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Investigation of factors related to performance and retention of engineering students.

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INVESTIGATION OF FACTORS RELATED TO PERFORMANCE AND
RETENTION OF ENGINEERING STUDENTS

By

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B.S. Virginia Polytechnic Institute and State University, 1987
M.S. Arizona State University, 1993

A Dissertation
Submitted to the Faculty of the
College of Education and Human Development of the University of Louisville
in Partial Fulfillment of the Requirements
for the Degree of

Doctorate of Philosophy

Department of Education Leadership, Foundations, and Human Development
University of Louisville
Louisville, Kentucky

May 2014

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A Dissertation Approved on

February 28, 2014

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DEDICATION

This dissertation is dedicated to Thomas and Nathanael.

ACKNOWLEDGMENTS

ABSTRACT

INVESTIGATION OF FACTORS INFLUENCING PERFORMANCE AND
RETENTION OF ENGINEERING STUDENTS

Nora B. Honken

May 9, 2014

This study was part of an ongoing effort to improve retention of engineering

students at the J. B. Speed School of Engineering at the University of Louisville. The

purpose of this study was twofold: (1) to gain a better understanding of the relationship

among interest in engineering, performance and first-year retention in engineering, and

whether this relationship is different for males and females, and (2) to better understand

the relationship among self-control, academic ability and first semester GPA for

engineering students.

To address the first research question investigating retention, survey responses

and data from student records were analyzed using logistic regression. Results of these

analyses showed students who indicated they had very high interest in engineering were

43 times more likely to be retained than students who indicated very low interest, and 6

times more likely than a student who indicated they had low to medium interest, given

the same GPA. There was not a significant difference in the probability of being retained

for students who indicated they had high or very high interest, given the same GPA.

Results also showed that a one point increase in GPA increased the likelihood of a

student being retained by 4.6 times, given the same level of interest.

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Based on these results, the Step-outs to Stars engineering retention framework was created. Students were separated into four quadrants based on their level of interest and first semester GPA. The framework can be used as a mechanism to allocate resources targeted to improve engineering retention and to frame future research on engineering retention.

Structural equation modeling was used to analyze survey and student data to answer the second research question related to first semester performance of engineering students. In the study academic ability was measured by algebra readiness test scores and ACT math, science, English and reading scores. Self-control was measured by self-reported scores on the Brief Self-Control Scale (Tangney, Baumeister, & Boone, 2004). Results confirmed prior research, which found a significant positive relationship between self-control and academic performance, and a lack of significance between self-control and standardized test scores. These results can be used to strengthen the argument for programs to help improve self-control in K-12 and post-secondary students. The results can also be used to help prospective and current engineering students understand that higher levels of self-control might improve their academic performance in engineering.

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CHAPTER 1

INTRODUCTION

Introduction

There is an active debate as to whether there is or in the future will be a shortage

of employees qualified to fill STEM positions (see Charlette (2013) and United States

Congress Joint Economic Committee (2012) for a discussion of both sides of the debate).

The debate is important as some people believe that having a qualified workforce in

STEM fields is a key to the country remaining competitive in the global market

(Microsoft, 2011; Sabochik, 2010). Based on this belief, and regardless of which side of

the shortage argument is accurate, multiple government agencies, private organizations,

corporations, and universities are working to ensure an adequate supply of qualified

employees to work in science, technology, engineering, and math (STEM) positions.

In 2004 alone, the United States government funded over $2.8 billion for

educational programs designed to either increase the number of students studying STEM

or to improve their learning (United States Government Accountability Office, 2005).

STEM-related funding covered programs that provided institutional support to improve

the quality of education, improve or build physical infrastructure, fund students, and train

teacher and faculty. The funding focused on students in K-12 through the post-doctorate

level.

Private organizations and companies also have made efforts to increase the number of STEM employees in the workforce. For example, NBC Learns and the National Science Foundation have collaborated with the National Football Association, the National Hockey League, and the Olympics to produce videos to increase students' interest in science, math and engineering (National Science Foundaton, 2011), and AT&T has provided funds to Florida schools to improve its STEM education (Consortium of Florida Education Foundations, n. d.).

While some efforts focus broadly on STEM, others focus solely on engineering. Still others focus on women or minorities in engineering and science. For example, the National Science Foundation's ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers grant (National Science Foundation, 2013) specifically supports efforts and research focused on increasing the number of women in engineering and science.

Colleges of engineering at universities also have been working to increase the number of engineering graduates. Purdue (Astin, 2012), Texas A&M (Hamilton, 2013), and University of Washington (Long, 2013) have funded strategic plans to increase their capacity to educate more engineers. Purdue instituted an aggressive plan to double its number of graduates in engineering and created new faculty positions to support this goal (Astin, 2012). Concurrently, many universities and scholars have focused on increasing the retention rates of their students enrolled in engineering programs. To help improve retention rates, colleges of engineering have tried multiple strategies, including redesigning freshman courses, restructuring departments, expanding supplemental instruction, and implementing "living learning" communities (Loftus, 2005). Many of

these strategies have been rooted in the growing body of research in engineering education that has emerged in the past few decades (Gonzalez, 2006; Hartman & Hartman, 2006; Stassen, 2003; Webster & Dee, 1998; Zhao & Kuh, 2004).

The engineering college at Virginia Polytechnic Institute and State University was one of the first colleges to have a department focused on freshman education and retention (Sutherland, 2013). Its efforts contributed to a 9.3% increase in freshman retention between the 2003 and 2006 freshman cohorts, and a 7.2% increase in four year graduation rate between the same cohorts (Office of Instituional Research and Effectiveness, 2010). The J.B. Speed School of Engineering at the University of Louisville (UofL) also has invested in efforts toward increasing freshman retention with the intent of increasing its graduation rate. According to university data (Barrow, 2013), the freshman retention rate steadily increased for five years after the 2007 establishment of the Department of Engineering Fundamentals to focus on freshman student education and first-year retention. The duration of this effort, though, has not been a sufficient length of time to determine if the increase in first-year retention has resulted in an increase in the graduation rate.

Research Problem

In addition to the goal of supplying an adequate number of qualified engineers to meet workforce needs, engineering programs have been affected by pressure on colleges and universities to increase their graduation rate. Multiple state legislatures are trying to make colleges and universities more accountable for the state funds they receive (Marcus, 2012) and states are increasingly including retention and graduation rates as part of their funding formulas (National Center of State Legislatures, 2013). Current government

statistics gathered from Title IV schools show approximately 38% of students graduate from the same college or university in which they started within four years, and approximately 58% graduate within six years (Knapp, Kelly-Reid, & Ginders, 2012).

Another factor increasing pressure on colleges and universities to graduate more students (with the added pressure of doing so in less time) is the concern at the federal level regarding students' ability to repay over one trillion dollars of outstanding student loans (Khimm & Mui, 2012). U.S. Department of Education figures show a three-year official default rate on student loans for the 2009 cohort of 13.4%, and a one year default rate for the 2010 cohort of 9.1% (Department of Education, n.d.). Meanwhile, 30% of students with loans drop out of college, and these students are more than four times more likely to default on their student loans (Nguyen, 2012). Students who switch majors may take longer to graduate, which could cause them to acquire more student loans and also delay the start of repayment.

Finally, in 1990, the Student Right-to-Know and Security Act (1990) required institutions to report their retention and graduation rates to the public. College ranking systems, such as U.S. News and World Report, started using this information in their formulas to rank post-secondary institutions which resulted in added pressure for colleges and universities to increase their retention and graduation rates (Deangelo, Fanke, Hurtado, & Pryor, 2011).

