathematics is more prominent in these STEM majors. Successfully completing the required mathematics credits is crucial to progress through the major (Chen, 2014). Additionally, being unprepared for university freshmen year mathematics is often cited as one of the reasons undergraduates drop out of math-intensive STEM majors (Budny, LeBold, & Bjedov, 1998). Thus, freshman year math experiences impact students' intention to persist in math-intensive STEM majors.

Undergraduate mathematics courses are infamous for their academic difficulty. Specifically, math-intensive STEM majors are prone to receiving lower grades as compared to non-STEM majors (Adelman, 2006; King, 2015). As most students who enroll in STEM majors are high achievers in high school, they may view low grades as a demotivator rather than an opportunity to learn (Marra, Rodgers, Shen, & Bogue, 2012; Simpson & Maltese, 2017). Even though overcoming academic challenges is an important trait of successful STEM professionals, research about how students process academic challenges is very limited (Henry, Shorter, Charkoudian, Heemstra, & Corwin, 2019). In order to help STEM retention efforts, there is a need for more research to understand student experiences as they progress through a challenging undergraduate major.

This dissertation aims to understand the challenges faced by freshmen in math-intensive STEM programs and their approach to dealing with academic difficulties. First, a meta-analysis is conducted to summarize the effect of freshmen year mathematics course-taking and performance on retention. Next, to explore the role of non-academic factors in navigating the freshmen year, students' journey through the freshmen year is qualitatively analyzed. Further, as all students had unique experiences during their freshmen year, an experimental study was designed to observe their reaction to receiving negative academic feedback in a controlled laboratory setting. Finally, the relationship between STEM freshmen's performance after receiving negative feedback and personality traits was observed.

Background

The journey to successfully completing a STEM degree is composed of multiple steps such as making the choice to pursue STEM, completing the pre-requisites in high school, enrolling in a STEM major at college and so on. With research being conducted at each of these levels, several predictive factors for STEM retention have been identified.

Academic Predictors

Academic indicators such as, high stakes test scores, GPA and math placement scores have been observed to be strong predictors of STEM student retention (Briller, Deess, Calluori, & Joshi, 2004). Specifically, mathematics has been consistently implicated as a major factor. Pre-college mathematics preparation affects the courses that students take in college. While students who take AP mathematics and science courses are more likely to choose and stay in STEM majors (Robinson & Croft, 2003), students who started with non-college level mathematics credits were statistically significantly less likely to persist in math-intensive STEM (Van Dyken, Benson, & Gerard, 2015). Being underprepared in mathematics leads students to enroll in pre-requisite courses, thereby, delaying their time to graduation (Klingbeil, Mercer, Rattan, Raymer, & Reynolds, 2004). Contrary to the common observation, some researchers have found that students are equally likely to persist irrespective of their high school mathematics preparation (Gardner, Pyke, Belcheir, & Schrader, 2007). Even with poor mathematics preparation, placing students into a course suitable for their needs helped students succeed in STEM majors (Buechler, 2004; Lesik, 2007). Course-taking during freshmen year influences students' perceptions of STEM and their trajectory through college.

Given that college mathematics is challenging, some demanding preliminary courses such as Calculus I and II are sometimes referred to as "weed out" or "barrier" courses. The performance in these courses positively correlates with retention (Jiang & Freeman, 2011). While some observed that the order of taking barrier courses impacted student retention (Ohland, Zhang, Thorndyke, & Anderson, 2004), some researchers found that the level of the first mathematics course was predictive of student retention (Van Dyken, 2016). Grades received in mathematics courses at college may serve as indicators of success, irrespective of the level of the course; for example: students earning a grade lower than B+ in Pre-calculus (Skurla & Jamshidi, 2013) or a grade lower than B in intermediate algebra (Buechler, 2004) were generally unsuccessful.

Non-academic Predictors

STEM retention efforts often concentrate on improving academic preparation of students entering STEM majors. However, prior academic achievement was a poor indicator of college performance among STEM majors as compared to non-STEM majors (Jagacinski, 2013). While the need for academic preparation is explicitly mentioned, the need for other skills such as understanding course expectations, navigating unfavorable academic situations and seeking help are implicit requirements to be successful in a STEM major (Cromley, Perez, & Kaplan, 2016). In order to perform and persist in STEM majors, students often have to juggle numerous tasks under stressful conditions.

In addition to cognitive strategies used for learning, behavioral strategies used by engineering students facilitate performance and retention. Students must be capable of using strategies such as managing time and regulating environment to allow learning (e.g., choosing a quiet study place), and recognize the need for assistance either from peers or teachers (Wolters, Fan, & Daugherty, 2003) for positive academic outcomes. Regulation of emotions during challenging situations to persist is also a critical factor for academic success (Pintrich, 2004). Psychological factors such as self-efficacy (Richardson, Abraham, & Bond 2012), motivation (Robbins et al., 2004), and effective coping (Suresh, 2006) have been established as predictors of STEM student retention. Further, individual behaviors vary with their personalities, which might also impact their academic achievement and retention in college (Farsides & Woodfield, 2003; Poropat, 2009). Along with academic preparation, individual characteristics influence STEM student persistence.

Journal Selection

For each of the articles, two possible journals were identified for submission for publication. In order to choose, the criteria used were (a) journal's aim and scope, (b) Impact factor (SCImago Journal Rank (SJR) and Source Normalized Impact per Paper (SNIP)), (c) acceptance rate, (d) type of review, and (e) length of the manuscript. For each article, one high impact and one lower impact journal have been chosen. Articles 1 and 2 have been submitted for publication, while article 3 is being prepared for submission. Table 1 presents the citations for articles 1 and 2 along with the journal choices for article 3.

Table 1
Articles and Proposed Journals

Article	Title		
1	Role of Mathematics in Engineering Freshmen Retention: Meta-Analysis	Accepted for publication in Journal of Mathematics Education: Kopparla, M. (2019). Role of mathematics in retention of undergraduate STEM majors: Meta-analysis.	
2	Maps of Meaning: A Qualitative Study of the Journey of Freshmen Engineering Students	Submitted to European Journal of Engineering Education (20th April, 2019): Kopparla, M., Nguyen, T. & Woltering, S. (2019). Maps of meaning: A qualitative study of the journey of freshmen engineering students.	
		Proposed Journal #1	Proposed Journal #2
3	STEM freshmen's Task performance after receiving negative feedback	*Biological Psychology* • Acceptance rate: 30% • Impact and ranking (SJR/SNIP): 3.07 • Editor in chief: O.V. Lipp • Publisher: Elsevier • Type of review: Peer review • Manuscript length: 21-25 pages	*Experimental Brain Research* • Acceptance rate: N/A • Impact and ranking (SJR/SNIP): 1.917 • Editor in chief: John C. Rothwell • Publisher: Springer • Type of review: Peer review • Manuscript length: maximum of 54000 characters

Article 1: Role of Mathematics in Retention of Undergraduate STEM Majors: A Meta-Analysis

Mathematics performance is important for entering and persisting in math-intensive STEM programs. Mathematics is relevant for STEM majors not only as a means of calculation, but also mathematical thinking supports problem solving and production of innovative solutions (Graves, 2005). STEM freshmen are placed into their first math course based on their high school preparation, and underprepared students are placed in remedial or developmental math courses (Suresh, 2006). While students starting with higher level mathematics are more likely to succeed (Nite, Capraro, Capraro, Morgan, & Peterson, 2014), failure in mathematics courses is a commonly cited reason for dropping out of math-intensive STEM majors (Budny et al., 1998). Specifically, high school mathematics preparation, initial math course and initial math grade in college were significant predictors of retention (Tyson, 2011; Van Dyken, 2016). Thus, students' intentions to stay in a math-intensive STEM major may be influenced by freshman year math course experience.

Purpose

Impact of academic preparation on STEM retention has been extensively studied. In addition, absolute grades received during the freshman year are known to be an important factor in retention of STEM undergraduates (Rask, 2010). As students use grades to assess their fit in the major (Stinebrickner & Stinebrickner, 2009), receiving lower grades in STEM subjects may lead them to perceive a better fit with non-STEM majors (Ost, 2010). Though initial grades received by STEM freshmen impact their trajectory through college, research investigating the role of initial grades has received limited attention. Therefore, the research data conducted through this study quantitatively summarize the role of initial grades in student retention compared to traditional retention such as SAT math scores and first college math course.

Research Questions

1. What is the relationship between SAT math scores and STEM undergraduate retention?
2. What is the relationship between first math course and STEM undergraduate retention?
3. What is the relationship between first math grade and STEM undergraduate retention?

Method

In order to summarize the role of SAT math scores, mathematics course-taking and performance in predicting student retention, a meta-analysis was conducted. A detailed description of the data extraction, adjustments, and analysis are provided in Chapter 2.

Data source. A literature search was conducted to gather existing research articles. The following criteria were used to select articles: (1) only empirical research articles analyzing primary data were included, (2) articles were included only if the participants were undergraduate STEM majors with most or all of them in math-intensive STEM majors, and (3) articles were included only if retention of students is studied in relation to mathematics either at the school or college level.

Data analysis. Methods described by Lipsey and Wilson (2001) were used as a guide for data extraction and analysis. Based on the percentage retention, effect sizes by course and grades were calculated. If point-biserial correlation was reported for ACT/SAT scores, they were converted to standardized mean difference. All effect sizes were converted to Hedge's *g* effect size and corrected for sample size. As the number of studies by predictor were small, a fixed effects model was used. The average effect size was calculated and a homogeneity test performed.

Article 2: Maps of Meaning: A Qualitative Study of the Journey of Freshmen Engineering Student

Several factors influencing STEM student retention have been identified. Exposure to STEM through family members or middle and high school experiences motivate students to pursue STEM majors (Takruri-Rizk, Jensen, & Booth, 2008). Further, successfully completing advanced math and science courses during high school increased the probability of completing a STEM degree (Van Dyken, 2016). Along with academic preparation, a variety of individual characteristics such as self-confidence, motivation, and personality influence college experiences (Robbins et al., 2004; Poropat, 2009). Due to the large number of predictive factors, predicting STEM student retention is very complex (Whalen & Shelly, 2010). There is a need to understand the complex interplay between the factors predicting STEM student retention.

Purpose

A majority of STEM retention research has been conducted using quantitative methodologies, which is restricted by existing literature and hypothesized predictors. However, as qualitative studies do not restrict the variables in the study, they provide a unique approach to understand and improve retention (Borrego, Douglas, & Amelink, 2009). Specifically, qualitative narrative inquiry highlights individual experiences that lead to their ultimate decision to stay or leave the STEM program (Case & Light, 2011). Therefore, a narrative inquiry approach was used to understand the lived experiences of engineering undergraduates and the role of these various factors contributing to either persisting or dropping out.

Research Questions

1. What factors contribute to making an engineering major challenging for freshman engineering majors?
2. What role do mathematics courses play in making an engineering major challenging for freshman engineering majors?
3. What individual factors, academic and non-academic, help engineering freshmen majors persevere in the program?

Method

I designed this study to understand student experiences as they progressed through a challenging STEM major like engineering. In order to understand the lived experiences of freshmen engineering majors, narrative qualitative inquiry was used. A detailed description of recruitment, data collection and data analysis is provided in Chapter 3.

Participants. A recruitment email was sent through the university listserv asking for volunteers to participate in a larger engineering retention study. The criteria to participate were that they must be at least 18 years of age and enrolled as a freshman in the college of engineering. Among the students recruited, those who were willing to participate in an interview were included in this study. The participants were eight freshmen engineering majors in their second semester of college. During the study, three forms of data were collected: (a) responses to a student persistence survey (AWE, 2007), (b) illustrated road map sketch (Meyer & Marx, 2014), and (c) semi-structed interview. All participants were compensated with a $15 Amazon gift card.

Data analysis. To explore the major academic struggles students face during their freshman year, a thematic narrative analysis was most appropriate (Riessman, 2008). The illustrated road maps drawn by the participants gave an overview of the most prominent events during their freshmen year. The participant interviews provided an elaborate description of their social, emotional and academic experiences. First, a narrative story of individual participants is presented highlighting their most prominent experiences or challenges during their freshman year. Through the lens of the Psychological Model for Retention (Bean & Eaton, 2000), the major recurring themes were identified.

Article 3: STEM Freshmen's Task Performance After Receiving Negative Feedback

STEM undergraduate retention efforts often concentrate on improving academic preparation of students entering STEM majors. However, prior academic achievement was a poor indicator of college performance among STEM majors as compared to non-STEM majors (Jagacinski, 2013). Students in undergraduate programs are prone to experiencing grades lower than they expect for the amount of effort they put in (Adelman, 2006). While the need for academic preparation is explicitly mentioned, the need for other skills such as understanding course expectations, navigating unfavorable academic situations and seeking help are unsaid requirements to be successful in STEM major (Cromley, Perez, & Kaplan, 2016). In such situations, psychological factors such as personality may be more crucial for persistence rather than prior academic performance. Even though overcoming academic challenges is an important part of STEM fields, research about how undergraduate STEM majors navigate these challenges is very limited (Henry et al., 2019). Thus, there is a need to understand the role of academic challenges in shaping undergraduate student performance, learning and persistence in STEM majors.

Purpose

Observing students' reactions to academic difficulties in a natural setting is extremely challenging. To the best of my knowledge, there has been no previous research study that observed STEM students' reactions to negative academic feedback. Therefore, this study was designed to observe STEM undergraduates' reactions to negative academic feedback in a laboratory setting. A situation where participants receive negative feedback was simulated and the effects of receiving negative feedback on future task performance was examined relative to personality traits.

Research Questions

The research questions driving this study are:

1. Does receiving negative feedback on task performance impact future task performance?
2. How does task difficulty influence reaction to negative feedback?
3. Do the five personality traits: conscientiousness, emotional stability, openness, agreeableness and extraversion impact student response to negative feedback?

Method

To answer the research questions, an experimental study design with random sampling was used. A detailed description of recruitment, data collection and data analysis are provided in Chapter 4.

Participants. A recruitment email was sent to all engineering freshmen at a university in Central Texas. The criteria to participate was that they must be at least 18 years of age and enrolled as a freshman in the college of engineering. Prospective participants who responded to the initial recruitment email were provided with a list of time slots for participation. Finally, a total of 40 participants registered for a time slot and successfully completed all the required questionnaires and the math task. For the math task, participants were randomly assigned to either a neutral feedback or negative feedback group. Feedback was provided to the participants after completing half of the problems. The neutral feedback read, "*You have finished the first block. Your performance has been recorded. Please start the second block when you are ready*", while the negative feedback reads, "*You have finished the first block. Your reaction times are in the bottom 20% compared to your peers at TAMU. This ranks you as 'poor'. Please start the second block when you are ready by pressing the spacebar*". The feedback given during testing was not representative of their performance. At the end of the experiment, the participants who received the negative feedback were debriefed about the intent of the experiment.

Data analysis. To investigate the effect of receiving negative feedback on immediate task performance, a factorial ANCOVA was performed with the dependent variable being post-test accuracy and independent variables being type of feedback (negative or neutral), task difficulty (easy or hard), and semester in college (1^{st} or 2^{nd}). The covariate was pre-test accuracy. Further, the relationship between personality traits and performance after receiving negative feedback were studied using multiple regression.

Research Compliance Information

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CHAPTER 2

ROLE OF MATHEMATICS IN RETENTION OF UNDERGRADUATE STEM MAJORS: A META-ANALYSIS [1]

The disciplines of STEM (science, technology, engineering, and mathematics) include a wide variety of majors. Some of the STEM majors are known to be math-intensive because they require "mathematics beyond and building upon a full year of single variable calculus" (Bressoud, 2011, p.1). Based on the average number of mathematics courses required, STEM majors such as physical science, computer science, engineering, and chemistry are classified as math-intensive (Musu-Gillette, Wigfield, Harring, & Eccles, 2015). By virtue of the curriculum, mathematics is more prominent in some STEM majors.

Successfully completing required mathematics credits is crucial to progress through math-intensive STEM majors. Students pursuing a bachelor's degree are placed into their first college-level mathematics course based on their high school preparation, and underprepared students are placed in remedial or developmental mathematics courses (Suresh, 2006). The mathematics preparation students receive prior to post-secondary education is critical; students who enter college with higher-level mathematics knowledge and skills are more likely than their peers to succeed within their STEM major (Nite, Capraro, Capraro, Morgan, & Peterson, 2014). Furthermore, failure in college-level mathematics courses has been found to be a critical factorthat influences dropout rates within math-intensive STEM majors (Budny, Bjedov, & LeBold, 1997).

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[1] Reprinted with permission from the Journal of Mathematics Education. Kopparla, M. (2019). Role of mathematics in retention of undergraduate STEM majors: Meta-analysis. *Journal of Mathematics Education*.

Specifically, students' high school mathematics preparation, first college-level mathematics course (e.g., remedial course vs. advanced course), and final grade in their first college-level mathematics course have been found to be significant predictors of retention (Tyson, 2011; Van Dyken, 2016). Thus, students' high school mathematics preparation for post-secondary education and their mathematics experiences during their first year of college have a critical role in determining their success and retention in STEM pathways.

The impact of students' first college-level mathematics course on their retention in STEM majors has been well established within previous research; however, the grade they earned within their first college-level mathematics course has received limited attention in relation to retention rates. Given that mathematics emerges as an important predictor of success in STEM majors, there is a need to summarize quantitatively the role of mathematics course-taking and achievement. Hence, the purpose of this meta-analysis was to summarize the role of mathematics course-taking and performance in predicting student retention. The research questions driving the meta-analysis were as follows:

1. What is the relationship between SAT mathematics scores and retention of undergraduate STEM majors?
2. What is the relationship between the first college-level mathematics course taken and retention for undergraduate STEM majors?
3. What is the relationship between the first college-level mathematics grade received and retention for undergraduate STEM majors?

Literature Review

Recruitment and retention of STEM undergraduates has received much attention in recent decades. The emphasis placed on examining matriculation and retention rates within STEM degree programs has grown as the need for well-educated STEM professionals has increased (President's Council on Jobs and Competitiveness, 2011). However, the percentage of bachelors' degrees received in math-intensive STEM majors has remained constant for over three decades (Bressoud, 2011). There is a need to better understand the factors contributing to undergraduate STEM retention.

SAT Scores and STEM Retention

Traditionally, students' high school grade point average (GPA) and SAT or ACT scores have been considered for admission into institutions of higher education. SAT mathematics scores are considered the most important indicator of high school performance (Jin, 2013) and the "best surrogate for HSGPA [high school GPA]" (Mendez, Buskirk, Lohr, & Haag, 2008, p. 64). Furthermore, research has indicated that higher SAT mathematics scores are correlated with higher probability of students declaring a STEM major, completing a STEM major, and changing from a non-STEM major to a STEM major (Crisp, Nora, & Taggart, 2009; Hielbronner, 2009; Zhang, Anderson, Ohland, & Thorndike, 2004). Moreover, mathematics scores on the SAT have been found to be stronger predictors of STEM major retention, as compared to other majors such as education or business (Hahler & Orr, 2015). As a result, the SAT mathematics score, or the equivalent ACT mathematics score, is considered as a factor when predicting student academic performance in STEM courses and retention in a STEM major.