The increase in pressure to improve retention and graduation rates at the institutional level (Deangelo et al., 2011) has been passed to the unit level, including colleges of engineering. This pressure, along with the national discourse on the need for

more engineers, has drawn attention to the retention of engineering students (Ferrini-Mundy, Peterson, & Jahanian, 2012).

Research has shown the first year of college is critical to students' decisions to persist in college (Tinto, 1993) as well as in engineering (Ferrini-Mundy et al., 2012). Due to the importance of first-year retention, multiple studies on retention of engineering students have focused on first-year retention (Besterfeld-Sacre, Atman, & Shuman, 1997; Moses et al., 2011; Veenstra, 2010), although some have taken a long term focus and have concentrated on graduation rates (Mendez, Buskirk, Lohr, & Haag, 2008; Zhang, Anderson, Ohland, & Thorndyke, 2004).

Multiple research studies have investigated factors related to both retention and academic performance (Besterfeld-Sacre et al., 1997; Veenstra, 2010). Some studies have shown a significant relationship between first semester or first-year GPA and first-year retention (Bundy, Lebold, & Bjedov, 1998; Hartman & Hartman, 2006; Mendez et al., 2008), although some did not (Seymour & Hewitt, 1997). In a study completed by Seymour and Hewitt (1997), there was no statistically significant difference in GPA between the students who remained in an engineering program and those who pursued a different program of studies, but students who had left engineering cited discouragement from low grades as a reason for leaving (Seymour & Hewitt, 1997).

Purpose of the Study

The current study was part of an ongoing effort at UofL to increase the graduation rate of engineering students by focusing on increasing first-year retention and gaining a better understanding of factors related to freshman engineering performance. The study was divided into two parts. The purpose the first part of the study was to gain a better

understanding of the relationship between first semester GPA, interest in engineering at the end of the first semester, and first-year retention in engineering. Previous research has shown that both lack of interest and poor academic performance are main contributors to students leaving engineering (Besterfeld-Sacre et al., 1997; Seymour & Hewitt, 1997). The first part of the current study was built on these studies and investigated the interplay of these factors for students who left engineering and those who were retained in engineering.

The purpose of the second part of the study was to gain a better understanding of the relationship among self-control, academic ability, and first semester GPA in engineering. Multiple studies discussed in Chapter 2 investigated factors related to performance of engineering students (Burtner, 2004; Moses et al., 2011; Veenstra, 2010) or the relationship between self-control and academic performance in non-engineering students (Tangney et al., 2004). Only one study could be found that investigated how self-control related to academic performance of engineering students (Honken & Ralston, 2013b). The authors investigated the relationship among first semester GPA, academic ability, and the frequency engineering students engaged in actions that showed lack of self-control in high school. Since the current study investigates only students studying engineering, the results add to the understanding of the relationship among self-control, GPA, and academic ability for students studying a specific major.

Research Questions

This study investigated the following research questions:

Research Question 1a: What is the relationship between the likelihood a student will be retained in engineering after one year and his or her first semester GPA and level of interest in engineering at the end of first semester?

Research Question 1b: What are the gender differences in the relationship between the likelihood a student will be retained in engineering after one year with his or her first semester GPA and level of interest in engineering at the end of first semester?

Research Question 2: What is the relationship among first semester GPA, academic ability and engineering student's level of self-control at the beginning and the end of their first semester of college?

Conceptual Underpinnings

Expectancy value theory (Atkinson, 1964) provided the conceptual framework for Research Questions 1a and 1b. Expectancy value theory is in a class of achievement motivational theories that attempts to explain why people choose to take on certain tasks, why they persist or do not persist on the task, the amount of effort they are willing to put into the task, and their level of performance on the task (Wigfield & Eccles, 2000). Others also have framed their research on engineering retention using this theory (Matusovich, Streveller, & Miller, 2010), but they have used different measures of value (operationalized as interest in engineering in this study) and expectancy (measured by first semester GPA in this study).

Research Question 2 which investigated factors associated with first semester GPA was grounded in empirical studies that have shown a relationship between self-control and academic performance (Duckworth, Quinn, & Tsukayama, 2012; Duckworth

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& Seligman, 2005; Hofer, Kuhnle, Kilian, & Fries, 2012; Tangney et al., 2004). These empirical studies were completed with students in the K-12 and postsecondary systems and are discussed in detail in Chapter 2. Despite multiple studies that investigated the relationship between self-control and academic performance, these studies did not have a large number of participants who were studying engineering, thus leaving an apparent gap in the literature.

Significance of the Study

Pressure to increase the retention rate of post-secondary students has increased due to state and federal governmental concerns over retention and the use of retention and graduation rates to rank institutions of higher learning (Deangelo et al., 2011). As a result, student retention is currently one of the most studied subjects in higher education (Tinto, 2006-2007). A subset of this literature concentrated on retention of engineering students has also been growing. Multiple reasons exist for studying engineers as a separate group including, (a) the differences in the demands of the engineering curriculum compared to other college majors (National Society of Student Engagement, 2011), (b) the types of students who choose to study engineering (Boylan, n.d.; National Center for Science and Engineering Statitistics, 2012; Zhang, Carter, Thorndyke, Anderson, & Ohland, 2003), and (c) a belief that factors effect engineering students' performance and persistence decisions differently than non-engineering students (Veenstra, Dey, & Herrin, 2008).

Since this study examined student performance and retention in engineering, results of the study have potential to benefit high school students who are choosing a major, college students who have already chosen to study engineering, high school and

college counselors who advise students, postsecondary faculty who plan curriculum and teach courses to engineering students, and administrators in the K-12 system who work to prepare students to study engineering.

Delimitations

The data used in the current study came from one cohort of engineering students from the University of Louisville which was less ethnically diverse than the national population of engineering students (National Science Board, 2010). A comparison of the cohort used in this study and the national population of engineering students is in Chapter 3. The independent variables used in the study (interest in engineering, first semester GPA, academic ability, and self-control) were extracted from survey data and student records. These variables measure factors that should apply in a similar fashion to students at colleges of engineering that are similar to UofL, the reader must determine if their institutions are comparable to UofL and if the results are applicable to their students.

Limitations

Within this study exist multiple threats to validity. Some of the threats are inherent in all studies using self-reported survey data and instruments to measure constructs such as self-control. Other threats are a result of the sample used in the study. A detailed discussion of the threats to validity is included in Chapter 3.

Definition of Terms

Engineering Cohort

The 2012 engineering cohort at the University of Louisville was comprised of all the full-time engineering students enrolled at the University of Louisville for the first time in the fall semester of 2012. The cohort does not include any transfer students, but

does include students who had enough Advance Placement credit to be considered a sophomore.

Retention

Retention is related to the ability of a college or university to retain a student to the given term or until graduation (Seidman, 2005). This study focused on first-year retention in engineering for students who entered UofL in the fall of 2012. A student was considered retained in engineering for the first year if he or she was enrolled at UofL for the fall semester of 2013 and his or her academic unit was engineering. A student was considered not retained if he or she was not enrolled at UofL in the fall semester of 2013 or his or her academic unit was different than engineering.

Self-Control

Many definitions of self-control can be found in the literature. The Brief Self-Control Scale (Tangney et al., 2004) was used in this study to measure self-control. The creators of the scale defined self-control as the "ability to override or change one's inner responses, as well as to interrupt undesired behavioral tendencies and refrain from acting on them" (Tangney et al., 2004, p. 275) in order to meet the highest order goal.

Student Records

Student records are maintained at the university level and include grades for all courses taken by students, their semester and cumulative GPAs, as well as demographic information and information used in the application process. This study used students' genders, first semester GPAs, and their ACT scores from these records.

University Official Enrollment File

Data on enrollment status, college major, and academic unit are maintained by the University of Louisville. This information is constantly changing as students change majors or withdraw from the university at different times during the year. On a specific date each semester, the university's Office of Institutional Research extracts enrollment data and creates a file which is used in all official university reports. Enrollment data used in this study was taken from this file which became official in December 2013.

Other University of Louisville Data

Statistics on the UofL 2010 and 2011 freshman engineering cohorts are used throughout this document as a comparison to the 2012 cohort. The Office of Institutional Effectiveness provided data on these cohorts for use in this study as well as other studies completed by the author while employed by the University of Louisville. These data were extracted from university student records, from University Official Enrollment Files, and from files containing results of surveys designed by faculty from the Department of Engineering Fundamentals and administered by the Office of Institutional Effectiveness. When data from these files are discussed in this document, they are referred to as "university data" and no further reference will be noted.

<div align="center">

Summary

</div>

The increased focus on retention is a result of many factors (Seidman, 2005). This interest, combined with the national discussion on the potential lack of engineers in the workforce (Committee on Prospering in the Global Economy of the 21st Century, 2007; Lederman, 2011; Salzman, Kuehn, & Lowell, 2013), has prompted more research focused exclusively on retention of engineering students.

This study contributed to the growing body of literature on first-year retention and first semester performance of engineering students. It added to the understanding of how interest in engineering and first semester GPA was related to first-year retention, which subsequently led to the creation of an engineering retention framework. This study also added to the understanding of the relationship between self-control, academic ability, and academic achievement for a specific group of students.

The next two chapters establish the foundation for the study. Chapter 2 contains a review of the relevant literature that justifies the conceptual framework of the study and further defines the gap in the literature this study attempted to fill. Chapter 3 contains a description of the methodology for the study. Chapter 4 contains the results from analyses of the data, and Chapter 5 contains the conclusions, recommendations, and potential topic for future research.

CHAPTER 2

LITERATURE REVIEW

Introduction

This study addressed the issue of retention of first-year engineering students. Much of the research in engineering retention draws from the university retention literature which dates back to the 1920s (St. John, Cabrera, Nora, & Asker, 2000). Early research in college retention was rooted in psychology and focused on individual skills, attributes and motivations. In the 1970s, research framed in theories from the field of sociology that focused on the role of the academic and social systems of the institution began to appear (Tinto, 2006-2007). This shift was influenced by the work of Spady (1970) that was later popularized by Tinto (1975). Another body of research in the university retention literature is focused on finances. This research (St. John et al., 2000) investigates the impact of students' ability to afford to remain in college and how personal finances interact with other factors to influence retention.

Many of the factors investigated in studies of university retention have influenced studies of retention in engineering. These factors include pre-entry characteristics such as skills and abilities (Burtner, 2004; Mendez et al., 2008), family background (Eris et al., 2010; Veenstra, 2010), and institutional experiences (Hartman & Hartman, 2006; Marra, Shen, Rodgers, & Bogue, 2009). While research in university retention has focused on

integration into the university, research in engineering retention has focused more on integration into the engineering culture (Matusovich et al., 2010).

Other factors, such as the ability to pay for university, play a different role in the study of university and engineering retention. In the university retention literature, the discussion on financial issues focuses on not having funds to pay for university. In the engineering retention literature, the focus is around students switching majors to help improve their GPAs so they do not lose their scholarships (Zhang, Min, Frillman, Anderson, & Ohland, 2006).

Factors not related to college retention, but instead related to college major and career choice, have also been investigated in studies of engineering retention. Some studies have focused on why students made the decision to study engineering (Honken & Ralston, 2013a; Mcilwee & Robinson, 1992; Microsoft, 2011). Others have focused on why students decided to switch majors (Besterfield-Sacre et al., 1997; Seymour & Hewitt, 1997). Collectively, these studies investigated factors that included the importance of available jobs, good pay, interest in the field, and ability to perform.

Similar to research in college retention, studies on college major and career choice have been grounded in psychology and sociology. In addition, college major and career choice research has also been grounded in economic theory. There is overlap in the variables studied in the fields of university retention and college major and career choice. One such example is the influence of others, such as parents, teachers and friends. Models in college retention, such as Tinto's (1993), include influence of others, as does social capital theory (Coleman, 1988; Lin, Cook, & Burt, 2001) which has been used to explain how students choose their college majors or careers.

Many of the studies on engineering retention are framed through the lens of university retention. Although there is value in this perspective, Research Questions 1a and 1b were framed in expectancy value theory (Atkinson, 1964), a theory from the college major and career choice literature.

The first part of this chapter is a review of the current literature on engineering retention, theories on college major and career choice, and justification for use of the framework. The second section of the chapter addresses the related topic of academic performance of engineering students. This section contains a review of literature influencing Research Question 2 that investigates the relationship among first semester GPA, self-control, and academic ability in engineering students. Within this part of the chapter is a summary of past research on academic performance of engineering students and literature that supports using self-control and academic ability to predict performance.

Retention of Engineering Students

Past Research in Engineering Retention

The current body of literature on retention in engineering can be divided into three broad categories: (a) correlational studies that investigate the relationship between various factors and retention in engineering; (b) survey- and interview-based studies, involving only students who have left engineering, that investigate why students decided to no longer major in engineering; and (c) quasi-experimental studies that investigate how changes to curriculum impact retention. Research on engineering retention reviewed for the current study is outlined in Appendix A. The following sections discuss the factors investigated in these studies and are separated by general categories.

Cognitive factors. Correlational studies on engineering retention based in psychology have investigated both cognitive and non-cognitive characteristics. Cognitive measurements investigated have included ACT and SAT test scores (Besterfeld-Sacre et al., 1997; Bundy et al., 1998; Hartman & Hartman, 2006; Zhang et al., 2004), high school GPA (Bundy et al., 1998; Mendez et al., 2008), scores on math readiness tests (Moses et al., 2011), and first semester GPA (Bundy et al., 1998; Burtner, 2004; Hartman & Hartman, 2006; Mendez et al., 2008). The results of these studies were dependent upon what variables were included in the model, what measure of retention was used, and the sample. For example, in a study performed by Bundy and colleagues (1998) to predict retention of engineering students (no other information was given as to time span), SAT math scores were statistically significant along with high school rank and first semester GPA. But SAT math scores were not statistically significant in a study to predict first-year retention in engineering by Moses and colleagues (2011). The significant variables related to cognitive ability in that study were scores on a calculus readiness test and high school GPA. In another study (Zhang et al., 2004), which used data from nine universities and investigated graduation rate of engineers, the significant variables varied by university. The independent variables investigated included ethnicity, gender, high school GPA, SAT math scores, SAT verbal scores, and citizenship. High school GPA and SAT math scores were significant in the models for all nine schools studied, but the significance of the other cognitive variable was not consistent among the university.

Non-cognitive factors from psychology. Non-cognitive personal characteristics that have been found to have statistically significant relationships with retention have included openness (Moses et al., 2011), confidence in study habits (Burtner, 2004),

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confidence in major (Hartman & Hartman, 2006), and confidence in math and science skills (Eris et al., 2010; Veenstra, 2010). Other non-cognitive personal characteristics have been investigated, but the relationship was not determined to be significant. These characteristics include confidence in subjects such as speaking, writing, computers, and chemistry, (Besterfeld-Sacre et al., 1997; Burtner, 2004); locus of control, neuroticism, extroversion, agreeableness, and conscientiousness (Moses et al., 2011).