Even though SAT mathematics scores are considered an important factor in predicting retention within STEM majors, SAT mathematics scores alone may not be able to predict retention of STEM majors. While some researchers have suggested that high school GPA is the only significant predictor of student retention in STEM majors (Johnson, 2012; Lackey, Lackey, Grady, & Davis, 2003), others have argued that the combination of SAT mathematics scores and high school GPA is an effective predictor of retention in STEM majors (Rohr, 2012; Vemulapalli, 2014). However, findings from several previous studies indicated that although the SAT mathematics score was a strong predictor of academic performance in college, it was an inadequate predictor of first-year undergraduate STEM retention (Burton & Ramist, 2001; Jin, 2013; Mattern & Patterson, 2009). Due to the lack of consistency among the research findings, SAT scores should be interpreted with caution.

Mathematics Course and STEM Retention

Successful academic performance and positive experiences during students' freshman year of college (i.e., their first year of college) are considered crucial for ensuring undergraduate retention in STEM majors; however, a majority of the courses a STEM major will take during his or her freshman year of college will be required courses rather than electives. Specifically, in math-intensive STEM degree programs, mathematics and science courses account for nearly half of the freshmen year credit hours (Chen, 2014). The intensive course load freshmen must undertake can be particularly difficult for students who are not prepared for college-level mathematics because they are required to take remedial courses. Mathematics is the most common subject requiring remedial coursework, and this additional coursework may increase the time it takes to complete an undergraduate STEM degree program (Radford, Pearson, Ho, Chambers, & Ferlazzo, 2012).

Students taking remedial courses often dropout of STEM at higher rates as compared to their peers (Van Dyken, 2016). While remedial courses are important for progressing through STEM majors, starting college with calculus or other advanced mathematics courses increases the probability of success.

The first college mathematics courses adequately prepared students will take are calculus courses. Accounting for approximately 8.3% of the total credit hours required to complete the degree plan (Chen, 2014), calculus is considered a major obstacle to receiving a STEM degree. Researchers have consistently observed that performance in calculus is representative of STEM major persistence (Felder, Forrest, Baker-Ward, Deitz, & Morh, 1993; Suresh, 2006). Students who took a calculus course as their first mathematics course in college were significantly more likely to persist in their STEM major (Van Dyken, 2016). However, students who enrolled in calculus during their first semester, but failed the course, were highly likely to leave (Flanders, 2017). Students are required to pass introductory courses to progress through their degree program, but the introductory courses may act as a "barrier" due to their difficulty.

As the academic difficulty level increases, STEM undergraduates are more likely to receive lower grades in college than those they received in high school. Alarmingly, "absolute grades are one of the largest and most persistent factors in the attrition of undergraduates from STEM departments" (Rask, 2010, p.899). Students tend to use grades as a mechanism to gauge their fit within the major (Stinebrickner & Stinebrickner, 2009). Thus, students who receive lower grades in STEM courses may begin to perceive themselves as better suited to a non-STEM major (Ost, 2010). The initial grades students receive during their first undergraduate STEM-related courses in college may significantly influence their inclination to continue or discontinue their journey as a STEM major.

Methods

Literature Search

An article search was conducted using the following databases: ERIC, JSTOR, PsycINFO, and ProQuest Dissertation and Thesis using the Texas A&M library and Google Scholar. The keywords included variants of the following combinations: (undergraduate OR freshmen) AND (science OR technology OR mathematics OR engineering) AND (retention OR persistence OR dropout OR withdrawal). In addition to the preliminary search, an additional manual search of *Journal of Engineering Education*, *Journal of College Student Retention*, *Journal of Higher Education*, *Research in Higher Education*, and *ASEE Conference Proceedings* was performed.

Inclusion Criteria

Only articles published in the past 20 years (between 1998 and 2018) were included. The search results were further narrowed based on the title, abstract, and the entire article. A total of 59 studies, including articles, proceedings, and dissertations were selected based on their title and abstract. After reading each of the 59 studies, 30 studies were found to be relevant to this meta-analysis. The following criteria were used to select articles:

1. Only empirical research articles analyzing primary data were included.
2. Articles were included only if the participants were undergraduate STEM majors with most or all of them in math-intensive STEM majors.
3. Articles were included only if retention of students was studied in relation to mathematics either at the high school or college level.

In case of inadequate information in the article, authors were contacted for required information. Articles were excluded if the authors did not respond or could not provide the requested information. Finally, 19 articles (9 journal articles, 8 conference proceeding articles, and 2 dissertations) were retained and included in the current meta-analysis (see Table 1).

Data Extraction and Coding

The dependent variable was retention in STEM major. While 10 studies included data on retention of students at the end of their freshman year, 7 studies included data on retention and graduation of STEM undergraduates 4-6 years after their initial enrollment. For 2 studies, retention was only reported after 2 and 3 years. For the purpose of this meta-analysis, studies in which researchers reported retention rates at the end of freshman or sophomore years were grouped together as "early retention", and studies in which researchers reported retention after junior or senior years, or degree attainment, were grouped as "later retention". From each study, the percentage retention of students in a STEM major by their first mathematics course and their first mathematics grade was extracted, if available. Because calculus is considered a "barrier" course for undergraduate STEM majors, groups were defined by the following in terms of their first mathematics course: (1) students taking courses below calculus, such as developmental math and pre-calculus, (2) students taking calculus or above, such as Calculus II. For course grade, groups were defined by (1) students receiving A, B, or C in their first mathematics course, (2) students receiving D, F (fail), or W (withdraw) in their first mathematics course.

Mean SAT quantitative score and standard deviation was extracted for both students who remained in their STEM degree program (referred to in this study as STEM *persisters*) and those who did not (referred to as *non-persisters*). Alternately, if group means were not reported, point biserial correlation between STEM major retention and SAT quantitative score was extracted. Other study characteristics such as (a) sample size, (b) gender distribution, (c) cohort year, (d) STEM major distribution, (e) retention measure, and (f) publication type were also coded.

Adjustments and Estimates

Whenever data were presented in the form of graphs instead of tables, WebPlotDigitizer (Rogatgi, 2011) was used to extract data from graphs. For two studies, the researcher of the present meta-analysis relied on the authors' descriptions of the data to obtain the best possible estimate for missing data. Specifically, Lougheed (2015) reported grade distribution only for the pre-calculus course because the other mathematics courses followed a similar distribution; therefore, the same grade distribution was assumed for all mathematics courses. In addition, based on the description in Gardner, Pyke, Belcheir, and Schrader (2007), the distribution of first mathematics course taken was assumed to be the same for students who enrolled and those who persisted in the program.

For pre-college variables such as SAT/ACT, if the scores were presented as intervals (e.g. 200-400), the means of the intervals were calculated based on Sandon (1961). On two occasions, ACT scores were scaled to equivalent SAT scores using the equi-percentile method (Dorans, Lyu, Pommerich, & Houston, 1997). The equi-percentile method ensures the same rank ordering of scores within the sample. If the standard deviation of SAT scores was not reported for the sample, the population standard deviation of 100 was assumed.

Data Analysis

All effect size calculations and conversions were done according to Lipsey and Wilson (2000). Based on the percentage retention, effect sizes by course and grade were calculated. If point-biserial correlation was reported for ACT/SAT scores, they were converted to standardized mean difference. All effect sizes were converted to Hedge's *g* effect size and corrected for sample size. As the number of studies by predictor were small, a fixed effects model was used. The average effect size was calculated and a homogeneity test performed.

Table 2

Summary of Studies Included in the Meta-Analysis. Reprinted with permission from Kopparla (2019).

Study	Publication Type	Major	N	Retention Variable	Predictor
Ackerman, Kanfer, & Calderwood (2013)	Journal article	STEM	23448	graduation	Course, SAT
Callahan & Belcheir (2017)	Journal article	STEM	1139	1-year retention	Grade, Course
Cambel (2012)	Dissertation	STEM*	310	1-year retention	Grade, Course
Cassady & Mulvenon (2009)	Proceeding	Engineering	336	1-year retention	Grade
DeJong & Langenderfer (2012)	Journal article	Engineering	445	graduation	Course
French, Immekus, & Oakes (2005)	Journal article	Engineering	1000	4year retention	SAT
Gardner, Pyke, Belcheir, & Schrader (2007)	Proceeding	Engineering	337	1-year retention	Grade, Course
Hall et al. (2013)	Proceeding	Engineering	289	2-year retention	SAT
Honken & Ralston (2013)	Journal article	Engineering	289	1-year retention	Course
Leuwerke, Robbins, Sawyer, & Hovland (2004)	Journal article	Engineering	844	1-year retention	ACT
Lougheed (2015)	Dissertation	STEM	3777	graduation	Grade, Course
Middleton et al. (2014)	Proceeding	Engineering	615	4-year retention	Grade, Course
Min, Zhang, Long, Anderson, & Ohland (2011)	Journal article	Engineering	35347	graduation	SAT
Moses et al. (2011)	Journal article	Engineering	129	1-year retention	SAT
Palm & Thomas (2015)	Proceeding	Engineering	239	1-year retention	Course, SAT
Reynolds (2008)	Proceeding	Engineering	266	4-year retention	ACT
Scott, Tolson, & Huang (2009)	Journal article	STEM	630	3-year retention	SAT
Van Dyken, Benson, & Gerard (2015)	Proceeding	Engineering	4040	1-year retention	Grade, Course
Yoon, Imbrie, & Reed (2014)	Proceeding	Engineering	1975	graduation	Grade, Course

Note. * Excluding engineering majors.

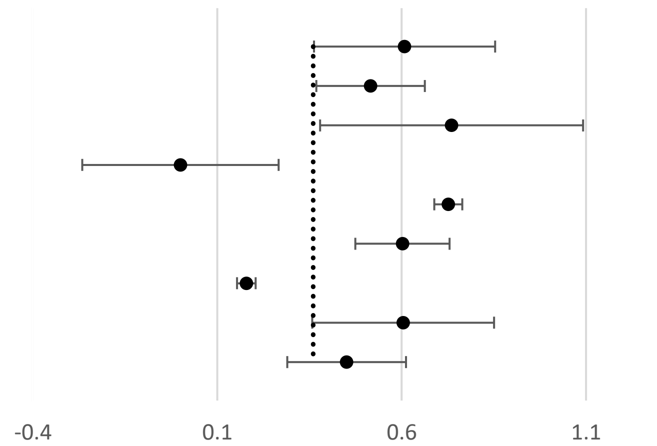
Results

Observations from a total of 75,455 participants were included in the current meta-analysis. Sample sizes of studies varied from 129 to 35,347 (see Table 2). Early retention rates ranged from 50.39% to 79.58%, with an average of 73.68%. Late retention rates ranged from 30.79% to 86.43%, with an average of 77.11%. The overall retention rate was 76.75%.

SAT Mathematics Scores and STEM Undergraduate Retention

There was a consistent positive relationship between SAT scores and STEM retention, with the exception of the findings from Palm and Thomas (2015), in which no relationship between these variables was reported. Standardized mean difference in SAT scores between persisters and non-persisters varied from 0 to 0.74 (see Figure 1). The average effect size was 0.36. Specifically, a moderator analysis with retention type revealed that the effect size for early retention (0.47) was statistically significantly ($p < 0.05$) larger than the effect size for later retention (0.36). The effect sizes were statistically significantly heterogeneous. However, rejection of the homogeneity assumption may be an artifact of large sample sizes. When studies with large sample sizes, Ackerman, Kanfer, and Calderwood (2013) and Min et al. (2011) were excluded, the average effect size increased to 0.52. After the exclusion of large sample sizes, the effect sizes were still found to be statistically significantly heterogeneous. Additionally, there was no statistically significant ($p > 0.05$) difference between the average effect size reported in the journal articles (0.42) and that reported in the conference proceedings (0.36).

	Study	% Weights	Hedge's *g* effect sizes
Early retention	Hall (2013)	0.67%	
	Leuwerke et al. (2004)	1.87%	
	Moses et al. (2011)	0.32%	
	Palm & Thomas (2015)	0.57%	
Late retention	Ackerman et al. (2013)	28.17%	
	French et al. (2005)	2.49%	
	Min (2011)	63.67%	
	Reynolds (2008)	0.67%	
	Scott et al. (2009)	1.57%	



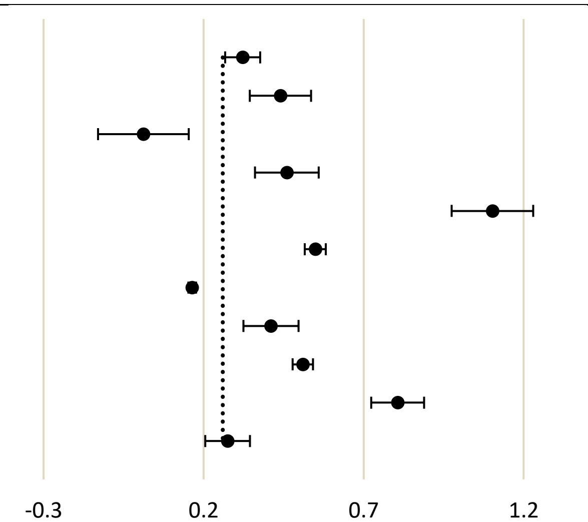
Test for Heterogeneity: Chi-squared = 594.45, df = 8, p < 0.05
$I^2 = 98.65\%$

Figure 1. Forest plot for the effect of SAT math scores on STEM undergraduate retention. Dotted line represents the overall effect size (0.36). Reprinted with permission from Kopparla (2019).

First Mathematics Course and STEM Undergraduate Retention

When separated by the first mathematics course taken, students whose first college-level mathematics course was calculus or another upper-level mathematics course were more likely to persist with an average effect size of 0.26. The effect sizes were statistically significantly heterogeneous. Specifically, the average effect size for early retention (0.5) was statistically significantly ($p < 0.05$) higher than the effect size for later retention (0.22). The early retention rate for students starting with calculus or higher was 83.33% as compared to 63.91% retention for students enrolled in courses that are mathematically less advanced than calculus. Late retention rates for students starting with a lower-level mathematics course (70.92%) were not drastically different from students starting with calculus or higher (72.16%). About 70% of the weight was assigned to Ackerman et al. (2013) due to the study's large sample size. When this study was excluded from the analysis, the average effect size increased to 0.5. Then, the average late retention rate of students starting with a calculus course or higher was 54.89%, and the retention rate for students starting with courses lower than calculus was 30.92%. Additionally, publication type was a moderator with journal articles (0.18) reporting a statistically significantly ($p < 0.05$) lower effect size as compared to dissertation and conference publications (0.53).

	Study	% Weights	Hedge's *g* effect size
Early retention	Callahan & Belcheir (2017)	3.36%	
	Cambel (2012)	1.10%	
	Gardner et al. (2007)	0.50%	
	Honken & Ralston (2013)	1.02%	
	Palm & Thompson (2015)	0.62%	
	VanDyken et al. (2015)	9.30%	
Late retention	Ackerman et al. (2013)	69.26%	
	DeJong & Langenderfer (2012)	1.36%	
	Lougheed (2015)	9.95%	
	Middleton et al. (2014)	1.47%	
	Yoon et al. (2014)	2.07%	



Test for Heterogeneity: Chi-squared = 826.58, df = 10, p < 0.05
$I^2 = 98.8\%$

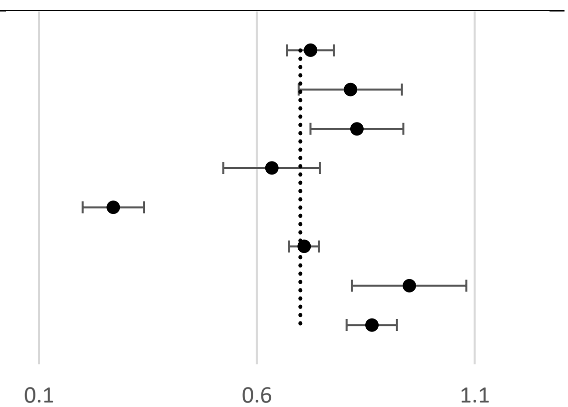
Figure 2. Forest Plot for the effect first math course on STEM undergraduate retention. Dotted line represents the overall effect size (0.26). Reprinted with permission from Kopparla (2019).

First Mathematics Grade and STEM Undergraduate Retention

When separated by the first mathematics grade, students who obtained a grade of C or higher were more likely to persist with an average effect size of 0.70. The average effect size for early retention (0.62) was statistically significantly lower than the effect size for later retention (0.76). The early persistence rate of students who received an A, B, or C grade (80.76%) was significantly higher than the persistence rates of students who received a D, F, or W grade (51.97%). Similarly, the late persistence rate of students who received an A, B, or C grade (54.08%) was significantly higher than the persistence rate of students who received a D, F, or W grade (16.48%). The effect sizes were statistically significantly heterogeneous. A subgroup analysis by publication type was not realistic because most of the articles reporting first course grade were conference proceedings.

	Studies	% Weights
Early retention	Callahan & Belcheir (2017)	17.19%
	Cambel (2012)	3.59%
	Cassady & Mulvenon (2009)	4.44%
	Gardner et al. (2007)	4.10%
	VanDyken et al. (2015)	10.21%
Late retention	Lougheed (2015)	42.46%
	Middleton et al. (2014)	2.93%
	Yoon et al. (2014)	15.08%

Forest Plot



Test for Heterogeneity: Chi-squared = 146.25, df = 7, $p < 0.05$
$I^2 = 95.21\%$

Figure 3. Forest plot for the effect first math course on STEM undergraduate retention. Dotted line represents the overall effect size (0.7). Reprinted with permission from Kopparla (2019).

Limitations

STEM retention is a heavily researched subject, and a variety of predictors and retention variables are used in literature. As a result, the number of studies included in this meta-analysis is small, and journal articles comprise only about 50% of the published works. Further, a publication bias between published and unpublished literature was found for first mathematics course. As a majority of the studies in which first mathematics grade was used as a predictor are unpublished, the effect size may be biased. There is a need for more empirical research to explore the role of initial grades in STEM retention.

Discussion

Mathematics performance is considered an important predictor of success in STEM majors. A meta-analytic approach was used to investigate the value of SAT mathematics score, first college mathematics course, and first college mathematics grade in predicting STEM undergraduate retention. On average, the strongest predictor of retention was first mathematics grade, followed by SAT mathematics score and first college mathematics course.