Factors from sociology. Studies have also focused on factors related to sociology. These studies have investigated the impact of parents, teachers, and friends on students' decisions to study engineering and how this related to their likelihood of staying in engineering. Again, the significance of the variables is dependent upon the design of the study. Studies have shown that having a parent (Eris et al., 2010; Leslie, Mcclure, & Oaxaca, 1998) or high school mentor (Eris et al., 2010) who discussed engineering with the student increased the likelihood of retention. Meanwhile, in Burtner (2004), parental influence to study engineering did not have a significant relationship with fourth year retention, and in Besterfield-Sacre et al. (1997), parental influence to study engineering was significantly related to first-year retention for students who left in good standing, but not for those who left in poor standing.

Other studies grounded in sociology have investigated the relationship between student engagement in university life and retention in engineering. Hartman and Hartman (2006) found that students who were involved in academic enrichment and counseling activities were statistically more likely to be retained, but satisfaction with their relationships with peers and faculty was not a significant factor in retention in other studies (Heller, Beil, Dam, & Haerum, 2010; Marra et al., 2009; Olds & Miller, 2004).

Changes to curricula. Published quasi-experimental studies have investigated the changes in retention after implementing changes to engineering programs. Changes included forming research partnerships between undergraduate students and faculty (Nagda, Gregerman, J., Vonhippel, & Lerner, 1998), implementing learning communities (Olds & Miller, 2004), having a series of classes all taught by the same professor (Felder, Felder, & Dietz, 1998), and restructuring first-year programs (Shuman, Delaney, Wolfe, Scalise, & Besterfeld-Sacre, 1999). All of these authors state the changes had a positive impact on retention in engineering.

College Major and Career Choice Literature

The majority of the studies cited in the previous section focused on factors within the college retention realm that fall under pre-entry characteristics, goal commitment, and institutional experiences. Other studies have focused on students' decisions to major in engineering. The following sections contain a review of these studies and the frequently applied theoretical work on career and college major choice.

Empirical studies. Empirical studies of college major and career choice focused around engineering students can be divided into three broad categories: (a) why the students decided to major in engineering, (b) why students decided to leave engineering, and (c) gender and ethnic differences in college major and career decision making. All of these types of studies add insights into the retention of engineering students. Since ethnicity was not investigated in the current study, literature in that area was not reviewed.

Why students choose engineering. Organizations and research teams have conducted survey research to determine why students choose to study engineering. Some

of these studies investigated solely engineering (Honken & Ralston, 2013a), while some studies also included science, technology and math majors (Microsoft, 2011). Conclusions from these surveys were dependent upon many factors such as the questions asked, the available responses, the number of responses that could be selected, and the population sampled.

Harris International (Microsoft, 2011) conducted a national online survey of college students currently pursuing engineering, as well as science, technology, and math fields. Results of the survey showed 86% of the students were motivated to choose their major based on the belief they could get a good salary; 68% were motivated by intellectual stimulation and challenges; and 66% were motivated by job potential. Females more frequently mentioned the belief that they could make a difference; males were more likely to highlight the influence of playing with games and toys, reading books, and participating in clubs related to STEM areas (Microsoft, 2011). Sixty-eight percent of the female students and 51% of the males chose *A teacher* or *A class* as the top factor that sparked their interest in STEM fields.

The same three factors – job availability, good pay, and interest – were cited in published studies at University of Louisville (Honken & Ralston, 2013a) and Arizona State University (Anderson-Rowland, 1997). In the Arizona State University study, students were asked why they were interested in engineering or applied science, and were given seven responses to rank in order of importance. In their top three responses, 79% included *Potential good salary*, 72% included *Interesting work*, and 63% included *Many job opportunities*.

In a similar study with the 2011 freshman cohort at the University of Louisville (*n* = 321) (Honken & Ralston, 2013a), students in the 2011 cohort were given nine factors and asked to rank the top three they considered when determining what career to pursue. The top reason, measured by both the percent of students who chose it as their top reason (34%) and the percent that choose it in their top three reasons (64%), was *That holds my interest*. The next highest response was *That I feel confident jobs will be available when I graduate*, which was selected as the top reason by 21% of the students and in the top three by 56% of the students. The final response that was selected in the top three by over half of the students was *That pays well*.

As mentioned previously, conclusions from studies on why students choose to study engineering were dependent upon how the question was framed and the options provided. McIlwee & Robinson (1992) concluded the top reason students chose to study engineering was that they were good at math and science. On a survey given to freshman engineering students at UofL in 2010 (Honken & Ralston, 2013a), students were also asked, "Why did you choose engineering as a major?" and they were free to choose multiple answers. The answers chosen most frequently were *Good at math and science* (88%), followed very closely by *Heard engineering had good job opportunities* (82%), and then *Researched what engineers do and think I'd like it* (69%). The lowest response was *A parent recommended it* (29%). The average number of reasons selected was 3.7 (out of 7 options). Since only 6% (*n* = 20) of students chose *Good in math and science* as the only reason they chose engineering, it is misleading to conclude the majority of students chose engineering solely because they are good at math and science. It is

appropriate to say that the majority of the students who chose to study engineering believed they were good in math and science.

Why students left engineering. Other studies have gathered data from students who started in engineering, but subsequently left. A well-referenced multi-institutional ethnographic study (*n* = 335) (Seymour & Hewitt, 1997) investigated why students who were expected to be successful based on their SAT math scores switched from engineering while others did not. Lack or loss of interest in engineering was one of the top contributing factors to students' decisions to switch out of engineering. A male student who switched out of engineering pointed out the importance of having interest in engineering: "You have to have the interest and the desire. I don't think the problem is preparation. I think it's more interest." (p. 179). Other top factors cited in the study related to difficulty of the curriculum, poor teaching and advising, and loss of confidence due to poor grades. In the Seymour and Hewitt study, 19.8% of the students who left science, engineering, and math cited they chose their major for the financial rewards and job availability; they left due to lack of interest.

Loss of interest in engineering was also documented as a major cause for leaving engineering in a study that analyzed survey results from students who transferred out of engineering at the University of Pittsburgh (Shuman et al., 1999). Of the 115 freshmen who completed the survey, 72% selected *Lost interest/developed new interest* as a factor in their decision to leave engineering. Additionally, 66% selected *Came to dislike engineering/studying engineering*, and 25% cited *Academic problems*.

Females' decisions about studying engineering. Based on the belief that females have different experiences in engineering, the Alfred P. Sloan Foundation funded a study

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to investigate female engineering students' experiences and their retention in engineering. In the longitudinal study (Goodman et al., 2002), students from 53 institutions (*n* = 9,071) were asked the top three reasons (in open response format) that they wanted to become engineers. The researchers classified the responses into nine categories. The category with the most responses was *Future job characteristics* (68%). Within this category, the top two subcategories were *Good salary* and *The number of job opportunities*. The second category (58%) was *Interest in engineering content process*. Within this category, the top two responses were *It interests me* and *I like math/science/technology*. The remaining categories were *Personal fulfillment* (46%), *Work that student wants to do* (20%), *Pride and achievement* (16%), *Reasons external to engineering* (13%), *Influence of others* (10%), *School programs* (9%), and *School climate* (2%).

In the same study, females who left engineering were asked (in open response format) for the top three reasons they decided to leave engineering. Of the 839 students who responded, 54% of the students had a response that was categorized as *Lack of interest*. Within this category, the top two subcategories were *It does not interest me (anymore)* and *I'm not interested in math/science work*. The category with the second most responses was *School programs* (50%). This included subcategories such as *Too much time/energy to become an engineer* and *Overwhelmed by the workload*. The remaining categories were *Reasons external to engineering* (37%), *School climate* (31%), *Personal fulfillment* (27%), *Pride and achievement* (27%) (which included poor grades), *Future characteristics* (18%), *Influence of others* (%), and *Work that student wants to do* (1%).

In the same study ($n = 5{,}560$), females who stayed in engineering and those who left were asked two separate questions about the main source of the most discouragement and encouragement in their freshman year. The most cited source of discouragement was *Grades*, which was indicated by 24% of all females and indicated by more who left engineering than those who continued to study engineering. Five percent of the students selected *Interest*. The top sources of encouragement were *Father* (18%), *Mother* (16%), and *Interest* (15%). The results of this study seem to suggest that interest can be a source of encouragement or discouragement.

In the Goodman study, the females who stayed in engineering had statistically higher average grades than those who left engineering. But almost 45% of the females who left engineering had an A or B average. The authors noted that some females who were doing very well were discouraged by grades, which might suggest some females set their grade standards too high.

Summary. In summary, empirical studies show engineering students were influenced by multiple factors when they decided to major in engineering. Based on the studies just reviewed, some of the top factors include students' interest in engineering, perceived availability of high paying jobs, influence of others, and confidence in math and science skills. There were also multiple factors influencing students' decisions to discontinue majoring in engineering. Based on the reviewed literature, loss of interest and academic difficulties are top reasons students left engineering.

Theoretical literature. The current study was framed in expectancy value theory which has been used to frame other retention studies of general college students (Eccles & Wigfield, 2002; Watt & Richardson, 2007) and engineering students (Matusovich et al., 2010).

Other theoretical perspectives have been used more extensively to frame research on college major and career choice, and, as such, have indirectly influenced this study. Elements of human capital theory (Becker, 1964), social capital theory (Coleman, 1988; Lin et al., 2001), and Holland's theory of vocational choice (Holland, 1997) influence how an individual determines value and expectancy of a task. The following section contains a brief description of these theories and a review of research in engineering retention that is related to each theory. Following this is a detailed discussion of expectancy value theory and justification for its use in framing the current study.

Human capital model. From a theoretical perspective, the human capital model is the most frequent economic framework applied to understanding college major choice (Kim, 2012). This model assumes individuals are rational and they decide on a college major by weighing the current and future costs of obtaining a degree in a particular major with the expected current and future benefits received from obtaining a degree in this major (Desjardins & Toutkoushian, 2005). An individual then chooses the major only if the expected benefits are more than the expected costs. What is included in costs and benefits varies between individuals and within an individual as priorities change. As the individual learns more about the costs and the benefits of pursuing and earning a degree, their ratio of cost to benefits might change. If the costs start to outweigh the benefits,

according to the human capital model, the individual would switch majors and/or select another career.

Data supporting the use of the human capital model to explain how individuals choose what to study are found in the previously mentioned research on engineering retention. In research by Harris Interactive for the American Society of Quality (ASQ, 2012), survey results indicated that students recognized the benefits of obtaining a STEM degree, yet were not considering engineering due to the amount of work that was required. In the Seymour and Hewitt (1997) study, 35% of the students who switched out of engineering, science, and math listed the large volume of work (cost) as one of the reasons they switched; likewise, in the Goodman study (2002), 21% of the students indicated the amount of work as a discouragement to studying engineering. Students selecting to major in engineering based on the benefits that can be gained from earning an engineering degree was evident in the survey results showing the high percentage of first-year engineering students who selected engineering based on the availability of jobs and high pay (Honken & Ralston, 2013a; Microsoft, 2011).

Social capital theory. Social capital theory (Coleman, 1988; Lin et al., 2001) has also been used to explain choice of college major. Social capital refers to the benefits gained through relationships and being part of a social network (Perna & Titus, 2005). According to Coleman (1988), there are three forms of social capital: obligations and expectations, information channels, and social norms. Some have concluded that parents have the largest impact on their children's career and college major choices (Porter & Umbach, 2006).

Within the research focusing on engineering students, multiple studies have concluded parents, teachers, and other role models have influenced students' decisions to major in engineering (Adelman, 1998; Astin, 1993; Goodman et al., 2002; Seymour & Hewitt, 1997). The influence seems to be particularly strong for women and minorities (Martin, Simmons, & Yu, 2013).

The use of social capital theory to explain why students choose engineering as a major was confirmed in a survey of Oregon State University engineering students where 66% of the participants indicated they were influenced to study engineering by parents/guardians, 45% by a friend/coworker, and 44% by a math/science teacher (Doolen & Long, 2007). The influence of parents was not as strong in a UofL (Honken & Ralston, 2013a) survey. This may be due to the low percentage (14%) of students in this cohort who had a parent working in engineering or the low percentage of engineers in the Kentucky workforce (National Science Board, 2010).

Holland's theory of vocational choice. Many people have concluded individuals of certain personalities are more likely to choose certain careers (Porter & Umbach, 2006). Holland's theory of vocational choice, considered by many to be the most influential theory on career choice (Feller & Honaker, 2001), is built on the premise that personality and interests are more important than aptitude and intelligence. The theory is based on the following four assumptions (Holland, 1997):

- Most individuals' personality types can be categorized as one of the following: realistic, investigative, artistic, social, enterprising or conventional.

- Environments can be categorized as one of the following: realistic, investigative, artistic, social, enterprising and conventional.

- Individuals gravitate to an environment in which they can use their skills and abilities, express their attitudes and values, and engage in agreeable problems and roles.

- The interaction between personality and environment determines an individual's behavior.

This model also is supported by data found by Seymour and Hewitt (1997) where over half of the students who left engineering cited loss of interest in engineering as a reason for leaving engineering. In a study at the University of Pittsburgh that included a survey of students, one-third of the students indicated they left engineering due to lack of interest (Besterfeld-Sacre et al., 1997).

Expectancy value theory. Expectancy value theory is considered a motivational theory that attempts to explain individuals' choice of behavior based on their expectation that they can do well and the value they place on the outcome of completing the task (Wigfield & Eccles, 2000). The behavior can be related to the decision to work on a task, whether or not to persist at a task, or the amount of effort to invest in a task. Expectancy value theory has also been used to explain performance on a task (Eccles & Wigfield, 2002). Atkinson was the first to form a mathematical model including expectancies and values that attempted to explain the choice among tasks and persistence at a task and achievement (Wigfield, Tonks, & Klauda, 2009). He hypothesized an inverse relationship between the ease of completing the task and the value placed on it, thus assuming a task that was harder to achieve had less value. He also hypothesized that a person's expectancy was based on a motive to find success and a motive to avoid failure. Since then, multiple models have been based on Atkinson's expectancy value theory

(Eccles, 1983; Feather, 1982). The modern theories assume a positive relationship between value and ease of completing the task. Thus tasks that are harder to complete are assumed to have more value (Eccles & Wigfield, 2002).