Researchers of STEM retention have primarily concentrated their research on academic factors such as SAT scores and students' first college mathematics course while frequently overlooking the affective components of transitioning to college. Students within math-intensive STEM majors have been found to receive relatively lower grades when compared to peers in non-STEM majors (King, 2015). Moreover, incoming STEM majors are often ill-equipped to deal with lower grades or academic challenges (Marra, Rodgers, Shen, & Bogue, 2012). As students generally use introductory course grades to assess their fit in the major, receiving lower grades may lead to discontinuing the major (Main, Mumford, & Ohland, 2015). Results from this meta-analysis reinforce the importance of initial college grades. Students' first mathematics grade was found to have the strongest relationship with STEM retention. Irrespective of the first college mathematics course taken, students who made a C or higher in their first mathematics course were more likely to persist. However, students who received similar grades might have had vastly different experiences during their first semester of college due to variables such as different classes/class structure, instructors, peers, or other factors. Additional research is required to understand the role of first semester experiences in relation to initial grades in student retention. There is a need to understand how students process their academic challenges at the university level. Further insight into this matter may help educators at both the K-12 and post-secondary level better understand how to prepare and foster their students' knowledge and ability to adapt within academic contexts.

While mathematics preparation (i.e., SAT mathematics scores and first college mathematics course) is considered an important predictor of retention, its impact on early retention was significantly larger than on later retention. Specifically, the impacts of placing students in remedial or developmental mathematics courses has been controversial. Previous reviews have indicated that these programs lower the rate of attrition (Lesik, 2007). Similarly, results of this meta-analysis suggest being placed in a mathematics course lower than calculus does not place students at a disadvantage. While students placed in remedial or developmental mathematics courses may leave at a higher rate during their first or second year, the 4-year retention or graduation rates only differed marginally. As students progressed through the major, their initial preparation seemed to have a smaller effect on retention. This trend may signify the role of other non-academic characteristics such as study skills, self-efficacy, motivation, or personality on retention (Moses et al., 2011; Robbins et al., 2004). In order to improve retention rates of STEM undergraduates, there is a need to understand the role of non-academic and affective factors during their journey through the major.

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CHAPTER 3

MAPS OF MEANING: A QUALITATIVE STUDY OF THE JOURNEY OF FRESHMEN ENGINEERING STUDENTS

A shortage of engineers and scientists has been identified in the United States. There is a need for well-educated engineers to take up important engineering and technology jobs, and withstand the upcoming wave of retirements (Vest, 2011). Recruitment and retention of engineers at the undergraduate level is crucial to sustain the high demand for engineers (Augustine, 2005). However, undergraduate engineering majors experience a high dropout rate. An overall four-year graduation rate of 33% and a six-year graduation rate of less than 60% was recorded (Yoder, 2012). This alarming trend has remained constant for the past several decades (Tinto, 2006) and reversing it would need immediate attention.

Engineering is considered a math-intensive major. Within the 4-year curriculum, mathematics courses constitute about 8.3% of the course load (Chen, 2014). Due to the change in difficulty level from secondary to postsecondary mathematics, students may receive unexpectedly low grades during their freshmen year. Unfavorable academic experiences in initial mathematics courses lead several engineering undergraduates to quit the major (Clarkson, Ntow, Chidthachack, & Crotty, 2015). While receiving grades lower than expected is a common occurrence among freshmen engineers, absolute grades significantly influence student's intent to persist in a STEM major (Rask, 2010). Thus, student success during the freshmen year depends not only on their academic preparation, but also their ability to persist in the face of academic challenges (Besterfield-Sacre, Atman, & Shuman, 1997). In addition to academic preparation, individual characteristics have a predictive effect on engineering retention.

While a variety of factors influencing retention have been identified, there is a strong impetus to understand the complex interplay between them. As qualitative studies provide an overview of the factors in a real context, they provide a unique approach to understand and improve retention (Borrego, Douglas, & Amelink, 2009). Specifically, qualitative narrative inquiry highlights individual experiences that lead to their ultimate decision to stay or leave the engineering program (Case & Light, 2011). In the current study, narrative inquiry is used to understand the lived experiences of engineering undergraduates and the role of these various factors contributing to either persisting or dropping out.

Theoretical Framework and Literature Review

The problem of student retention in college can be explained using (a) external factors such as institutional characteristics, economic and societal influences, or (b) individual factors such as psychological characteristics and interaction with environment. Individual models or psychological models assume that an individual's strengths, weaknesses and behavior within the institution are responsible for retention (Aljohani, 2016). In this study, student retention is approached through an individual perspective; therefore, a psychological theoretical framework is suitable.

The psychological model of retention (PMR) by Bean and Eaton (2001) was chosen as the theoretical framework for this study. PMR is one of the most comprehensive psychological models in the field of undergraduate retention (Braxton & Hirschy, 2005; Steenkamp, Nel, & Carroll, 2017). PMR indicates that students enter the institution with several unique characteristics such as varying degrees of subject knowledge, self-efficacy beliefs, preferred study techniques, and other skills developed through past experiences. When introduced to the new institutional environment, students are required to adapt. The interaction between the student experiences, individual characteristics and behavior contribute to the final decision of persistence or dropping out of college (Figure 4).

PMR draws on four psychological theories to explain student behavior in the new institutional environment, namely, (a) Attitude-behavior theory, (b) Self-efficacy theory, (c) Attribution theory, and (d) Coping behavioral theory. Attitude-behavior theory forms the structure of the model, while self-efficacy theory, attribution theory, and coping behavioral theory explain interactions and psychological processes within the institutional environment (For more detailed description of the PMR, refer to Bean and Eaton, 2001).

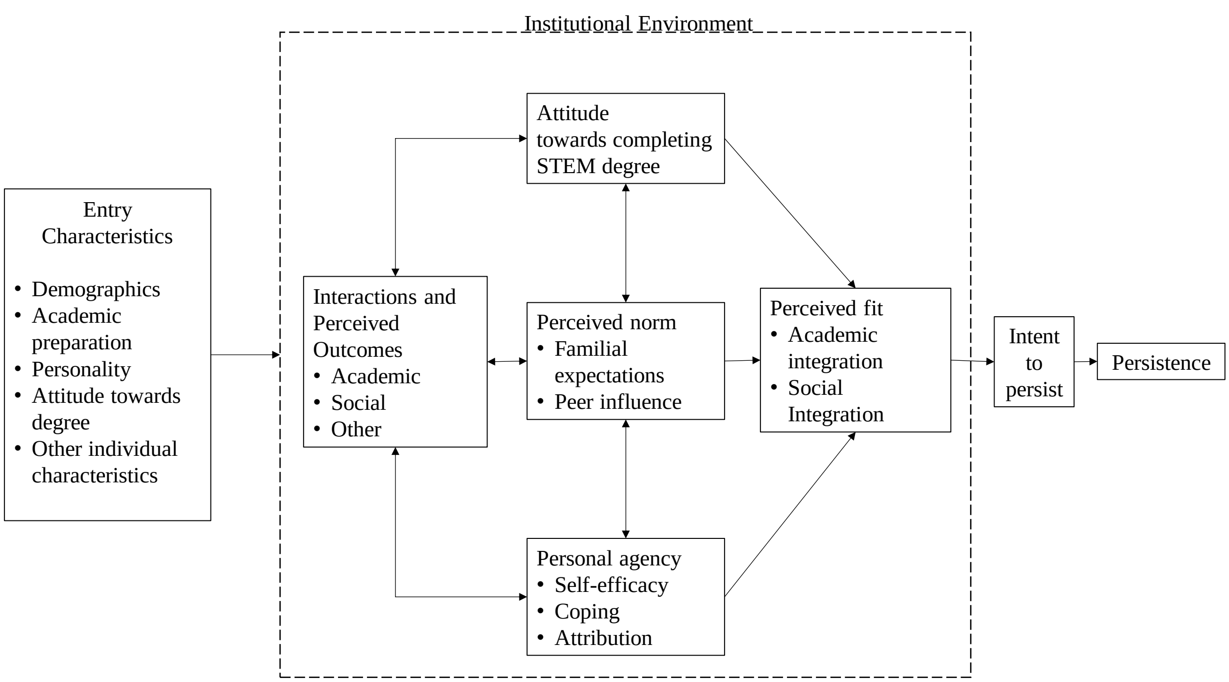

Figure 4. Pictorial representation of theoretical framework used in this study, based on the Psychological Model of Retention by Bean and Eaton (2001).

Attitude-behavior Theory

Ajzen (1993) described attitude as "an individual's disposition to react with a certain degree of favorableness or unfavorableness to an object, behavior, person, institution, or event – or to any discriminable aspect of an individual's world" (p. 41). Attitude-behavior theory suggests that the intent to behave in a specific manner is the strongest predictor of behavior (Bentler & Speckart, 1979). In the context of the psychological model of retention, the behavior under observation is persistence. Intent to graduate was an important predictor of undergraduate retention, and more specifically for engineering undergraduates (Eris et al., 2010). The factors shaping intent have been researched and updated since the model was first proposed. Intent to behave is determined by (a) attitude towards behavior, (b) perceived norm, and (c) personal agency (Montaño, Kasprzyk, Glanz, Rimer, & Viswanath, 2008).

The first determinant, attitude refers to the individual's attitude towards persisting in the program and receiving the engineering degree. The difference between a student who left in good academic standing and bad academic standing could be explained by their difference in attitude towards the degree and their confidence in completing it (Besterfield-Sacre, Atman, & Shuman, 1997; Hilpert, Stump, Husman, & Kim, 2008). A student with a positive attitude towards receiving the engineering degree was more likely to persist.

The second determinant, perceived norm refers to the social and environmental expectation or pressure a student feels towards receiving the degree. Students in engineering reported that their positive interactions with peers, faculty and advisors impacted their decision to stay (Brown & Williamson, 2005). In addition, having a high achieving peer group or high expectations from family compels students to persist (Mbuva, 2011).

The third determinant, personal agency is comprised of self-efficacy beliefs and perceived control, whose roles are further explored using self-efficacy theory and attribution theory.

Self-efficacy Theory

Self-efficacy is the perception of one's own ability to perform a specific academic task and thereby achieve a specific academic goal or outcome (Bandura, 1986). It is a motivational factor that "affects people's choice of activities and behavioral settings, how much effort they expend, and how long they will persist in the face of obstacles and aversive experiences" (Bandura & Adams, 1977, pp. 287-288). An individual with higher self-efficacy, tends to put in stronger effort towards a desired goal. Self-efficacy beliefs are subject specific (Marsh, Walker, & Debus, 1991), i.e., an individual may have high self-efficacy in mathematics, but not in science.

According to the psychological model of retention, students enter an institutional environment with certain self-efficacy beliefs because of their past experiences. Self-efficacy is majorly derived from personal accomplishment; therefore, repeated success improves self-efficacy and repeated failures lower it (Hutchison, Follman, Sumpter, & Bodner, 2006). However, in unfamiliar situations, source of efficacy beliefs may shift towards peer comparisons. Specifically, engineering freshmen primarily estimated their self-efficacy or their ability to perform based on their peer performance (Hutchison-Green, Follman, & Bodner, 2008). Through interactions with the institutional environment, students constantly revise their self-efficacy beliefs and adjust their goals.

Coping Strategies

Coping is a collection of behaviors that individuals use to deal with stressful situations. Two major types of coping strategies are approach and avoidance which refer to the "cognitive and emotional activity that is oriented either toward or away from" the cause of stress (Roth & Cohen, 1986). Coping strategies are necessary especially for undergraduates to deal with social and academic stress and build resilience (Wright & Masten, 2005). Using approach strategies was a significant predictor of academic success (DeBerard, Spielmans, & Julka, 2004), whereas students who use avoidance behaviors were less likely to be integrated into the institution and persist. Students' choice of coping strategy was associated with personal characteristics. Students with lower self-efficacy employed avoidance strategies to deal with challenging situations rather than proactively approach them (Hsieh, Sullivan, Sass, & Guerra, 2012). Coping strategies play an important role as engineering undergraduates are often required to deal with social and academic stress.

Attribution Theory

Attribution is defined as the perceived relationship between one's behavior and outcome (Weiner, 2010). An aspect of attribution theory, locus of control (LoC), refers to "general predisposition to perceive control, or lack thereof, across various situations" (Turner & Gellman, 2013, p.74). While individuals with an internal LoC identify personal attributes to explain outcomes and experiences, those with an external LoC identify external factors beyond one's control to explain outcomes or experiences (Rotter, 1966). According to the psychological model of retention, as students with an internal locus of control believe that they can control the outcome, they are more motivated, driven to achieve, and likely to persist.

LoC is a prominent factor in unstructured environments like college (Anderson, Hattie, & Hamilton, 2005). Specifically, among engineering freshmen, retention positively correlated with an internal locus of control (Moses et al., 2011). While high external LoC is detrimental for academic performance, high internal LoC is beneficial. In addition, an internal LoC was associated with higher self-efficacy and use of approach coping strategies (Sullivan, 2010). While the significance of LoC as predictor of engineering retention is debated (Hall et al., 2015; Moses et al., 2011), LoC is an affective factor that indirectly influences student behaviors and eventually retention.

In summary, PMR suggests students enter the institution with unique characteristics. These entry characteristics influence student's experiences during college. Further, through interactions with the environment, they constantly revise their beliefs, attitudes, perceived norms and behaviors. Students are successful if their interactions with the new environment lead to a positive attitude, constructive approaches to dealing with challenges, better self-efficacy, and an internal locus of control. The interactions between individual dispositions and institutional environment shape students' perceived fit within the institution. Students who feel academically and socially integrated have a higher likelihood of persisting. While students who perceive a good fit intend to persist, those who perceive a poor fit may not intent to persist in the major.

Research Questions

1. How do freshmen engineering majors characterize their first year in college? What factors contribute to making an engineering major challenging?

2. Using the psychological model of retention as a framework, do specific individual characteristics, academic or non-academic, help engineering freshmen majors persevere in the program?

Methods

Setting

Kingslanding University (pseudonym) is a large public University in central Texas. The college of engineering reported that six-year graduation rates were about 80%, and four-year graduation rates were only about 40% ("Student Retention and Graduation", n.d.). With multiple engineering degree options, all students were first admitted into general engineering and through the entry-to-a-major (ETAM) process, could choose their major after they completed their pre-requisites.

Participants

A recruitment email was sent through the university listserv asking for volunteers to participate in a larger engineering retention study. The criteria to participate were that they must be 18 years of age and enrolled as a freshman in the college of engineering. Among the students recruited, those who were willing to participate in an interview were included in this study. As all participants were freshmen, they were 18-19 years old and enrolled in general engineering major. Eight students, Ned, Benjen, Jon, Rob, Theon, Arya, Bran and Rickon (pseudonyms) volunteered to participate. Arya was the only female participant. All participants were compensated with a $15 Amazon gift card.

Data Collection

To answer the research questions, a narrative inquiry approach was used. Narrative inquiry method explores "the lived and told stories of individuals" (p. 67, Creswell & Poth, 2018). Narrative inquiry is based on the premise that human beings are natural story tellers who experience and visualize life as a story (Connelly & Clandinin, 1990). In order to understand individual experiences through the first year of the engineering program, three forms of data were collected: (a) Student persistence survey, (b) illustrated road map sketch, and (c) semi-structured interview. The interview protocol is provided in the Appendix.

Student persistence survey. The student persistence in engineering survey was developed by an NSF funded project, AWE (Assessing Women and Men in Engineering) to understand the factors affecting retention. The persistence questionnaire was composed of 17 multiple choice questions and 3 free response questions (AWE, 2007). The survey measured (a) initial commitment towards engineering, (b) factors contributing to persistence/leaving, (c) participation in academic and extra-curricular activities, and (d) confidence in completing the current degree.

Illustrated roadmap sketch. The participants were asked to think about their journey into the engineering program and through the first year. They were provided with different colored pens and asked them to draw an illustrated road map of their journey. The road mapping activity to study undergraduate retention was adapted from Meyer and Marx (2014). Once they completed their sketch, they narrated their experiences during the first year of college and explained their illustrated road map. An audio recording of the conversation was made and transcribed.

Semi-structured interview. After the road mapping activity, a semi-structured interview was conducted to further explore participant experiences during their freshmen year. While an interview protocol (see Appendix A) was followed, occasionally additional questions were asked for the sake of clarification or elaboration. The interviews were recorded and transcribed.

Analysis

To explore the major academic struggles that students face during their freshman year, a thematic narrative analysis was most appropriate (Riessman, 2008). The illustrated road maps drawn by the participants gave an overview of the most prominent events during their freshmen year. The participant interviews provided an elaborate description of their social, emotional and academic experiences. First, a narrative story of individual participants is presented highlighting the most prominent experiences or challenges during the freshman year. Through the lens of the Psychological Model for Retention (Bean & Eaton, 2000), major recurring themes were identified.

Participant Narratives

Based on the participants' narratives, road map sketches and survey responses, these freshman engineering majors were categorized into three types: (1) students who were well prepared for the program, and faced little or no difficulty navigating the freshman year, (2) students who were prepared for the program, faced moderate difficulties, and were confident about finishing, and (3) students who were un-prepared for the program, faced severe difficulties and were not confident about finishing the degree. This categorization, similar to prior literature (Arendale, 2001; Malm, Bryngfors, & Morner, 2011), represent groups with "strong", "average" and "weak" academic preparation. The groups were used to highlight the differences and similarities between the participants. Within each group, participant experiences are described through the lens of the theoretical framework.

Group 1

Group 1 was composed of Benjen and Theon. They were high performing engineering freshmen. They both reported having almost no difficulty during their freshmen year.

Benjen. One of the main reasons Benjen had chosen to take up engineering was the job prospects. He elaborated:

> graduating as an engineer will not completely ensure that you'll get a paying standard job, but it does make it really likely. I've heard so many horror stories about people going to college and then just drowning in debt and I didn't want that to be me.

Besides the monetary benefits, he enjoyed problem solving and mathematics. Benjen had a few friends who were going into engineering and interacting with them was an added motivation. Coming into the program at Kingslanding, Benjen noticed his high school had adequately prepared him as he "knew what [he] was signing up for before [he] came" to Kingslanding and the experience was "pretty much what [he] expected". As a result, Benjen did not face any academic challenges during the first year.

However, he still considered engineering as a challenging major because of the time commitment and the difficulty of the material. Comparing the difficulty level of high school and college, Benjen commented that he "definitely did not have to work nearly as hard in high school". He also noticed that he, as an engineering major, had to work ten times harder than his roommate, who enrolled for the same number of hours having taken a different major. He further explained, "I've heard that a lot of the material just gets harder from this point on. So, if this is the easiest point, I think things get pretty hard … So, I would say it is a heart pounding major."