Modern expectancy value theories also expanded on the factors that contribute to an individual's expectancy and value beliefs. Feather (1982), who verified this theory for several types of behavior including selecting an academic major, broadened the concept of value. Heckhausen expanded on expectancy to include four types of expectancy: situation-outcome, action-outcome, action by situation outcome, and outcome. Heckhausen considered value as the consequences on one's actions (Eccles & Wigfield, 2002).

Eccles and colleagues further expanded on factors that determined both expectancy and value. They hypothesized a detailed model of expectancy value theory which they used to guide their research on, among other things, how girls make decisions to take upper-level math courses, to predict performance in math and English, and to explain career choices (Eccles & Wigfield, 2002).

Expectancy. Bandura (1997) discussed two types of expectancy: outcome expectancy and efficacy expectancy. Outcome expectancy deals with the belief that a behavior will lead to a desired outcome; for example, the belief that "If I study hard, I will get an A in this class." Efficacy expectancy concerns an individual's belief that he or she can be successful in completing a given task, such as the belief that he or she can complete an engineering degree. The current study focused on efficacy expectancy.

There are multiple factors that impact whether an individual believes he or she can be successful at a task. These include competence, self-efficacy, and control over the

outcome (Eccles & Wigfield, 2002). Rotter (1966), who produced a locus of control scale, theorized that individuals who feel as though they are in control are more likely to have a higher expectancy of being successful. Therefore, if a student believes a professor is a hard grader and it is impossible to do well in the class, the student will have lower expectancy. Bandura (1997) focused on self-efficacy that he defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). He theorized that people with higher self-efficacy would have higher expectancy for success on a task. An individual's view of his competence reflects his perception of his ability and his perceived difficulty of the task (Wigfield & Eccles, 2000). Expectancy will be lower if the individual's perceived ability is low or his perceived difficulty of the task is high (Weiner, 1976). Studies have shown a person's perception of his ability to achieve at a task (expectancy) can be related to how others view his abilities (Eccles, 1983). This can be considered a form of social capital since the person's expectancy can be impacted by a positive relationship with others that instills confidence.

Competency, self-efficacy, and control contribute uniquely as well as interactively to the level of expectancy. Wiener (1976) states that if an individual assumes that conditions will remain the same, (for example, he has the same level of control) and that his past success was due to ability, he will anticipate success in another similar task.

The current study used first semester GPA as measure of expectancy. Seymour and Hewitt (1997) reported that 25% of the students who switched from engineering cited poor grades as a factor in their decision to switch and 40% cited it as a concern. Shuman,

et al. (1999) showed that students on academic probation accounted for half the students who left engineering. At the same time, GPA was not a statistically significant predictor of who switched majors in the Seymour and Hewitt study. Other research has shown a statistically significant difference in the GPA for students who remained in engineering versus those who left the university or switched to another major (French, Immekus, & Oakes, 2005; Goodman et al., 2002; Moses et al., 2011; Veenstra, Dey, & Herrin, 2009). Hartman and Hartman (2006) found significant difference in GPA for males who left engineering and those who stayed, but there was no significant difference for females. A study at UofL showed a significant difference in GPA for the students who switched out of engineering or left the university after one semester compared to the students who remained in engineering (Honken & Ralston, 2013a); but, when the time span was expanded to one year, the results changed. Although there was still a significant difference in average GPA between students who left the university and those that stayed in engineering, there was no significant difference in average GPA between the students who stayed in engineering and those who switched majors out of engineering, but remained at the university.

GPA is important to students due to university-established GPA requirements as well as personally established standards. For some students, grades help define their self-worth and a drop in grades can be devastating and can lead students to switch out of challenging disciplines such as engineering (Seymour & Hewitt, 1997). One female participant in the Seymour and Hewitt study who switched out of engineering made the following comment in reference to self-esteem and GPA: "A lot of people let their self-esteem get caught up in their grades. So when their grades are going down they are

pretty miserable" (p. 109). Another participant, who also switched out of engineering, commmented on the impact of getting her first B in engineering school after receiving all A's in high school: "By my second mid-term, I was still pulling around the mean – which is okay – even pretty good. But I was still a B- or C+, which is horrible for someone who does well in high school and is accepted into a school as good as this. I mean, I never got a B until I got to college. It was very discouraging" (p. 108).

Two policies at UofL and some other universities that place importance on GPA are the requirement to earn a minimum GPA to retain a scholarship and stay off academic probation. Many scholarships, such as Georgia's Hope Scholarship (Georgia's Student Finance Commission, 2012), South Carolina's Life Scholarships (Mobley, Brawner, & Ohland, 2009), and Florida's Academic Scholarship (Zhang et al., 2006), require students to maintain at least a 3.0 GPA to keep their scholarships. According to national results from the 2011 Cooperative Institutional Research Institute (CIRP) Freshman Survey, 27% of all college freshmen who completed the survey specified they had scholarships of over $10,000 and 70% of the freshmen had some form of grant or scholarship (Pryor, Deangelo, Blake, Hutado, & Tran, 2011). In the cohort used in this study, 25% of students self-reported they had full scholarships and 56% indicated they had partial scholarships. Their scholarships were awarded from a variety of organizations within the university as well as outside organizations. The majority of the awards required a minimum GPA of 3.0, but some allowed students who fell below a 3.0 to petition to keep their scholarships. After one semester, 31% of the students with full scholarships and 50% with partial scholarships had GPAs of less than 3.0 and were in danger of losing their scholarships if they did not improve their GPA by the end of their first year.

Keeping a certain GPA is also important to stay off academic probation. College students at most universities must maintain a GPA of 2.0 or above to stay in good academic standing. In UofL's 2010 cohort, 17% of the students were either on academic probation or had received an academic warning at the end of their first year (Guild for Engineering Education Achievement, Retention and Success, 2010).

GPA can also be important when looking for a job. In the National Association of Colleges and Employers (NACE) Job Outlook 2011 survey, 77% of the employers reported they screen college students based on GPA. Sixty-four percent of those who screened said they used 3.0 as a minimum GPA (Nace, 2010). At the end of the first year, 56% of the cohort in this study had a GPA of less than a 3.0.

Due to the importance of GPA to students and the results of the previously discussed studies which showed a high percentage of students who left engineering stated one of the reasons they left was poor grades, GPA is an appropriate measure of expectancy. The measure of first semester GPA was used in this study for three reasons. First, some students leave engineering after one semester and thus would not be included in the study if first-year GPA was used. Second, the level of interest in engineering was measured at the end of the first semester, and this study investigated both interest and expectancy (GPA) simultaneously, and it was important that they were measured at a common time. Finally, in past studies at UofL, the first semester GPA had a strong correlation with first-year GPA. According to University of Louisville data for the 2010 cohort of engineering students, the correlation between first semester and first- year GPA was .93 (Guild for Engineering Education Achievement, Retention and Success, 2011).

Value. The other construct in the model for the current study is value**.** Value is

related to the incentive or gain from doing or completing a task (Eccles & Wigfield,

2002). Values can be thought of as the costs and benefits in the human capital model.

Eccles and Wigfield (2002) list four components that determine the value of completing a

task: intrinsic, utility, attainment, and cost. Intrinsic value is related to the enjoyment a

person gets from engaging in the task. The more interested one is in the task, the higher

the intrinsic value. Utility value is based on the contribution the activity makes toward

meeting a long-term goal. Attainment value includes the benefits gained from

completing the task, such as doing a good job or earning an engineering degree.

Attainment value can also be related to less concrete results such as confirming an aspect

of one's self-schema (Matusovich et al., 2010), or the relevance of engaging in the task.

Finally, cost value includes the effort needed to engage in the task, as well as the inability

to do other tasks, and emotional costs such as anxiety and fear.

The importance placed on each type of value varies by individual and can vary

within an individual over time. For example, research has shown some individuals place

more importance on finding a job that they like (intrinsic value), while another places

more importance on finding a job with high pay (attainment value) (Honken & Ralston,

2013a). Earlier in one's schooling or career, an individual could potentially make

decisions based on pay; but, later in his career, the same individual might look for a job

that is more interesting for him. In Seymour and Hewitt's (1997) study, 19% of the

students who left engineering mentioned they had chosen engineering based on financial

rewards (attainment value) but left due to lack of interest in engineering (intrinsic value).

Matusovich and colleagues (2010) completed a qualitative study of engineering students framed in expectancy value theory in which they investigated all four domains of value: intrinsic, utility, attainment, and cost. The qualitative study with 11 students (all but one remained in engineering) focused on the importance of perception of self as an engineer in a student's decision to study engineering (the authors considered attainment value).

Based on the previously discussed theories, particularly Holland's theory of vocational choice, and empirical research on college major and career choice, interest in a discipline is an appropriate measure to represent value. Using interest to measure value when looking at retention in a major also is supported by studies that showed interest was the primary factor in the general college student population's college major and career choices (Allen & Robbins, 2008; Malgwi, Howe, & Burnaby, 2005; Morgan, Isaac, & Sansone, 2001). Studies with only engineering students have shown students chose engineering based on interest (Honken & Ralston, 2013a; Microsoft, 2011) and students left engineering due to lack of interest (Anderson-Rowland, 1997; Besterfeld-Sacre et al., 1997; Burtner, 2004; Seymour & Hewitt, 1997; Shuman et al., 1999). No studies could be found that specifically investigated the relationship among interest, first semester GPA, and first-year retention of engineering students.

Academic Performance of Engineering Students

A second focus addressed in this study was the performance of first-year engineering students. This section of the literature review relates to Research Question 2 which investigated the relationship among first semester GPA, self-control, and academic ability. As discussed in the previous section, studies have linked first semester and first-

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year GPA with retention in engineering (Bundy et al., 1998; Hartman & Hartman, 2006). The motivation behind research on academic performance falls into three general categories: (a) to find variables that can be used as criteria for admission into an engineering program, (b) to identify students who will most likely need interventions to be successful, and (c) to evaluate student performance after changes in instruction or programs. The following section discusses the current research in academic performance in engineering, followed by a discussion of the factors used in this study.

Research Predicting Academic Performance of Engineering Students

Appendix B contains information on studies found in the literature that investigate factors related to academic performance of engineering students. Most of these studies include a measure of cognitive ability such as ACT or SAT scores, high school GPA, high school rank, and/or scores on subject-specific tests or classes (Cummings & Knott, 2001; French et al., 2005; Gonzalez-Barreto & Gonzalez-Quevedo, 2005; Lackey, Lackey, Grady, & Davis, 2003; Levin & Wyckoff, 1988). Published studies exist that do not include a variable related to cognitive ability, but instead focus on single factors such as learning style (Bernold, Spurlin, & Anson, 2007) or personality type (Felder, Felder, & Dietz, 2002), or multiple non-cognitive factors such as the study by Vogt (2008). Vogt's study investigated the relationship between academic performance and faculty distance, academic integration and the students' self-efficacy, and academic confidence.

In studies that included multiple measures of cognitive ability, the statistical significance of the relationship between the measure of cognitive ability and GPA is not consistent. For example, in Cummings and Knott's (2001) study, the SAT verbal score was significant, while it was not in the studies by Lackey et al. (2003) or Besterfield-

Sacre et al. (1997). In the studies listed in Appendix B, when measure(s) of academic ability were included in the study, at least one of the ability variables was significant.

Variables not related to ability have also been included in models with mixed results. For example, analysis has shown measures of self-confidence or self-efficacy to not be significantly related to GPA (Besterfeld-Sacre et al., 1997; Jin, Imbrie, & Chen, 2011), but in Vogt (2008), self-efficacy had a significant relationship with GPA. The same is true with measures of motivation, leader experiences, and gender; in some studies they were significant (Cummings & Knott, 2001; Jin et al., 2011; Ting, 2001) and in other studies these variables were not significant (French et al., 2005; Hacket, Betz, M., & Rocha-Singh, 1992; Jin et al., 2011; Schuurman, Pangborn, & Mcclintic, 2008; Ting, 2001).

Studies have investigated the relationship between students' motivation to study engineering and their GPA. In a study at the University of Pittsburgh (Besterfeld-Sacre et al., 1997), students who were influenced to study engineering by the potential high salary had higher first semester GPAs after controlling for measures of academic ability, level of enjoyment of math and science, and study habits. In the same study, family influence to study engineering was not related to GPA. Levin & Wyckoff (1988) studied 1,220 freshman engineering students and concluded students who chose to study engineering for intrinsic reasons on average had higher grades in math, physics, and chemistry compared to students who were influenced to study engineering by extrinsic factors. Intrinsic factors included enjoyment of math, science and problem solving. Extrinsic factors included job opportunities and good pay. The study accounted for measures of academic ability and anticipated study time. The inconsistency of the results

could be due to the way the variables were measured, the other variables that were included in the model, or the inherent differences in the samples.

Studies have found a significant relationship between GPA and interest in engineering (Besterfeld-Sacre et al., 1997; Levin & Wyckoff, 1988), learning style (Bernold et al., 2007), and personality type (Felder et al., 2002). Not enough research has been completed on these factors to determine the strength of the relationships across samples.

Academic ability. From the variety of factors that have been researched, predicting performance of engineering students is a complex issue. Based on the reviewed research, some measure of cognitive or academic ability is helpful in a model to predict college GPA. The two most frequently used measures of academic ability found in the literature were standardized test scores and high school GPA. These measures have the advantage of being readily available in university records since many universities require this information on admission applications.

Standardized tests. In the reviewed literature, the majority of the studies involved students who attended schools that required SAT scores for admission and, therefore, SAT scores instead of ACT scores were included as a factor in the study. The majority of the studies included math SAT scores, although some included verbal, composite, or a combination of scores. In all of the reviewed studies (see Appendix B) that included SAT scores, at least one SAT score was significant. A few of the studies in Appendix B included ACT scores in addition to or instead of SAT scores. In a study by Veenstra, Dey and Herrin (2008) ($n = 183$), the predictive ability of ACT and SAT scores were analyzed separately. In the study, ACT math and science test scores or SAT quantitative

scores were combined with math and chemistry placement test scores to form a construct called "quantitative skills." The quantitative skills construct that included ACT scores explained 23% of the variability in first-year GPA and the quantitative skills construct that included SAT scores explained 18% of the variability in first-year GPAs of students who took the SAT.

In a small study (Lam, Doverspike, & Mawasha, 1999) with only minority students ($n = 27$), ACT composite scores were a significant predictor of college GPA even when high school GPA was included in the model. In a larger study of 321 students (Honken & Ralston, 2013b), math, science, reading and English ACT scores were used as indicators of academic ability and were found to be significant in predicting first semester GPAs of engineering students.

In a meta-analysis (Robbins et al., 2004) of 31 studies investigating GPA for students from the general college population ($N = 16,648$), the authors analyzed SAT and ACT test scores together and determined that test scores were significantly correlated with college GPA ($r = .37$) and that 25% of the variability in college GPA was explained by standardized test scores and high school GPA.