In his road map (Figure 5), he depicted his experience in terms of the relative time he had spent on his course work. As he was drawing his road map, Benjen noticed the prominence of math courses during his first year:

> it's interesting to look now that I've actually thought about how much more effort, I had put in like Calc I and Calc II … not like in an absolute sense but relative to all of my other classes. Last semester, Calc 1 was one of my only hard classes and now I think Physics 218 is just as hard. And so, I spend just as much time with those.

While most of his journey was smooth, his only hiccup was that he took 17 credit hours during his second semester. Once he had dropped four credit hours, he was comfortable with the course load.

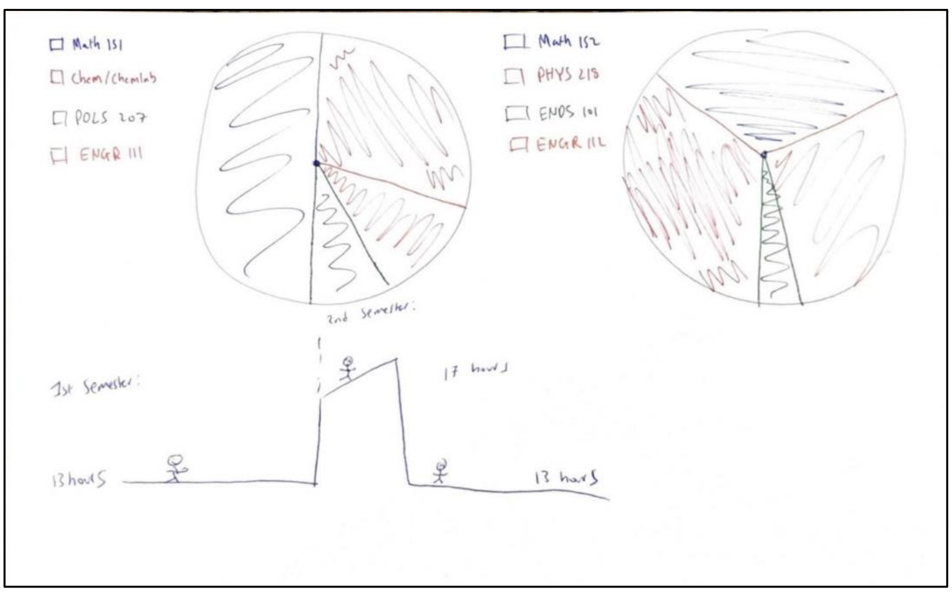

Figure 5. Road map sketch by Benjen.

Theon. The biggest factor for Theon to take up engineering was that his dad was an engineer. He was inspired to pursue engineering from a very young age. Additionally, he was fascinated by airplanes “since [he] was a little kid” and wanted to “do something with that, when [he] got older”. He added that engineering allows him to earn “lots of money straight out of college”, which was helpful in making his choice. In preparation to go into the engineering major, Theon attended a rigorous high school. Talking about his high school experiences, Theon explained:

> while it was definitely a very stressful 4 years, it probably over prepared me for college … they'd make us take college level classes right from our freshman year. Although it was a pretty big jump from middle school to high school the classwork was definitely very challenging. I mean it was on the college level.

As a result of his preparation, Theon was having a much easier time in college as compared to high school. He added:

> I kind of feel like there is a lot more work in high school that I didn't really care about but [in college] I mostly take … classes that I care about ... I think because I actually care about what I'm doing it's a lot easier

In addition to facing no academic difficulties, Theon appeared to be underwhelmed by his freshmen year. As he drew his road map (Figure 6) as his journey on an upward slope, he explicitly mentioned that the slope did not indicate difficulty, but only a progression through his courses. Describing most courses as “easy”, “pointless”, or a “joke”, Theon was able to earn A’s in most of his courses. He indicated his distaste for certain group projects, which were not a major setback, by saying that the experience made him “want to drink bleach, honestly”.

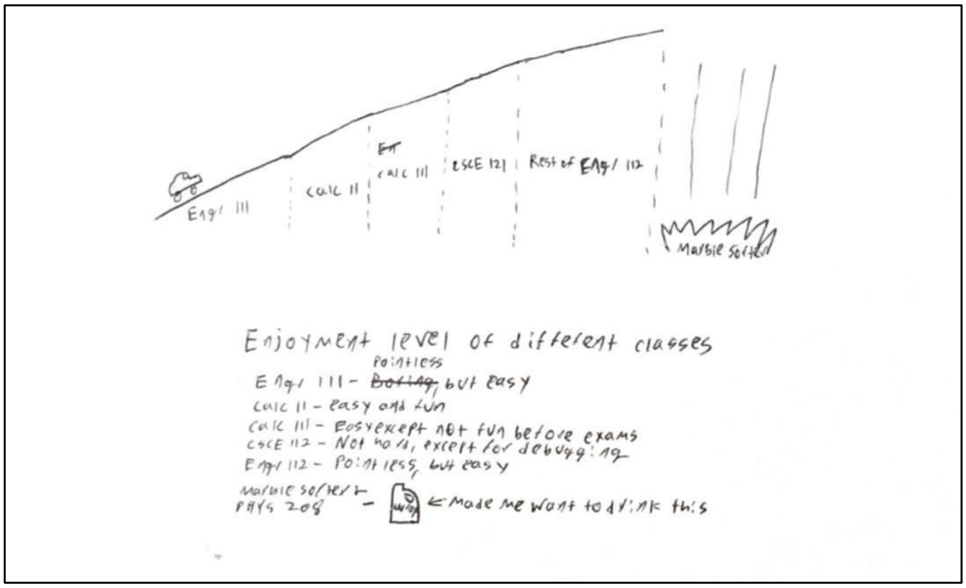

Figure 6. Road map sketch by Theon.

Characteristics of Group 1. Both Benjen and Theon noticed that they were outliers in the sense that most of their peers were having a much harder time navigating through the freshmen year. Benjen explained:

> I was more prepared, more than other people I know, like a … few people I know who came here [from other high schools] … they thought they were super prepared for college and then they came here and they've been struggling a lot.

Theon had a similar experience and explained, “the math courses [at college], some people claim they're really hard, but for [him] they were like a complete joke compared to high school”. Benjen thought “it was kind of fun like silently laughing at all [his] friends who were spending hours [studying] … while [he] was just, you know, having a good time”.

Due to their academic preparation, both Benjen and Theon showed very high self-efficacy. They were not discouraged by grades or the effort needed to be successful in the program. Benjen explained that he was expecting a lower grade in one of his classes, “not because [he couldn't] learn the material, but because [he] was an idiot and skipped a lot of labs and" classes. Theon blamed his habit of procrastination for having to work extra hard on some assignments where he had to stay "up to like 4 am" the day before to finish.

Group 2

Jon, Rob and Arya were prepared for the rigor of college through their high school experiences. Unlike participants in group 1 who had no academic struggles, participants within group 2 reported their journeys through the first year of college as somewhat challenging. However, group 2 was very confident about completing their engineering degree.

Jon. Jon knew that the engineering program at Kingslanding University was great, mainly because of his dad who went through Kingslanding as an engineer, Jon further described, "my whole family is … engineers, I have two older sisters and they both went to engineering and one was actually at Kingslanding also." In addition, he acknowledged that he "hated English and History", and was "only good at math and science" which steered him towards choosing an engineering major.

In his road map (Figure 7), during the first semester, Jon illustrated himself as being attacked with arrows by chemistry, as it was the "the hardest part about first semester." In addition, he is seen dodging a football as Jon was enrolled in the Corps of Cadets, and attending the football home games was a prominent part of the corps' requirement. As the football game took "the whole Saturday, which wasn't too bad", it still took time away from studying. During his first semester, he felt that a hill was protecting him from being hurt by the arrows and the football. The hill represented his high school preparation in addition to "a lot of cushion" that freshmen are provided with, to correct their behavior.

During his second semester, Jon was no longer being attacked but held the bow and arrow, indicating an internal LoC. While he was shooting on target for most courses, differential equations course was particularly challenging. “[He] drew targets, like blurred in and out of reality, because that's how [he was] picturing differential equations like, it's not like real”. Jon was elated that differential equations would be the last math course he was required to take. Explaining the difficulty of classes at college, Jon said, “take your toughest class in high school and that’s probably going to be your easiest class in college.”

Further, he explained the role of his peers in successfully navigating the first year:

the problem is, [studying a lot is] all people do, so... I'd say get involved and make friends with people in their major. Because that helps the most … If I didn’t know anyone, I would miss a lot of assignments because … there's so many things you have to do. Even in the face of moderate academic challenges, Jon was very confident that he would complete the degree.

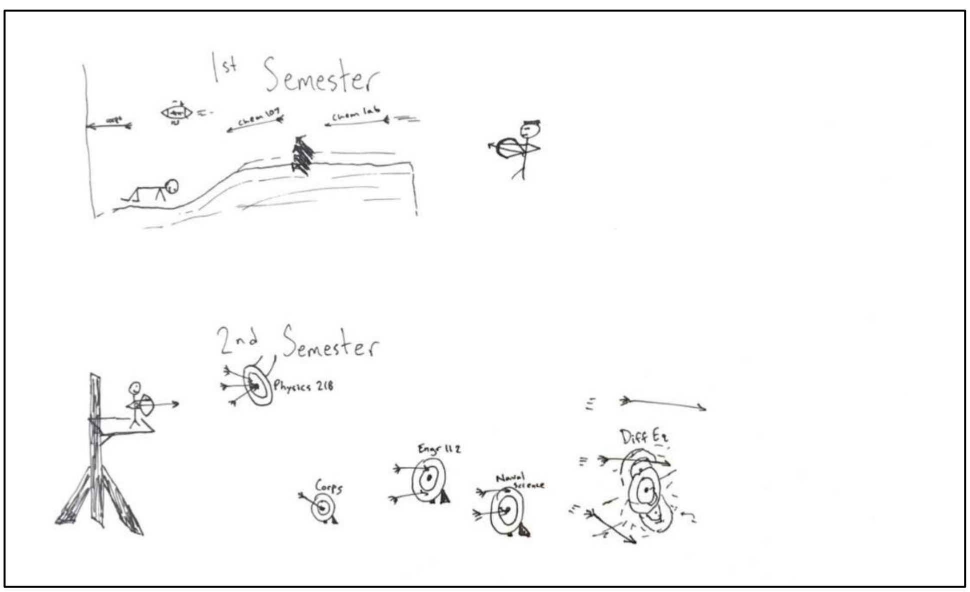

Figure 7. Road map sketch by Jon.

Rob. Rob came into the engineering program with a positive attitude towards his major. He had developed a high self-efficacy for hands-on exploration through his prior experiences where he worked on cars and other equipment. He also explained his love for problem solving:

> I started having this want to just do problem solving, just because of computer science and stuff like that where, you know, the little short little high you get every time you solve a really hard problem. That feeling, well, that's why I choose engineering.

Rob reported that his pre-university experiences had "kind of" prepared him for the engineering major. While he was happy with the STEM content knowledge and problem-solving skills he had acquired, he was unhappy with the non-STEM related courses.

Rob's road map showed four distinct stages during the freshman year which grew darker and less colorful as time passed representing the intensity of the program and hardships that students endure. He depicted freshmen as naïve fish subjected to the horrors of college. Rob depicted the beginning of college as a warm colorful time when the idea of college was exciting. Transitioning from the "good old days", he viewed that first few weeks of the semester as the "honeymoon phase". As "classes aren't that hard in the beginning, no one is really doing anything", and this was a relatively laid-back period where Rob got acquainted with his peers and life as an undergraduate.

Rob titled the rest of the first semester as "shark" phase, where the professors are the sharks yelling at the freshmen, "suffer!" when they actually mean "learn". The second semester escalated in terms of difficulty and thus was titled "viperfish" phase, where the professors and college in general represented the viperfish. Rob elaborated the perceived viperfish malice:

> bunch of fish in the middle [are] huddled around each other, trying to survive, get through and these viperfish are surrounding them and showing them pieces of light that

> you're going to make it to the end, but you won't because we [viperfish] are going to eat you before you do.

Rob’s road map, which showed him as a fish navigating a dangerous college terrain, indicated an external locus of control. Further, he was not convinced that the classes were structured for student success, he questioned, “how are we supposed to learn all this advanced physics and mathematics in 4 months? They just kind of shove it down your throat and call it weed out classes and those are really fundamental classes”. Rob had a negative attitude towards the courses he was taking, he explained:

> I don't think we're paying for classes at this point, even though they make it sound like it. The real thing we're paying for is the [Kingslanding] network we're going to have when we leave and the jobs we might get. It's the opportunity cost that we are paying.

Within the ongoing struggle at college, Rob indicated an approach coping strategy by seeking opportunities that could help him academically (reported on persistence survey). He emphasized that students should ask for help when they need it. He noted that there are a lot of good opportunities from which the students choose. Rob using “food” as a metaphor for “anything like opportunities, friends, people, decisions” noticed that “there’s food, there’s really good food, there’s awesome food, tasty food, best food and we really can’t decide which one to get”. Rob, when faced with academic challenges not only spent more time studying but also sought help from professors, SI (supplementary instruction) sessions, and peers. He was thankful that he had made “smart friends unknowingly”.

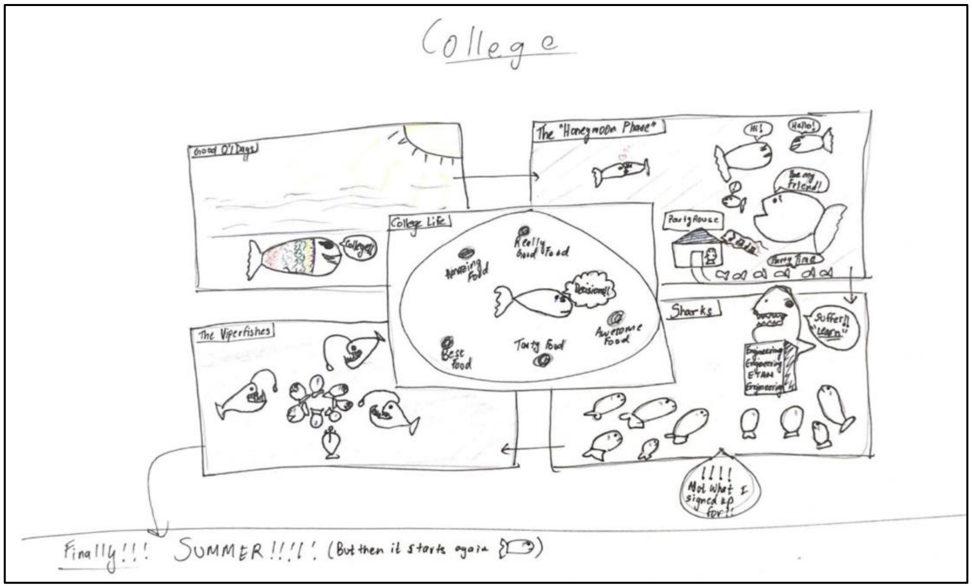

Figure 8. Road map sketch by Rob.

Arya. Arya described her family expectations as prominent factors in her career choice, “I guess this is very stereotypical, but there’s always that thing that Asians become doctors or engineers and that’s same for my family…to become successful you have to be an engineer or a doctor”. Choosing engineering was easy for her as she enjoyed doing math and science. In preparation to take up engineering, Arya went to a math and science academy in high school. Arya was very glad that she went to the academy as she learnt about the “connections between like all the math and science to engineering”.

Arya, having come into the program with sufficient preparation, still considered the program challenging. In her road map, she separately depicted her academic and social involvement. She noticed that her social life during the two semesters was a “huge contrast”. While she was uncomfortable being involved in the Bollywood team during the first semester, Arya felt more comfortable in the redcross during her second semester. Within red cross, finding “the other members are really friendly and are new friends too”, she found her social niche.

Arya’s major of choice was bio-medical engineering which had a high GPA cut-off for automatic admission through the ETAM (entry to a major) process. As “most people who do biomedical engineering [are] keeping med school in mind, so, … they're trying to have like a really high GPA”. Therefore, Arya was working hard to maintain a high GPA to be able to compete with other students who were interested in the same major.

She represented in her road map (Figure 9) that most of her courses were extremely challenging and she often needed to put-in long hours of work. If Arya was still unable to make an A, she would “kind of [break]down and … cry”. However, by the end of the first year, she described her strategy to regulate her emotions and cope with her grade:

> I cry like every bad grade I get, so it's kind of normal for me now, so I just ended up crying … for like a couple hours and then I'm like, you know what? I have to do homework now. I watched a couple YouTube videos just to get my mood back up and then I went back [to do homework].

Arya noticed that she had devoted more time studying during her second semester. She had “a couple of friends in each class so, if [she] was struggling with the material … then [they] would get together and study it and figure [it] out”. Arya sought out ways to help her academically and she was glad to have supportive friends and family.

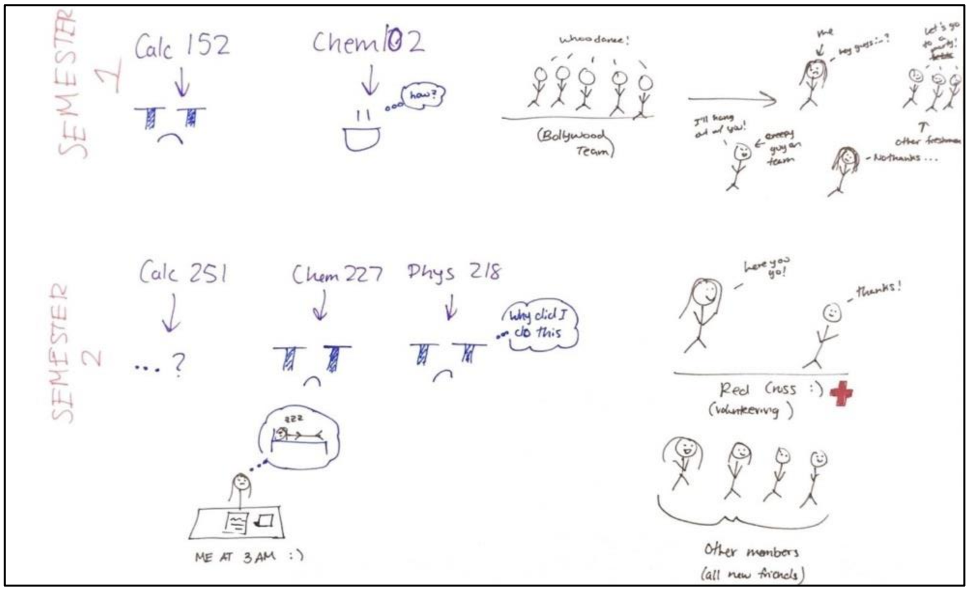

Figure 9. Road map sketch by Arya.

Characteristics of Group 2. Similar to group 1, participants in group 2 noticed that they were performing better than some of their peers. Jon explained, "[freshman year] was just a sort of a review for me. I'm not saying that I breezed through, but it made sense to me. And other people, I feel didn't get that sense". In addition, all three reported to having a peer group that they closely associated with and could rely on.

While Jon, Rob, and Arya were prepared for college, they occasionally had academic struggles depending on their choice of courses and professors. Jon found his calculus class challenging mainly because his "professor didn't speak English well and it was his first year … but it wasn't horrible". Rob was frustrated with the grading system where he could lose points for "something stupid". Arya explained further with a specific example:

> For math, I really enjoyed the subject and I feel like it's not like I don't know the material, because when it comes to free response, I usually know it, it's just multiple choice that I

> really don't like it …It depend so much on how they construct the multiple choice because some of them can be very tricky even though you know the answer.

While Arya did not want to blame the professor for her mistakes, she questioned the intent of the assessments as they are supposed to be “testing [their] knowledge, not [their] awareness on small details”. Jon Arya, and Rob were confident that they would graduate with an engineering degree.

Group 3

Ned, Bran, and Rickon formed group 3. Unlike groups 1 and 2, participants in group 3 did not feel adequately prepared for the rigor of college. After facing significantly more academic difficulties as compared to high school, they were not confident about finishing the engineering degree.

Ned. Ned considered himself good at mathematics and being an engineer was one of his top career options. He explained, “I wanted to be an engineer because it’s kind of prestigious, like my sister is a dog trainer, my brother is a choir director, so I wanted to one up them.” Soon after he began the program, Ned was overwhelmed by the academic rigor. In his road map (Figure 10), he demonstrated a changing thought pattern as he progressed through the first year of college. Comparing his mind set before and after entering the engineering program, Ned explained:

> before engineering I was kind of like focused on my future, work, and family and stuff that kind of mattered. And then as I started the semester off, one of the first thoughts was dropping out, you know cause engineering's pretty hard … just passing my classes was like the main priority at that time. I didn't have time to think about my future or anything like that, it was pretty hard.

While being good at mathematics was a primary reason for choosing engineering, he had almost no experience in coding. Learning that engineering was heavily dependent on coding, Ned was shocked and frustrated. He elaborated:

> I hate coding with my life and so it's really hard. Our professors were just pretty tough on us and I'm a pretty old guy on the inside, so, I don't do very well with technology. I didn't know how to work my computer … just computer work sounds like UGH!

Describing himself as a "math person", both physics and chemistry were tough for Ned. While his positive attitude towards mathematics helped him perform on-par with his expectations, his lack of association with other subjects made them hard for him. In order to deal with the academic difficulties, Ned explained his thought process:

> how is this class going to affect my overall career?... Just passing one class doesn't really affect me. So, I just kind of lower my expectations. If I fail, I say, Oh! I can take it again as long as I get a degree and if I don't, I can still get a job.

Further, Ned attributed the challenge of the major to poor teaching practices. Describing his professors as "bad teachers, in [his] opinion", Ned mentioned that "they don't ever help you and they don't explain the projects or homework or anything well at all … and they don't respond [to questions]". Throughout the second semester, Ned represented himself (Figure 10) constantly wondering, "Why? Why are they giving me so much work? Why is this needed or necessary? Can I change my major?" At the end of the semester, he found industrial distribution, "which had nothing to do with engineering". Ned enjoyed his new major choice and was able to "focus back on [his] future, work, and family."

By the end of the first year, dissatisfied with engineering course instructors and the overall experience, Ned had essentially moved away from main stream engineering, even though he was technically in the college of engineering. Once he chose Industrial distribution, Ned felt more integrated into the institution and his confidence that he would complete the degree improved.

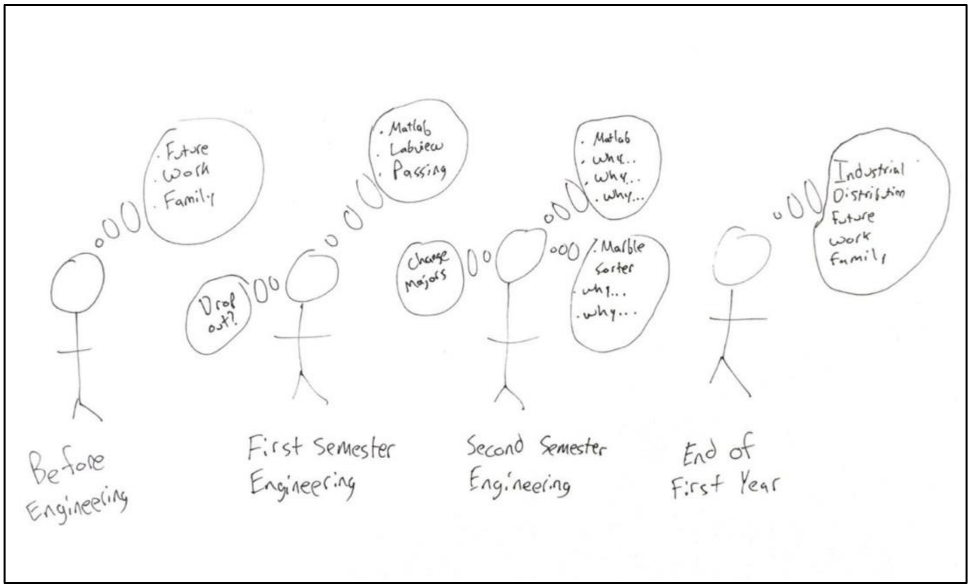

Figure 10. Road map sketch by Ned.

Bran. Until his senior year in high school, Bran wanted to go to business school. However, during a summer class, he was impressed with coding and the atmosphere of the tech world. Recognizing "that's where [his] interest was … [he] just picked [engineering] and just wanted to see where it takes [him] and if [he likes] it down the road or not". Being able to get a well-paying job after graduating was his major reason for taking up engineering.

Bran was a high achieving student in high school but realized that he was "far back in the crowd" soon after he started at Kingslanding University. Symbolically, in his road map (Figure

11) Bran drew himself "on a parachute, parachuting down into a race that has already started." Talking about his accomplished peers at Kingslanding, he described:

> honors students here like saying, "I got like a 4.3 in high school" and AP students like telling me like, "Oh! I got a 5.0 on AP physics test" and so like that's just been my experience so far.

Not only were his peers out-performing him in engineering courses, but few were racing towards "internships and opportunities ahead" even before Bran could begin the race. Bran felt that he had acquired "quite a bit of knowledge in high school" in terms of subject content, but lacked "time management skills or study skills" required to fare well in college. Analyzing the reason for his academic struggles, Bran said:

> I feel like if I really put the time to, I can do really well. I think my problem is just like time management and like knowing when to. I mean everybody could do well if they had enough time, but it's about utilizing that time to when you really need it. So, I would say… I could do well.

Talking specifically about his math courses, Bran reported to have "felt pretty confident in high school about doing calculus" but was struggling in Calculus I course at Kingslanding. Unhappy with his professor's methods of teaching, Bran relied on his high school calculus knowledge to navigate the course and "ended up making a C when [he] should have been well in the A's". While he partly blamed the poor teaching for his struggles, he often took it upon himself to fix the problem. He explained his panic soon after he received a C, his first thought was that his parents were going to see his grades. Then he thought of ways to fix his GPA:

> I went on the GPA calculator …like for hours and I was like if I take this class and make an A in this [class]. Oh my! I can't, I have to take physics, but I can't make an A in that. I didn't take AP physics in high school and all these kids are coming in with so much experience. But now … after I got that C, I made sure like I'm going to get a good prof this semester and I like I have to fix this.

Bran tried to be more proactive in asking for help during his second semester, apart from using online forums to answer his questions, he attended office hours and SI sessions.

In the road map, Bran represented his friends and family as birds that were accompanying him as he was parachuting down. He indicated a reluctance to sharing his academic struggles with his friends and family. He explained, “I try to hide [academic difficulties] as much as possible … for me it’s just whining, and no one wants to hear you whine about stuff, like I don’t even want to hear …”. From his narrative, Bran was unhappy with both his academic performance and the social environment of engineering. His confidence to perform academically was seen to continuously drop throughout the first year. Bran reported that his confidence in graduating with an engineering degree had decreased since he first started at Kingslanding.

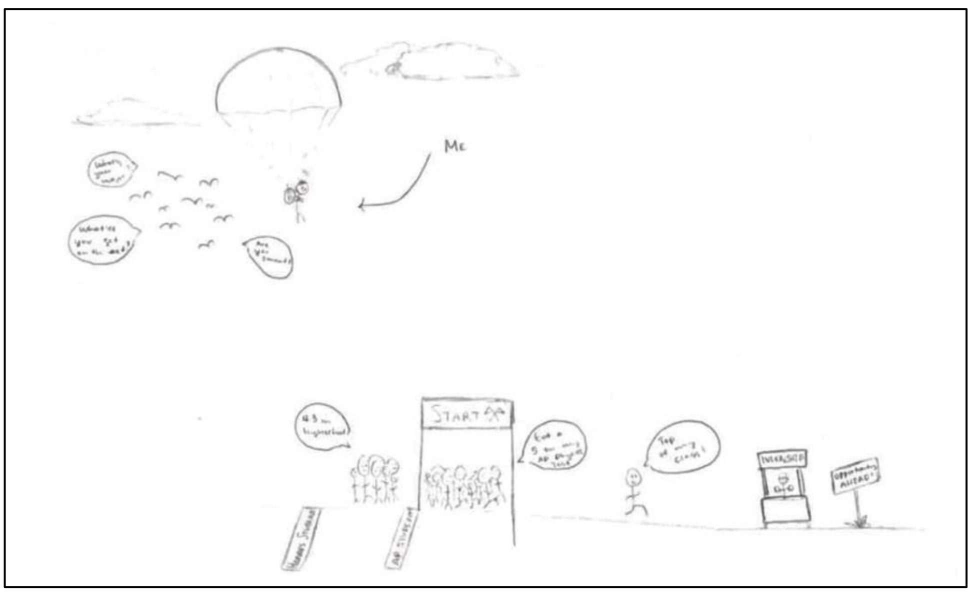

***Figure 11*. Road map sketch for Bran.**

Rickon. Rickon took up engineering as it was a "lucrative" field, even though he felt that it was a hard major. He, "as a person born in the turn of the millennia", thought that "going into engineering would be a good opportunity … because [technology is] the future". In addition, Rickon, though did not subscribe to this belief, perceived a social norm that "if you don't major in engineering, if you're not in STEM, [then] you're not going to be successful in life".

Rickon had taken advanced classes during his high school and was used to a heavy course load, however, on hind sight, he noticed that his preparation might not have been adequate. Specifically referring to his calculus AP class, Rickon described his teacher as very competent, but "still fel[t] like it should have been a little more [sic] harder than it was", further he noticed some "cracks in the system":

> senioritis is a thing that at the end of the year, students start slacking off ... for the seniors at least, [teachers] kind of start like accommodating so like you can turn in an assignment 3 months late and still get full credit … And that kind of hurt, coz when I came into college, I was still stuck in like fun mode and I didn't necessarily take it as seriously as I should have.

The first few weeks of college seemed really easy, but Rickon was soon engulfed by academic challenges. Rickon spent most of his first semester in disbelief, he explained,

> I always think I can fix it [problem situation]. I can fix it, even though it's falling apart. I was too stubborn and my ego was too big to [say to myself], "hey, you need to Q drop this or talk to your professor about what you can do next" and I never did.

During the first semester, Rickon had a bad experience with a professor and believed most professors and TAs would dismiss him, especially because he had bad grades. Receiving an F on one of his first semester courses was a wakeup call for him, when he told himself, "you need to act like you don't know anything, and then that's how you succeed". Thus, during his second semester, he was more proactive by getting more involved in GroupMes, SI sessions, study sessions, office hours and reading textbooks weeks ahead.

In his road map, Rickon represented his difficulties during a majority of his first and second semesters by drawing himself on a path of fire. He indicated the semester break as an oasis where most students have a chance to relax and rest, but his oasis was on fire as he had no time to relax. He noted:

> So, I'm ending off the year with a bad GPA and I have to worry about if I'm going to be able to still be in engineering afterword, and I have to worry about what's my next move and I have to keep moving even though I want to stop.

After thinking long and hard about his future, he felt he was being led towards a variety of career paths that his university could offer. He represented the possibilities as a maze because "it's a lot of loops and lot of going places you don't know if you want to go to". He included dropping out as an option,

> Not because I like want to drop out, but … it feels like that no matter how hard I try, the degree that I want to get in engineering is going to be blocked off and since ultimately like I wasn't made for that degree, I'll end up being a drop out trying to pursue it in the end.

He described "the biggest obstacle to the engineering major isn't itself but the mindset that comes with it". Being in a competitive environment and seeing his peers perform better than him, he had to constantly "overcome [an] inner sense of I can't do this".

Rickon's academic self-efficacy constantly reduced ever since enrolling in college. Further, his lack of academic and social integration negatively impacted his intent to persist. While he shifted from avoidance to approach coping strategies, he still struggled to catch-up with his peers.

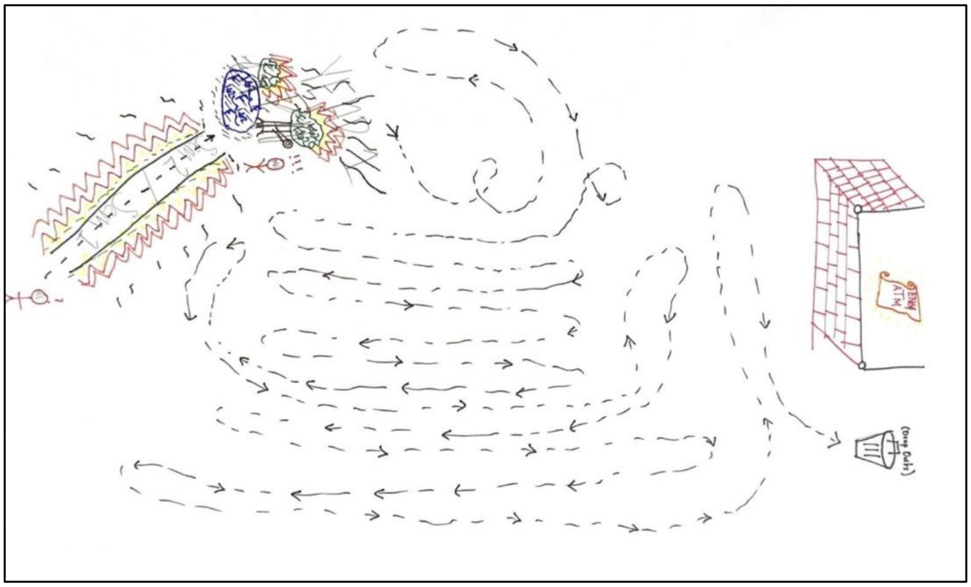

Figure 12. Road map sketch by Rickon.

Characteristics of Group 3. Unlike groups 1 and 2, participants in group 3 noticed that they were not performing on par with their engineering peers. Bran noticed that most people he knew “who's in the engineering program, [were] kind of prideful of what they've done and also kind of little bit of bragy [sic]”. Specifically, during engineering class, Ned considered coding as his weakness. Rickon noticed that while he was struggling to write a program in one computer language, there were “kids in [his] classes who knew the program in five different languages”. Viewing the environment as extremely competitive, Ned, Bran, and Rickon immediately realized they were not performing on par with their peers. While Ned started looking for backup major options, Bran and Rickon were hesitant to ask for help during the first semester. Bran described asking a professor for help as “iffy sometimes, because their expectation of you is a lot higher than it actually might be”. Rickon did not want to “annoy [TAs and professors] especially when you're doing bad … you think they're going to dismiss you”. However, by the second semester, they realized that TAs and professors were more approachable than they had assumed.

Within group 3, Bran and Rickon did not describe a consistent peer group that they could approach for help. Bran having grown up in the same town, was able to visit his family and friends very often. However, he did not depend on his friends in times of academic difficulties. While Rickon considered his family as his strongest support system throughout his first year, he had difficulty finding reliable friends at Kingslanding, he explained:

> I'm friends with my roommates and I've known them since high school and so that kind of helped but you know they had their own cliques and they're own friend groups and their own problems, so I couldn't really go to them.

Ned described himself as a “social person”, reported to having a consistent group of friends. He emphasized the need for freshmen to “build themselves up with friends” to make up for their weaknesses.

Finally, while Ned found an alternate path within the college of engineering, Bran and Rickon consciously reminded themselves that being an engineer was not necessary to be successful. While Bran, Rickon, and Ned started the major with a positive attitude towards the degree, their attitude had changed by the end of the first year. Rickon aiming to seek happiness rather than money explained:

> I think it doesn’t matter what you major in, obviously you don't want to major in under water basket weaving, because that's not viable in any situation, but … you know you have to really do what makes you happy at the end of the day…you only get to live once and if you're spending the whole time doing [something you hate], you're only paying for a life that you don't even want to live.

Major Themes

Based on the road maps, interviews and survey responses, all of the participants reported to viewing engineering majors as challenging. To answer the first research question, the common themes among participant challenges were extracted. Due to the implicit difficulty of the course material, students considered the courses time and effort intensive. Additionally, the faculty and advisors sometimes amplified the academic difficulty during the freshmen year. At the end of the freshmen year, some participants were keen on becoming engineers in spite of the challenges, some were re-evaluating their major choice. To answer the second research question, factors that influenced student's reaction to challenges were extracted. Participants intent to stay in the major was driven by motivation to be an engineer, and themes of being academically and socially integrated.

Challenge of Engineering Major

Engineering subjects were considered challenging either because of difficulty of the material or the time spent studying. While four participants Benjen, Theon, Jon, and Arya, included mathematics as a component of their road map, Bran and Rickon mentioned their challenges with math courses. Even though mathematics was one of the challenging subjects during the freshmen year, being prepared for mathematics alone did not guarantee a smooth transition into college (e.g., Ned). Chemistry and coding were some other major problem areas. As opposed to mathematics, which was time-consuming for most students, coding was only a problem when students were unprepared. Specifically, Bran, Rickon and Ned experienced difficulties and frustration with coding. Theon noted that the creator of C++ once taught at

Kingslanding, which resulted in a difficult coding curriculum and discouragement among students.

In addition, participants suggested that academic difficulty could be amplified by their course taking choices. Arya and Rickon, on the recommendation of their advisors, retook some calculus courses for which they already had college credit. They were extremely unhappy with this decision as they believed the courses were made "harder than necessary" and it negatively impacted their grade. Theon, based on his observations, also suggested that freshmen should accept all the credit they have to advance through the courses instead of retaking them. A sense of general discontentment with advising was often reported among engineering freshmen (Meyer & Marx, 2014; Seymour, 2000).

Further, most participants commented on the importance of carefully choosing their professors and courses. Benjen noticed that "the quality of education depends more on your teacher [at college] than it did [in high school]". From personal experience, Bran realized that "understand[ing] the whole like professor system and picking your classes around that … it really affects your GPA". As the course experience could vary greatly by the professor choice, Arya explained that students may feel unprepared sometimes depending on the professor. In agreement with the participants, inconsistencies between engineering faculty ideologies and practices have been documented (Haag, Hubele, Garcia, & McBeath, 2007; Seymour, 2000). Given the challenge associated with engineering majors, participants' intent to persist was influenced by their motivation to pursuing engineering. Whenever participants lacked an intrinsic motivation to persist, they relied heavily on perceived academic and social integration to adjust their intent to persist.

Motivation

With STEM majors being associated with high paying jobs, participants echoed a common societal norm that engineering majors are successful. Participants in groups 1 and 2 reported a strong affinity to pursue engineering. Arya, Jon and Theon had family members who inspired them to pursue engineering, while Benjen was inspired by his friend group. Rob was motivated by his passion for problem solving. However, participants in group 3 reported a weaker motivation to pursue engineering. Bran wanted to "see where [engineering] takes" him, and engineering was one of 6 possible major options for Ned. Rickon was compelled to take up engineering due to the stereotype that other majors are pointless and lead nowhere. While friends, family and educators influence student's initial motivation, their intent to persist in the major driven by internal motivation (Whitehead, 2018).

During the freshmen year, most of the courses were introductory science and mathematics which were almost unrelated to their intended major. Participants with a strong internal motivation considered this year as a stepping stone to enter their major. For example, Jon stayed in engineering "because it's the best major" and was looking forward to be an engineer and work for the military like his father and grandfather. Arya, aiming to go into biomedical engineering, was optimistic:

> sophomore year of classes are not that difficult except for one computing class but I'm actually pretty excited for it because I'm really interested in computer sciences. And then .... there's a lot of research behind it too and I really enjoy research. I don't think I'll find that aspect of it difficult

In agreement with previous research, participants who identified as being engineers were likely to persist irrespective of the difficulty or effort required (Matusovich, Streveler, & Miller, 2010). For these students, the challenge was "meaningful and even enjoyable" (Cruz & Kellam, 2018). However, participants who were not as strongly motivated (Ned, Rickon and Bran), used the first-year experiences to assess their fit in engineering.

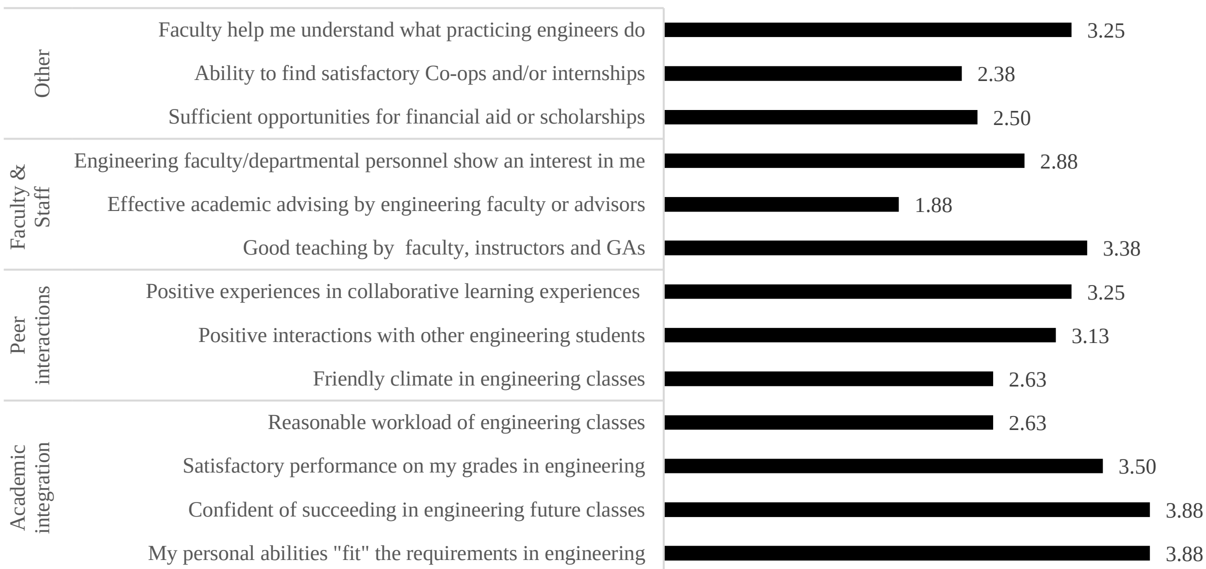

Figure 13. Mean scores indicating the influence of factors on persistence in engineering. Scores range from 1 (No influence) to 4 (Significant influence).

Academic Integration

Participants considered academic integration as the most important factor, followed by good teaching and positive interactions with peers (Figure 13). As suggested by the prominent theoretical models (Bean & Eaton, 2001; Tinto, 2006), feeling of academic integration was a prominent factor for persisting in the engineering major. Among the participants, a sense of academic integration was mainly derived from prior exposure to academic rigor and grades. Further, as suggested by prior research (Eris, 2007; Marra, Rodgers, Shen, & Bogue, 2012; Vogt, Hocevar, & Hagedorn, 2007) academic integration had a positive reciprocal relationship with the self-efficacy, attitude, help-seeking, and effort to persist among engineering undergraduates.

Based on the interviews, students in three groups varied based on high school preparation. However, on the survey, all students reported that their high school coursework prepared them to be successful in an engineering curriculum. This discrepancy between actual preparation and perceived preparation could be due to variance in exposure to academic rigor. Being prepared for college was viewed differently across participants. Groups 1 and 2 associated preparation with being exposed to advanced content through college level courses (Theon, Arya and Jon), learning effective study strategies (Benjen) and problem-solving skills (Rob) that can be adapted over different disciplines. In contrast, participants in group 3 associated preparedness with being "somewhat familiar" (Rickon) with content or having "quite a bit of knowledge" (Bran) in Calculus. As all participants believed they were prepared, those in group 3 were unable to initially identify their lack of preparation.

In agreement with previous research, participants with rigorous high school preparation (Zhang, Anderson, Ohland, & Thorndyke, 2004; French, Immekus, & Oakes, 2005) were able to transition smoothly into college. In addition to academic preparation, study habits influenced undergraduate persistence (Bernold, Spurlin, & Anson, 2007). Specifically, participants in groups 1 and 2 were aware of what to expect as an engineering major. They were prepared with the required study skills and committed to put in the effort. Thus, they felt academically integrated and their intent to persist had not changed since the beginning of the freshmen year. Being well-prepared, participants in groups 1 and 2 identified as high achievers in college, and maintained a high self-efficacy. While they occasionally received unfavorable grades, they attributed it to rigorous grading system rather than their inability to perform. They were less likely to interpret their grades as a form of threat.

On the other hand, participants in group 3 were overwhelmed by the jump in difficulty level from high school to college. Specifically, Bran and Rickon recognized their lack of study skills as an additional drawback compared to their high achieving peers. Further, participants in group 3 used grades throughout the freshmen year to assess their academic fit and revise their intent to persist. Satisfactory grades were ranked as an important factor affecting persistence (**Error! Reference source not found.**). However, as grading standards in STEM majors are s tringent, engineering freshmen are likely to receive lower grades in college as compared to high school (Ost, 2010). Poor grades and a feeling of under-preparedness for the rigor of engineering lowered their self-efficacy. While Bran and Rickon reacted emotionally to their poor grades, Ned lowered his expectations to avoid disappointment. By the end of the first year, group 3 felt less academically integrated as compared to groups 1 and 2, which adversely affected their intent to persist.

Social Integration

As suggested by Bean and Eaton (2001), participants' sense of being socially integrated influenced their self-efficacy, help-seeking and intent to persist. Specifically, comparison with engineering peers was a major source of self-efficacy. For example, Rickon explained a lowering in self-efficacy:

> everybody else around you …although they're struggling too, they seem to be doing better than you, you know, no matter how hard they struggle…when I see that I feel like since they're struggling and I'm struggling, there's kind of that connection that I should be able to get past it, but I'm not able to … so it kind of makes me like look at myself and say like what's wrong with me.

Even though a variety of academic help was provided by the engineering department at Kingslanding University, participants demonstrated a hesitation to approaching faculty. In agreement with previous research (Marra et al., 2012), talking to other students and/or friends was the most popular option for dealing with academic difficulties (Figure 14). Specifically, participants who were struggling indicated a lack of confidence to approach faculty or staff for help. While participants who were integrated into a peer group often asked their friends for help (approach coping), those who felt isolated tended to use avoidance coping strategies. Thus, being socially integrated into a peer group was positively associated with self-efficacy, grades and intent to persist.

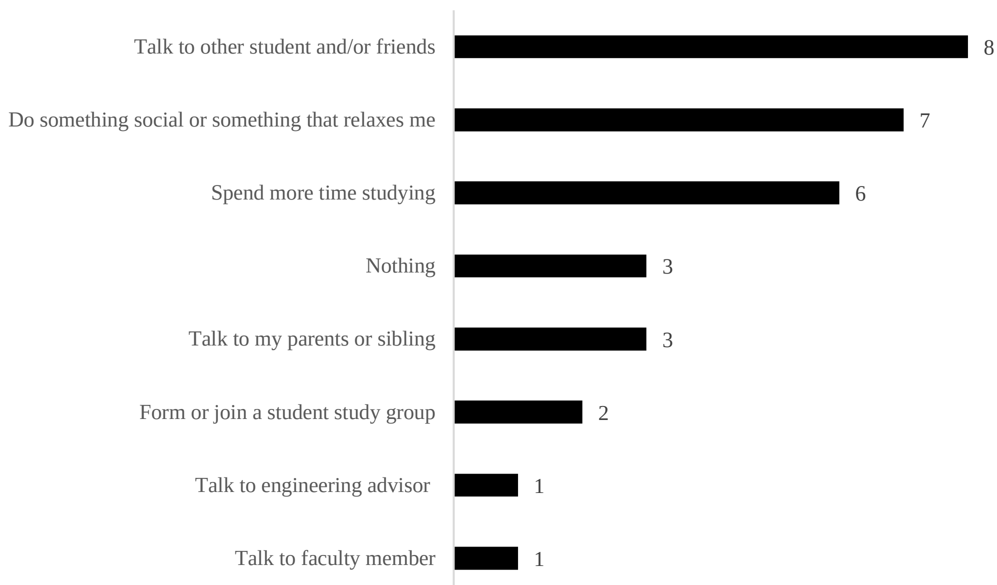

Figure 14. Frequency of student responses to the question, when you have an academic problem, what do you do? None of the participants chose the options: I never feel this way, seek academic help at a tutoring center, visit the women in engineering or minority offices, or other.

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Limitations

This study is limited by a small sample size. In this sample, all students in groups 1 and 2 had strong motivation towards being engineers and adequate academic preparation. While it is possible that most students who have a strong motivation look for better high school preparation, this sample excludes an important section of the engineering ungraduated population. Inclusion of more participants, especially students who have high motivation to be engineers, but lack preparation may provide a better picture of the dynamics within the engineering department.

As the data analysis was performed by the first author, her background as a STEM major influences the interpretation of participant narratives and major themes. In efforts to avoid bias, multiple sources of data such as road maps, surveys and interviews were cross-referenced.

Conclusions

The engineering major was considered challenging in comparison with most other majors at college. Students who wanted to be engineers without a doubt, were able to navigate the challenges effectively as they viewed them as a stepping stone to their ultimate goal. Alternately, students who were persuaded to take up engineering by external factors, constantly evaluated their fit within the program. When faced with challenges, they often evaluated if the end goal was worth the effort. As first year course work was far removed from their intended major, including applications within the introductory courses may improve motivation and intent to persist.

In addition to motivation, students' perception of academic and social fit within the major influences their self-efficacy, help-seeking behavior and intent to persist. While the institution has no control over student motivation, ensuring better academic and social integration might improve retention. To this end, researchers have suggested the inclusion of group work, co-operative learning and peer mentoring (Marra et al., 2012; Moore, 2005; Pendergrass et al., 2001). In addition, there is a need for more research about smoothly transitioning students into a more rigorous grading system at college.

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CHAPTER 4

REACTION TO RECEIVING NEGATIVE FEEDBACK: TASK PERFORMANCE AND ROLE OF PERSONALITY TRAITS

Low rate of engineering undergraduate retention has been consistently documented for the past several years. Feeling academically integrated and being able to obtain satisfactory grades are important for engineering student persistence. However, given the academic rigor of engineering majors, experiencing academic challenges is an integral part of the program (Adelman, 2006). Engineering freshmen are often ill-prepared to perceive academic difficulties as opportunities to learn (Simpson & Maltese, 2017). As most students who enroll in engineering majors are high achievers in high school, some of them struggle with receiving lower grades in college (Marra, Rodgers, Shen, & Bogue, 2012). Thus, successfully navigating academic challenges is an important trait to be successful in engineering majors.

Traditionally, high school GPA and scores from high stakes testing are considered to admit students into higher education. However, high school performance predicts only about 25% of the variance of STEM student retention (Shaw, Kobrin, Patterson, & Mattern, 2012). Specifically, in face of academic adversity, psychological factors such as personality are crucial for persistence rather than prior academic performance (Carver, 2010). Even though overcoming academic challenges is an important part of STEM fields, research about how undergraduate STEM majors navigate these challenges is very limited (Henry, Shorter, Charkoudian, Heemstra, & Corwin, 2019). Thus, there is a need to understand the role of academic challenges in shaping undergraduate student's performance, learning and persistence in STEM majors.

As observing student’s reaction to academic difficulties in a natural setting is extremely challenging, this study was designed to observe STEM undergraduate’s reaction to negative academic feedback in a laboratory setting. A situation where participants receive negative feedback was simulated and the effects of receiving negative feedback on future task performance is examined. Further, the role of personality traits and performance after receiving negative feedback was explored.

Literature Review

STEM and Academic Challenges

As the level of academic difficulty is higher in college compared to high school, freshmen are more likely to receive negative academic feedback at college. Specifically, failure experiences are more common among STEM majors (Kokkelenberg & Sinha, 2010); but STEM professionals “attributed at least part of their success … to their experiences with failures” (Simpson & Maltese, 2017, p.223). Treating academic challenges as learning experiences is a critical characteristic of successful STEM majors (Henry et al., 2019). Thus, STEM freshmen’s reactions to challenges or failure experiences impact their persistence in the major and trajectory through college.

Academic feedback such as grades are critical components of higher education. While adapting to the unfamiliar college environment, students use their grades to assess their fit within the program (Stinebrickner & Stinebrickner, 2009). Specifically, absolute grades consistently influence student attrition in engineering majors (Rask, 2010). Receiving high grades in non-STEM subjects is easier than STEM subjects (Kokkelenberg & Sinha, 2010), which leads engineering students to perceive a better fit with non-STEM majors (Ost, 2010). Academic feedback from instructors often elicits an emotional response among undergraduates (Robinson, Pope, & Holyoak, 2013), and feedback is known to have both positive and negative effects on student performance (Doughlas, Salter, Iglesias, Dowlman, & Eri, 2016). While some students use the feedback to improve their performance, others may lack the skills to use academic feedback productively (Weaver, 2006). Especially students with lower confidence feel discouraged after receiving negative feedback (Young, 2000) and are likely to leave the program.

In the face of negative feedback, individual dispositions determine their reaction and intention to persist. Along with academic performance, student's academic goals and self-efficacy were important predictors of retention (Mau, 2003; Robbins et al., 2004). While students who felt academically confident were likely to persist, those who focused on avoiding a bad grade were more likely to switch out of an engineering major (Shedlosky-Shoemaker, 2015). Further, students who considered "the effort required to be successful in the STEM major as not worthwhile and …the need to sacrifice other valued activities as a consequence of majoring in STEM" had a higher probability of leaving the major (Perez, 2014, p.324). In addition to traditional measures of achievement, psychological factors such as personality traits influence persistence in college.

Personality

Personality, being independent of intelligence or cognitive abilities (Moses et al., 2011), was a predictor of academic achievement at primary, secondary and tertiary levels of education (Poropat, 2009). Undergraduate retention models draw on personality traits to explain student-to-student variability within a given institutional environment (Bean & Eaton, 2001; Tinto, 1987). Even when prior academic performance was controlled for, personality was a strong predictor of college performance (Noeftl & Robins, 2007). Further, personality traits influence student's perception of academic challenges and reactions to stressful situations (Bell, 2008; Carver, 2010). Individuals' behavior varies with their personality traits, thereby impacting academic achievement and retention in college.

In this study, the Five Factor Model (FFM) of personality is adopted. According to the FFM, personality is composed of five traits: Extraversion, Agreeableness, Conscientiousness, Emotional stability and Openness to experience. The first two factors, extraversion and agreeableness refer to individual behaviors relative to other people. The third factor, conscientiousness is characterized by orientation towards achievement, while the fourth factor emotional stability refers to regulating emotions. The fifth factor, openness is characterized by the extent of unconventional behavior. Table 3 represents the characteristics of individuals based on their scores on the personality scales.

Table 3
Characteristics of High and Low Scores on the Five Personality Variables

Low score	Personality trait	High score
socially withdrawn, Indifferent, cold, isolated	Extraversion	Outgoing, attached, cordial, sociable
Skeptical, manipulative, aggressive, boastful	Agreeableness	Naïve, trusting, co-operative, empathetic
irresponsible, distracted, disorganized, aimless, rash	Conscientiousness	dependable, perfectionism, organized, ambitious, reflective
Fearful, angry, bitter, helpless, fragile	Emotional Stability	Relaxed, even-tempered, self-assured, restrained
Practical, unaware, routine, rigid	Openness	Imaginative, self-aware, eccentric, creative

Personality and Engineering Retention

The most important personality trait in the context of academic performance is conscientiousness. As conscientiousness is a measure of will to achieve, it is closely related to academic achievement (Steel, 2007). Students scoring high on conscientiousness are known to manage resources effectively to achieve academic goals (Bidjerano & Dai, 2007). Across numerous meta-analyses, conscientiousness has emerged as the strongest predictor of undergraduate achievement among the five personality factors (McAbee & Oswald, 2013; Poropat, 2009; Richardson, Abraham, & Bond, 2012). Conscientiousness is considered a protective factor from stress as conscientious people tend to make responsible and healthy choices that avoid stressful situations (Connor-Smith & Flachsbart, 2007). In addition, individuals with higher conscientiousness view challenges as learning experiences (Bartley & Roesch, 2011). The other personality traits had weaker relationships with academic achievement.

Theoretically, students experiencing emotional instability may direct their cognitive resources towards coping with their emotions, thereby reducing their academic performance (De Raad & Schouwenburg, 1996). While emotional stability correlates with higher academic performance (Robbins et al., 2004), the relationship was moderated by age and education level. Specifically, individuals with lower levels of emotional stability performed better in tertiary education (Poropat, 2009). Traits associated with low emotional stability, such as anxiety and fear of failure, were beneficial for academic success; however, students with lower emotional stability were more likely to drop out due to low academic performance (Novikova & Vorobyeva, 2017). Emotional Stability was a consistent predictor of academic achievement and coping with academic challenges.

While relatively less researched, openness was an important trait for success in higher education. Openness corresponded with higher levels of motivation towards learning (Tempelaar, Gijselaers, van der Loeff, & Nijhuis, 2007), use of effective learning strategies, deep learning (Chamorro-Premuzic, 2009) and overall achievement (Komarraju, Karau, Schmeck, & Avdic, 2011). Higher openness correlated with better engagement with the problem situation (Afshar et al., 2015). When exposed to stress, higher openness was associated with lower perceived stress and positive affect (Schneider, Rench, Lyons, & Riffle, 2012). Students with higher openness were more likely to persist and perform in face of academic adversity.

The personality traits extraversion and agreeableness were associated with an individual's ability to function socially. Extraversion has an ambivalent relationship with academic outcomes. While some researchers suggest extraverted students tend to perform better due to their high energy levels and positive attitudes (De Raad & Schouwenburg, 1996), some students may deviate from academic activities due to their involvement in social activities (Richardson, Abraham, & Bond, 2012). Specifically, for engineering students, extraversion was an inconsistent and weak predictor of academic success (McAbee & Oswald, 2013). On the other hand, more agreeable students are more cooperative and actively participate in learning (Vermetten, Lodewijks, & Vermunt, 2001). In addition, agreeableness is strongly associated with regulating emotional experiences (Tobin, Graziano, Vanman, & Tassinary, 2000). Moreover, agreeable and extravert people had strong social networks (Okun & Finch, 1998), and were likely to engage in help-seeking behavior and proactive problem-solving approaches (Amirkhan, Risinger & Swickert, 1995; Connor-Smith & Flachsbart, 2007;). While extraversion and agreeableness had weak relationship with academic achievement, they were predictive of social integration into college.

Research Questions

The research questions driving this study are:

1. Does receiving negative feedback on task performance impact future task performance?
2. How does task difficulty influence reaction to negative feedback?
3. Do the five personality traits, conscientiousness, emotional stability, openness, agreeableness and extraversion impact student response to negative feedback?

Methods

To answer the research questions, an experimental study design with random sampling was used. The study took place at a large university in Central Texas during the calendar year 2018.

Participants and Procedure

A total of 40 freshmen participants were recruited in two phases: Spring, 2018 and Fall, 2018. A recruitment email was sent to all engineering freshmen through the university listserv. The inclusion criteria were that participants be at least 18 years of age and enrolled as freshmen in the college of engineering. There were no exclusion criteria to ensure that the sample was representative of the engineering freshmen population.

Prospective participants who responded to the recruitment email were provided with a list of time slots for participation. When the participants arrived for the testing, first, informed consent documents were completed. Next, they were asked to complete questionnaires presented using Qualtrics software on an iPad. Finally, they were seated in a closed room to complete the mathematics task on a computer. All participants were compensated with a $25 Amazon gift card.

Questionnaire Measures

Student Persistence Survey. The student persistence in engineering survey was developed by an NSF funded project, AWE (Assessing Women and Men in Engineering) to understand the factors affecting retention. The persistence questionnaire was composed of 17 multiple choice questions and 3 free response questions (AWE, 2007). The survey measured (a) initial commitment towards engineering, (b) factors contributing to persistence/leaving, (c) participation in academic and extra-curricular activities, and (d) confidence in completing the current degree.

Ten Item Personality Inventory (TIPI; Gosling, Rentfrow & Swann, 2003). TIPI was developed as a very brief measure of the Big Five personality measure. TIPI is a 10 item 7 point Likert scale with responses ranging from "disagree strongly" to "agree strongly". TIPI generally has a high test-retest reliability and convergent reliability with the 240 item NEO-PI-R scale (Rammstedt & John, 2007). Several researchers have implicated the role of personality in undergraduate retention (Farsides & Woodfield, 2003; Poropat, 2009). However, only a brief measure of personality is most suitable for the current study as the math task was time intensive.

Mathematics Task

A challenging mathematics task involving checking divisibility of three-digit numbers by one-digit numbers was used. This task was an adaptation of the math task by Skrandies and Klein (2015). The math task was based on a well-established phenomenon known as the problem size effect, to manipulate task difficulty. The problem size effect suggests that individuals solve small problems with more accuracy and speed as compared to large problems (Zbrodoff & Logan, 2005). In this task, division of three-digit numbers by 2,3, and 4 were considered easy and division of three-digit numbers by 6,7, and 8 were considered hard similar to the Skrandies and Klien (2015).

During the task, the participants were instructed to indicate if the three-digit number displayed was evenly divisible by the one-digit number displayed on screen using the arrow keys. For example, for the prompt "2/ 341", the participants were required to press "→" if evenly divisible, or "←" if not evenly divisible. Participants were required to respond within 3 seconds of seeing the stimulus. Participants could take breaks between problems when a "press space to continue" screen was presented (Figure 15). The task was programmed and administered using EPrime software.

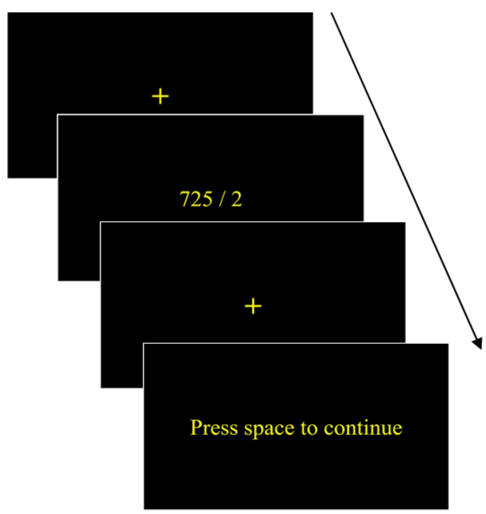

Figure 15. Example of division task as displayed to participants.

Participants were given a set of 5 untimed and 20 timed practice problems for familiarity with the task. They then solved ten blocks of 30 problems each. After the first five blocks of problems, participants were randomly given a neutral or negative feedback. The feedback given during testing was not representative of their performance. At the end of the experiment, the participants who received the negative feedback were debriefed about the intent of the experiment. The neutral feedback reads, "*You have finished the first block. Your performance has been recorded. Please start the second block when you are ready*". While the negative feedback reads, "*You have finished the first block. Your reaction times are in the bottom 20% compared to your peers at TAMU. This ranks you as 'poor'. Please start the second block when you are ready by pressing the spacebar*".

Results

Data analysis was performed using JMP software. The average performance of each participant on pre-test (before receiving feedback) and post-test (after receiving feedback) was calculated for easy and hard problems. In order to answer the first research questions, the accuracy of participants on pre-test and post-test were compared by task difficulty (Table 4). The neutral feedback group significantly improved their accuracy from pre to post test on both easy and hard problems. However, the negative feedback group had no significant improvement from pre to post-test. In addition, reaction times were similar for both groups on pre-test, but negative feedback group had significantly longer reaction times on post-test as compared to neutral feedback group.

Table 4

Comparison of Accuracy from Pre- to Post-test by Feedback Group and Task Difficulty

Feedback	Accuracy Rates (in %) for Easy Problems		
	Pre-test	Post-test	P value
Neutral	71.94 (10.66)	76.44 (9.62)	0.01*
Negative	72.49 (5.85)	75.09 (9.60)	0.11
	Accuracy Rates (in %) for Hard Problems		
	Pre-test	Post-test	Cohen's d
Neutral	60.83 (6.2)	64.32 (6.95)	0.01*
Negative	61.68 (7.87)	63.51 (5.32)	0.36

Note. * significant at 0.05 level

In order to understand the role of personality in reacting to feedback, an ANCOVA was performed with the dependent variable being accuracy after receiving feedback and independent variables being type of feedback (negative or neutral), task difficulty (easy or hard) and scores on the five personality dimensions. The covariate was accuracy before receiving feedback. The descriptive statistics and correlations between the continuous variables are present in Table 5.

Table 5

Descriptive Statistics and Correlations Between Pre-Test Accuracy, Post-Test Accuracy, and Personality Variables

Variable	Mean	SD	Sk	2	3	4	5	6	7
1. Accuracy Pre-test	66.71	9.54	0.13	0.73	0.03	-0.12	0.16	0.03	0.05
2. Accuracy Post-test	69.87	9.95	0.96		-0.1	-0.22	0.14	0.04	-0.06
3. Extraversion	4.45	1.57	-0.23			-0.11	0.19	0.17	-0.27
4. Agreeableness	4.35	1.16	-0.18				0.02	0.00	0.26
5. Conscientiousness	5.35	1.2	-0.93					0.33	0.01
6. Emotional stability	4.46	1.43	-0.33						-0.12
7. Openness	5.47	0.88	-0.31						

All personality variables were negatively skewed, with conscientiousness being most skewed. ANCOVA was run with all main and interaction effects. Interaction effects that were not significant at the 0.05 level were removed from the model, and for significant interaction effects, all lower level effects were retained. The final model (Table 6) had a R^2 = 0.765 [F (15, 62) = 13.48, p < 0.05] and an adjusted R^2 = 0.71. Shapiro-Wilks test showed no violation of normality of residuals (W = 0.97, p = 0.11). Brown-Forsythe test revealed no violation of homogeneity of variance between the groups (F (3, 76) = 1.99, p = 0.12).

Table 6
Results of the ANCOVA with Dependent Variable: Accuracy Post

Source	DF	Sum of Squares	F Ratio	Prob > F
Continuous Predictors				
Accuracy Pre	1	0.1546	52.2877	<.0001*
Agreeableness	1	0.0066	2.2423	0.1394
Emotional stability	1	0.0008	0.2854	0.5951
Openness	1	0.0014	0.4609	0.4998
Extraversion	1	0.0075	2.5306	0.1167
Conscientiousness	1	0.0000	0.0060	0.9385
Categorical Predictor				
Feedback	1	0.0126	4.2512	0.0434*
Difficulty	1	0.0215	7.2864	0.0089*
Interactions				
Feedback*Agreeableness	1	0.0199	6.7139	0.0119*
Feedback*Emotional stability	1	0.0199	6.7240	0.0119*
Feedback*Accuracy Pre	1	0.0003	0.1073	0.7443
Feedback*Difficulty	1	0.0007	0.2351	0.6295
Difficulty*Accuracy Pre	1	0.0185	6.2720	0.0149*
Difficulty*Openness	1	0.0144	4.8565	0.0313*
Feedback*Difficulty*Accuracy Pre	1	0.0345	11.6817	0.0011*
Error	62	0.1833		
Total	77	0.7814		

Task Difficulty

Due to the design of the task, hard problems had lower accuracy rates as compared to the easy problems ($p<0.05$). Further, based on the ANCOVA, the relationship between pre and post test scores appears to be influenced by feedback and difficulty of the task. Participants who received neutral feedback had similar slopes for both easy and hard problems (Figure 16), but participants who received negative feedback had significantly different slopes for easy and hard problems.

In general, we expect an increase in post-test accuracy with an increase in pre-test accuracy. However, the rate of change or slope was statistically significantly different based on feedback and task difficulty. For easy problems, the mean change in post-test performance for 10 units increase in pre-test performance was 5.6 units more for negative than for neutral feedback. On the other hand, for hard problems, mean change in post-test performance for 10 units increase in pre-test performance was 5.1 units more for neutral than for negative feedback.

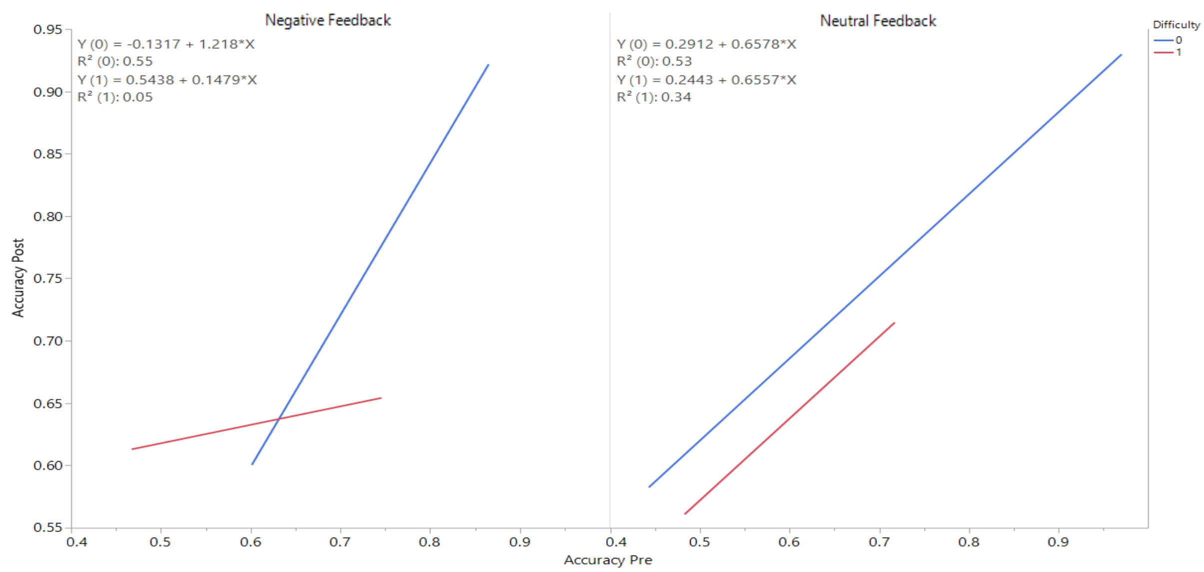

Figure 16. Interaction plot for Feedback*Difficulty*Accuracy pre, representing the linear relationship between pre- and post-test scores by feedback groups and task difficulty.
Note. Difficulty = 0 represents easy problems, and Difficulty = 1 represents hard problems.

To further understand the interaction effect, for each difficulty level, the median of the pre-accuracy scores were used to separate participants into two groups. Graphs were drawn to investigate the effects of feedback and difficulty at different pre-test accuracy levels (Figure 17). On receiving neutral feedback, participants who performed below the median on pre-test continued to perform significantly worse than the above median group on post-test on easy and hard problems ($p < 0.05$). However, on receiving negative feedback, there was no significant difference in post-test scores of below-median and above-median groups.

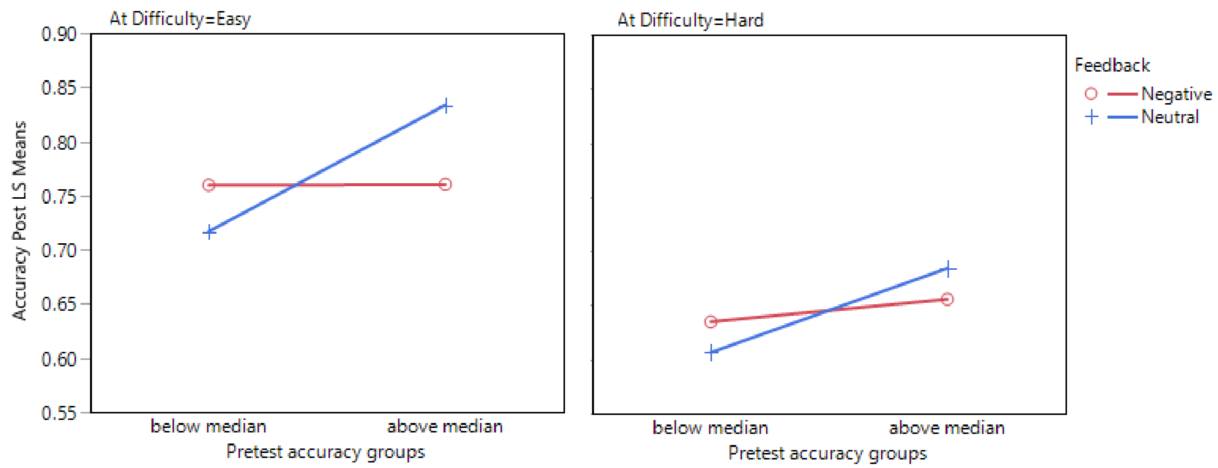

Figure 17. Variance in post-test performance based on pre-test performance groups by feedback and task difficulty

Task Difficulty and Openness

To understand the relationship between openness and difficulty, post-test accuracy rates at different levels of openness were calculated (Figure 18). Participants with low openness scores has significantly different scores on easy and hard problems (t (67) = 4.21, $p < 0.05$), while there was no significant difference between easy and hard problems for students with high openness scores. Within each difficulty level, there were no significant difference between high and low openness groups.

Feedback and Emotional Stability

To understand the relationship between emotional stability and feedback, post-test accuracy rates at different levels of emotional stability were calculated. As demonstrated Figure 19, there was no significant difference between feedback groups for participants with low emotional stability. However, participants with high emotional stability performed significantly worse on receiving negative feedback as compared to the negative feedback group (*t* (67) = 2.62, *p* < 0.05).

Feedback and Agreeableness

To understand the relationship between emotional stability and feedback, post-test accuracy rates at different levels of agreeableness were calculated. As demonstrated (Figure 20), on receiving neutral feedback, participants with low agreeableness performed significantly better than the high agreeableness group (*t* (67) = 2.97, *p* < 0.05). However, on receiving negative feedback, there was no significant difference between the agreeableness groups (*t* (67) = 0.41, *p* = 0.67).

Openness Group	N	Openness Score Mean (SD)
High Openness	20	5.68 (0.49)
Low Openness	19	3.18 (0.87)

	Post-test Accuracy	
	Easy Problems Mean (SD)	Hard Problems Mean (SD)
High Openness	74.43 (10.29)	64.75 (6.35)
Low Openness	78.25 (8.17)	62.58 (6.01)

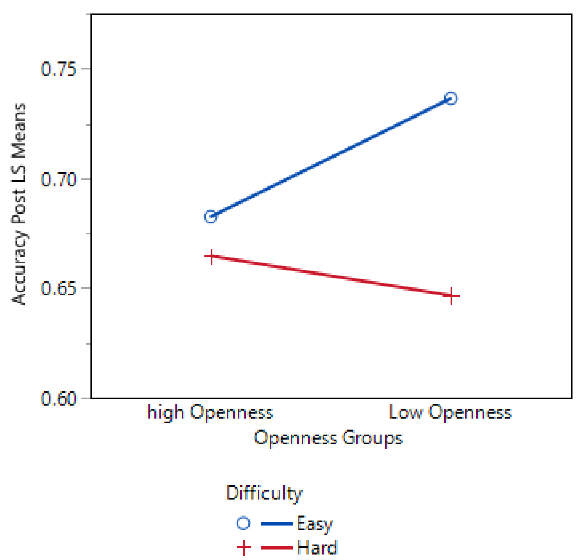

Figure 18. Interaction plot representing the variance in post-test performance based on task difficulty and Openness scores.

Emotional Stability Group	N	Emotional Stability Score Mean (SD)
High Emotional Stability	20	5.68 (0.49)
Low Emotional Stability	19	3.18 (0.87)

	Post-test Accuracy	
	Negative Feedback Mean (SD)	Neutral Feedback Mean (SD)
High Emotional Stability	67.41 (10.07)	70.83 (11.39)
Low Emotional Stability	71 (9.73)	69.78 (8.96)

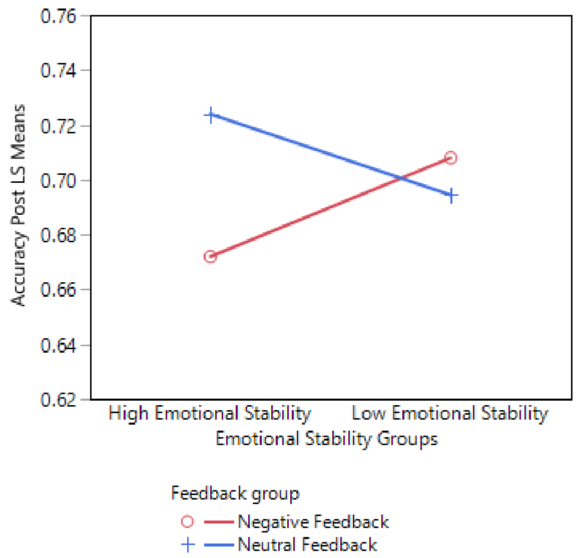

Figure 19. Interaction plot representing the variance in post-test performance based on feedback and Emotional Stability scores.

Agreeableness Groups	N	Agreeableness Score Mean (SD)
High Agreeableness	24	5.06 (0.7)
Low Agreeableness	15	3.2 (0.76)

	Post-test Accuracy	
	Negative Feedback Mean (SD)	Neutral Feedback Mean (SD)
High Agreeableness	69.28 (9.18)	66.83 (7.16)
Low Agreeableness	69.67 (11.65)	75.11 (12.07)

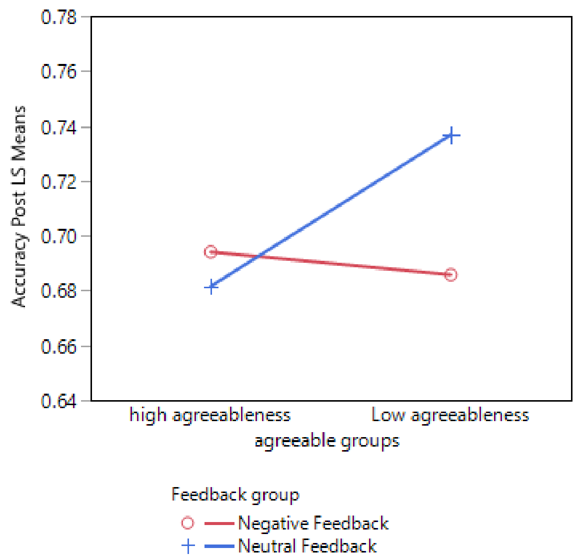

Figure 20. Interaction plot representing the variance in post-test performance based on feedback and Agreeableness scores.

Discussion

Entering an academically rigorous program, the major challenges faced by freshmen engineers are higher content difficulty and lower grades. To reflect these obstacles, the experiment was designed with two levels of task difficulty and feedback. In agreement with the problem size effect, participants performed significantly better on the easy problems as compared to hard problems. Further, feedback had a significant effect on post-test performance. The neutral feedback group significantly improved their post-test accuracy rate on easy and hard problems. While the, negative feedback group appeared to exert more effort after receiving feedback (i.e., longer reaction times), they had no significant improvement in performance.

The hard problems on the math task were considerably more difficult and it is possible that participants attributed the negative feedback to poor performance on hard problems. Specifically, on receiving negative feedback, below median students performed worse on easy problems. These participants appear to divert their attention to performing better on hard problems assuming that their performance on easy problems was adequate. On the other hand, above median students performed worse on hard problems after receiving negative feedback. These participants possibly targeted the easy problems as opportunities to score more, rather than exerting more effort on hard problems.

Further, interaction between task difficulty and openness was a significant predictor of post-test performance. In the context of post-secondary performance, openness has mixed results with positive, negative or insignificant relationship with academic outcomes (O'Connor & Paunonen, 2007). Similarly, the results indicated a small positive correlation between pre-test score and small negative correlation with post-test scores. However, in the case of exposure to stress, openness was positively associated with creative problem solving and perseverance (Scherer & Gustafsson, 2015; Williams, Rau, Cribbet, & Gunn, 2009). In agreement with the literature, participants with higher openness were able to solve hard problems as efficiently as easy problems.

Personality traits influence individual behaviors such as approach to learning, academic performance, and perseverance. However, the relationship between reaction to feedback and personality traits lacks consistent empirical evidence (Atwater & Brett, 2005). To this end, this study supports the hypothesis that emotional stability influences reaction to feedback. Students with lower emotional stability are prone to negative emotions. However, low emotional stability is associated with higher academic achievement and college GPA (Laskey & Hetzel, 2011). Results indicated the low emotional stability group was almost unaffected by negative feedback while the high emotional stability group was significantly underperforming after receiving negative feedback. Having dealt constantly with emotional reactions, students with low emotional stability have probably learned strategies to maintain their academic performance in spite of their emotional state (Poropat, 2009). In contrast, students with higher emotional stability appeared to be at a disadvantage when provided with negative feedback.

Theoretically, higher agreeableness is expected to correlate with higher feedback acceptance (Atwater & Brett, 2005). However, the results did not support this hypothesis, as there was no significant difference between high and low agreeableness groups when given negative feedback. Within the neutral feedback group, participants with low agreeableness performed better than those with high agreeableness. This may be an artifact of the population. As engineering students low in agreeableness were high in conscientiousness (Van Der Molen, Schmidt, & Kruisman, 2007), they continued to perform well irrespective of the feedback.

Among the five traits, conscientiousness was the strongest predictor of academic performance (Poropat, 2009; McAbee & Oswald, 2013; Richardson, Abraham, & Bond, 2012). In this study, while conscientiousness had the strongest positive relationship with task performance, it was not a significant predictor of performance after receiving feedback. This result, in agreement with previous feedback research (Bell, 2008) indicates conscientiousness was not a prominent predictor of reacting to feedback. An alternate explanation is that engineers in general are known to be more conscientious (Van Der Molen et al., 2007), which was true in the current sample. As individuals with higher conscientiousness perceive higher responsibility and control over the task performance (Penley & Tomaka, 2002), feedback did not have a significant effect on their approach to the task. Finally, in agreement with prior research (Swift & Peterson, 2008), extraversion was not a significant predictor of performance after receiving feedback.

Limitations

This study was designed to understand student's response to negative feedback on challenging academic tasks. The study design limits the generalizability of the results. As the study was conducted in a controlled lab setting, reaction to negative feedback might not be representative of a real academic setback. Students might not react to negative task feedback with the same intensity as receiving negative feedback on a college test or assignment, mainly because the task is not associated with a grade. Further, they were required to perform the rest of the task immediately after receiving feedback. The results might be different if students were provided adequate time to process the feedback and prepare for the task, which is usually several days in the case of academic feedback at college.

Further, statistical analysis chosen in this study has limitations. To understand the interaction effects within the ANCOVA model, continuous variables were dichotomized. The purpose of this study was to understand individual characteristics that influence reaction to feedback rather than find a cut-off score for effectively reacting to feedback. Thus, a median split was used to observe the differences between high and low groups. However, statisticians have suggested alternate methods such as Johnson-Neyman procedures to study interaction effects as dichotomization reduces the statistical power (Aguinis & Gottfredson, 2010; D'Alonzo, 2004). The use of more statistically robust analysis might provide more insight into the exact relationship between the variables.

Conclusions

The system used to admit students into the engineering program is biased towards individuals with higher conscientiousness. However, when faced with academic adversity, emotional stability was predictive of student performance. Additionally, openness moderated the relationship between task difficulty and performance. This study highlights the possibility that individual characteristics associated with academic performance may not be helpful for coping with academic challenges. Along with personality variables, there is a need to explore the role of cognitive and psychological factors that help students cope with academic challenges, especially among STEM undergraduates.

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CHAPTER 5

CONCLUSIONS

Math-intensive STEM majors such as engineering are known for their academic rigor. As freshmen use their academic performance to assess their fit into the program, grades are a crucial factor in predicting student retention (Ost, 2010; Rask, 2010). Engineering majors often reported receiving lower grades or experiencing academic failure (Kokkelenberg & Sinha, 2010), which could lead them to perceive a poor fit with their major. In order to improve undergraduate retention in engineering majors, there is a need to understand how students perceive and process academic challenges.

During the first year of math-intensive STEM majors, the curriculum is majorly composed of introductory math and science courses (Jin, 2013). Successfully completing the introductory courses is mandatory to progress through these STEM-focused majors (Ohland, Yuhasz, & Sill, 2004). While students who attained a more rigorous high school preparation are at an academic advantage, experiences during the first math course have been known to influence a student’s intent to persist in an engineering major (Tyson, 2011; Van Dyken, 2016). The first article written for this dissertation was a meta-analysis to quantitatively summarize the role of SAT math score, first math course at college, and first math grade on undergraduate retention in STEM focused majors.

Given that undergraduate retention is a complex problem, a number of academic and non-academic factors have been implicated. In order to understand the complex interplay between these factors, a narrative inquiry was performed. Using the psychological model of retention (Bean & Eaton, 2001), lived experiences of engineering undergraduates at Kingslanding

University was explored. The second article written for this dissertation work was a qualitative investigation of freshmen engineer's journey and challenges during the first year of college.

Due to the increase in academic difficulty from secondary to post-secondary education, students are more likely to experience academic challenges at college. STEM professionals noted that they were ill-equipped to handle academic failure as adolescents and had to reconfigure academic failure as a positive experience while students transition into post-secondary STEM majors (Simpson & Maltese, 2017). Even though experiencing failure is an integral part of an engineering major, very few studies investigate how successful students navigate these challenges (Henry, Shorter, Charkoudian, Heemstra, & Corwin 2019). To this end, the third article written for this dissertation study was an experimental design to observe freshmen engineer's reaction to negative feedback conducted in a lab setting. Further the relationship between student's reaction to negative feedback and personality traits was explored.

Summary of Findings

The results of the meta-analysis (see Chapter 2) revealed that first math grade had the strongest effect on STEM retention, followed by SAT math scores and first math course. SAT math scores and first math course in college were indicative of academic preparation. In agreement with the widely accepted notion, students with better math preparation were more likely to persist in STEM majors. Similarly, the findings of the second article suggested that students with rigorous academic preparation were less likely to face academic challenges and had stronger intentions for persisting in their chosen majors.

Academic advisors at the university, taking into consideration students' high school preparation, suggested the first math course for freshmen. Participants in this study showed a general discontentment and frustration with the advising process. This was a similar trend throughout other engineering programs as well (Goodwin, 2008; Haag, Hubele, Garcia, & McBeath, 2007; Meyer & Marx, 2014). Advisors at Kingslanding University tended to advocate starting with a lower level math course even though students had credit to waive out of a particular course. Given that initial university experiences were crucial for freshmen, the suggestions made by the academic advisors could change their trajectory through college. Therefore, improving advising at Kingslanding could lead to better student outcomes.

A relatively less explored factor, first math grade appeared to be a stronger predictor of retention as compared to traditional academic predictors. Students consider being academically integrated or receiving good grades as an important factor for persisting in the major. However, adjusting to a rigorous grading system is a major challenge for students transitioning into engineering (Marra, Rodgers, Shen, & Bogue, 2012). Due to prior academic achievement, students entering engineering majors generally perceived adequate preparation. However, as documented by prior research (Rask, 2010), there was a gap between perceived and actual preparation. In comparison with their peers at other colleges, students receiving better grades perceived a good fit between their abilities and requirements of the major, while interpreting poor grades as a lack of fit within the program. Students unprepared for the rigor of courses contained within a STEM major are immediately demotivated by poor grades. While STEM retention research strongly advocates for better preparation at high school, freshmen are often ill-prepared to view academic challenges as learning experiences (Henry et al., 2009). In addition to academically preparing students, there is a need to psychologically prepare them for the rigors of college.

While grades play an important role in student retention, a small percentage of students were retained in STEM majors at the end of four years despite receiving poor grades. This result can be explained by individual factors such as motivation, social support, and personality traits (Honken & Ralston, 2013). Students who were strongly motivated to become engineers were more likely to persist as they considered their effort to be worthwhile. For these students, academic challenges were a stepping stone to reaching their goal of becoming engineers. On the other hand, students who pursued engineering due to external factors such as social norms were prone to continuously evaluate their fit in the program. Further, as the freshmen year curriculum is heavily geared towards introductory content, students who choose to drop out did not have a chance to experience any engineering courses. As suggested by National Academy of Engineering (2004), findings from this dissertation reinforce a need to engage students in the engineering design process beginning in the first semester.

Even though literature emphasizes that conscientiousness is associated with academic performance, the results from this dissertation (see Chapter 4) indicated that conscientiousness, was not predictive of performance after receiving negative feedback. While the admissions process was effectively screening for conscientious students, other personality traits such as emotional stability, and openness play an important role in navigating academic challenges. Given that receiving negative feedback is an emotional process, students who are emotionally stable are at a disadvantage as their emotion regulation strategies are not well developed. Helping students develop stronger and better emotional regulation strategies may smoothen their transition into post-secondary education.

Another noteworthy observation was that students, in general, hesitated to approach faculty and teaching assistants for academic help, especially because they may consider asking for help as a threat to autonomy (Thompson & Mwavita, 2006). However, students preferred approaching friends when faced with academic challenges. Thus, being socially integrated was important for help-seeking and coping with academic challenges. Even though peer tutoring and other student led help is available for engineering students, they are as unlikely to approach unfamiliar peers as a teacher for help (Karabenick, 2003). In order to improve social interactions among engineering freshmen, integrating co-operative learning and group work into engineering classrooms may be beneficial for freshmen engineering majors.

Conclusion

Feeling academically integrated was vital for student persistence in engineering majors. However, in the case of academic difficulties, personal and social factors influenced student intent to persist. While the research conducted during this dissertation investigates students' reactions to academic challenges, this area of research is vastly under explored, especially in the context of undergraduate STEM majors. While facing failure is a common experience among most STEM students, this important factor is often ignored by educators. In order to support aspiring STEM students, there is a need to understand how individuals overcome adversities and become successful STEM professionals.

Implications

Traditionally, preparation to enter college is primarily academic. While academic preparation is an important factor, psychological factors such as motivation and personality are important for perseverance and success in post-secondary environments. Especially for STEM majors who are likely to face academic failure, psychological factors play a crucial role.

Recommendations for High School Educators

As high school experiences are an important part of student's academic behavior, high school educators can contribute to improving STEM undergraduate retention. Students develop their self-efficacy based on academic experiences in high school. However, when academic rigor is compromised, their self-efficacy may be artificially inflated. Additionally, the phenomenon of "senioritis", or lack of motivation during the senior year of high school is dangerous. Teachers often support senioritis by reducing the required work, which leaves students unprepared for college. In order to ensure student success, high school educators must set high expectation and academic rigor.

As coding plays a prominent role in first year curriculum (see Chapter 3), freshmen engineering majors drop out due to under preparation in the field of coding. In terms of academic preparation, high school educators generally prepare student with the required mathematics and science content. However, there are inconsistencies between the amountof coding experience that different high schools offer. Both Texas Essential Knowledge and Skills (TEKS) and common core state standards (CCSS) do not explicitly require coding in the classroom. While CCSS mentions the relevance of coding within mathematics and language arts class, TEKS does not mention coding within the standards. Educators are emphasizing the need for coding at all great levels (Kafai & Burke, 2013) and drawing on mathematics content and process standards to guide coding instruction (Coding: TEKS Alignment for Coding, n.d.). As merely including technology in the classroom does not adequately prepare students for STEM fields (Warschauer,

& Matuchniak, 2010), various online coding communities like scratch (http://scratch.mit.edu) have been developed. A greater emphasis on coding, at least for aspiring STEM majors at high school is necessary. In order to help students better prepare for college, I strongly recommend developing concrete state and national standards to include coding at school.

Recommendations for Engineering Educators

Academic and social integration are important factors for undergraduate engineering retention. Student's interaction with peers, advisors and faculty influences their overall experience in the major and institution. First, dissatisfaction with advising was consistently reported by engineering freshmen in this study (see Chapter 3) and at many other universities (Meyer & Marx, 2014; Seymour, 2000). Students did not believe that advisors were keenly aware of how best to helpthem succeed, but rather felt that their counselors made generic suggestions. In addition, advisors were hard to reach. As suggested by retention research, the results of this study reinforce the need to improve advising to help students make appropriate course and major decisions.

Second, large class sizes have been a cause for concern in higher education. Especially for introductory STEM courses, large class size limits the amount of student-teacher interaction and effects the overall quality of instruction (Gilbert, 1995; Swap & Walter, 2015). Due to the large class sizes, assignments usually required answers to be exact and students might be unfairly penalized for technical errors (see Chapter 3). Students often questioned whether the grades were an accurate estimate of their knowledge. To avoid this discouraging trend, instructors should consider alternate forms of assessment. While I recognize that subjective and hands on assignments may not be realistically administered due to the class size, there is a need to develop better testing and assessment methods within large university freshman STEM classrooms.

Third, the teaching style in most freshmen university classrooms is generally lecture based. Students who were underperforming felt especially isolated from both their peers and their teachers. Including more interactive elements and cooperative group activities into the classroom with more student-student and student-teacher interactions may be beneficial to help students view the classroom environment as more friendly. While there has been some research about including interactive teaching elements in undergraduate STEM classrooms, (e.g. Smith, Vinson, Smith, Lewin, & Stetzer, 2014), there is a need for more research in this area. Finally, including elements of real engineering scenarios in introductory classes may encourage student persistence in their chosen majors.

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APPENDIX

INTERVIEW PROTOCOL

1. Think about your journey into the engineering program and through the first year. Please draw an illustrated road map of your journey.
2. How and why did you choose the engineering program?
3. Do you consider it a challenging major? Why or why not?
4. How was your experience during your math classes?
5. Have you received a grade lower than you anticipated during your freshman year? How would you describe the situation and your thought process?
6. Have you received a grade lower than you anticipated during your high school? How would you describe the situation and your thought process?
7. When you have academic difficulties, how do you deal with them?
8. How would you describe your social support system?
9. What advice would you give to an engineering freshman?