Other math assessments. Multiple studies investigating factors related to GPAs of engineering students have also included a score on a math assessment beyond the math ACT or SAT scores. Levin and Wyckoff (1988) found algebra readiness test scores explained variability in grades in required math and science courses after accounting for SAT math scores. A study with students at the University of Louisville (Chariker, Ralston, Hieb, & Wilkins, 2013) concluded the score on an algebra readiness test was a significant predictor of performance in engineering calculus.

The measure used as indicators for the construct of academic ability in this study were scores on the ACT math, science, English and reading tests and scores on an algebra readiness test. Although high school GPA could not be used in this study due to the university policy of truncating all GPAs over 4.0, there are other reasons for using ACT scores instead of high school GPA. First, using ACT scores eliminates the issue of variability between high school grading policies. More importantly, research has shown a significant relationship between self-control (another variable used in this study) and GPA, but no significant relationship between self-control and standardized test scores (Duckworth, 2008).

Self-control. Along with academic ability, Research Question 2 investigates how self-control is related to academic performance. Multiple published studies have shown a relationship between self-control and GPA in students in K-12 and college (Duckworth et al., 2012; Duckworth & Seligman, 2005; Hofer et al., 2012; Tangney et al., 2004). The trait of self-control is found in a plethora of research studies, predominately in the field of psychology. Although self-control is considered an important trait, no one accepted definition or name exists. Self-control also has been referred to as self-regulation, self-discipline, willpower, among other names (Duckworth & Kern, 2011).

With the growing popularity of the term "self-regulated learning," the difference between the terms "self-regulation" and "self-control" has become more important to articulate. Some authors use the terms "self-regulation" and 'self-control" interchangeably, while others distinguish between the two (Baumeister & Vohs, 2004). Duckworth, Quin and Tsukayama (2012) acknowledge the confusion between the meaning of self-control and self-regulation and differentiate them as "self-control" being

a personality trait that voluntarily regulates impulses to meet long-term goals and as "self-regulation" being metacognitive strategies that help in meeting personal goals. Kuhl and Fuhrmann (1998) differentiate between self-regulation and self-control by considering self-control the cognitive process an individual uses to commit to an action to support a personal goal. They define self-regulation as the way to maintain the actions towards the personal goal. McCullough and Willoughby (2009) contend that individuals use self-control to modify their response tendencies to promote actions that help meet the highest level goal, and that self-regulation is a deliberate process of guiding or adjusting behaviors to meet a desired goal through evaluating the individual's current state. Carver and Scheier (1998) consider self-control a process of selecting behavior that helps to meet a personal goal, intention or value. They considered self-regulation a process of using what they call an internal guidance system to regulate the quality of experiences. This system includes a feedback loop.

Some authors such as Baumiester, who has written extensively on self-control, have changed their views on self-control over time. In 1994, Baumiester, Heatherton and Tice (1994) viewed self-control and self-discipline as conceptions of self-regulation and stated that self-control has a very similar meaning. They formulated four domains of self-control as controlling thoughts, emotions, impulses, and performance. They used self-regulation in a broader sense to refer to overriding a natural response in favor of another response. In 2004, Baumeister and Vohs (2004) used self-control and self-regulation interchangeably and define it as "any efforts by the human self to alter any of its own inner states or responses" (p. 2). Storch (2005) sets self-control and self-

regulation apart by saying "self-control helps you meet small challenges, but to change your life significantly you'll need self-regulation" (p. 88).

A few other authors have written extensively on the subject of self-control and have slightly different definitions of self-control. Goldfried and Merbaum (1973), who have written extensively on the relationship between crime and self-control, state "Self-control can be viewed as a process through which an individual becomes the principle agent in guiding, directing and regulating those features of his own behavior that might eventually lead to desired positive consequences" (p. 11). Tangney et al. (2004), who developed the Brief Self-Control Scale used in the current study, state that central to self-control is the "ability to override or change one's inner responses, as well as to interrupt undesired behavioral tendencies (such as impulses) and refrain from acting on them" (p. 274). In sum, self-control deals with a process through which an individual determines behavior, thoughts, and emotions based on meeting the highest order personal goal, intention or value at that time.

Self-control and academic performance. Research has shown a relationship between self-control and many factors important to health, success, well-being, and crime (Baumeister & Vohs, 2004; De Ridder, Lensvel-Mulders, Finkenauer, Stock, & Baumeister, 2012; Duckworth et al., 2012; Duckworth & Seligman, 2005; Goldfried & Merbaum, 1973; Moffitt et al., 2011; Tangney et al., 2004; Zettler, 2011). Policy-makers have considered large-scale programs aimed at improving self-control with the hope of improving the health and wealth of the citizenry and reducing crime (Moffitt et al., 2011). Important to this research is the link between self-control and academic performance. Baumeister and Tierney (2011), who in the past focused on increasing self-efficacy as a

means to increase academic performance, more recently supported the theory that the best thing parents can do for their child is teach their child self-control (Baumeister & Tierney, 2011).

   Self-control and academic performance in K-12. In their well-referenced article on delayed gratification in children, Mischel, Shod, and Riodriguez (1989) drew connections between self-control and academic success. In what many refer to as "the marshmallow test," four-year-old children were set in a room with one marshmallow and nothing else of entertainment value. They were told that after the researcher left, they could consume the marshmallow; however if they waited until the researcher returned, they would be given two marshmallows. Years later when the test subjects were adolescents, the researchers contacted the children's parents and asked them to supply information on their children. When SATs were available ($n = 35$) for the children, both their verbal ($r = .42$) and quantitative ($r = .57$) scores were significantly related to the number of seconds the child had delayed eating the marshmallow as a preschooler. Although the author cautioned of the small sample size and suggested further research is necessary, this study was pivotal and is referenced by many researchers in the study of self-control.

   The relationship between self-control and academic performance was investigated with students at the middle school level, which is a time of transition and a point when students typically start to become more aware of the contribution of effort and intelligence (Duckworth et al., 2012). In a study of two consecutive 8th grade cohorts from a public magnet school, Duckworth and Seligman (2005) found a significant relationship ($p < .001$) between self-discipline and first marking period grades ($r = .52$

and $r = .66$) and final grades ($r = .55$ and $r = .67$) in both groups of students. To measure

what they called self-discipline, they had students complete the Brief Self-Control Scale,

the Eysenck 1.6 Junior Impulsiveness Subscale and the Kirby Delay Discounting Rate

Monetary Choice Questionnaire. Parents and teachers completed the Self-Control Rating

Scale (study 1) or the Brief Self-Control Scale (study 2). In study 2, the students also

participated in a Delay Choice Task Test. In their multiple regression analysis, $\beta_{self\text{-}discipline}$ was significant ($p < .05$) even after controlling for first marking period GPA. IQ

was not significant.

These results were supported by a study of German students using the 14 item

Child Self-Control Rating Scale measure of self-control (Hofer et al., 2012). Hofer and

colleagues also studied a group of eighth graders (48% male, 52% female) who were

from 10 different schools with different levels of challenging curriculum. The variables

investigated in their study included: measures of cognitive ability, self-control, use of

time structure, academic procrastination, and motivation interference during learning.

The study found that self-control and procrastination explained four times more variance

in grades than did cognitive ability, but that cognitive ability was more strongly

correlated with standardized test scores.

Duckworth (2012) also led a study using scores on questions from the Social

Skills Rating System that had been completed by teachers of the students when they were

in fourth grade. After analyzing these scores from the teachers along with students' IQ

scores, grades in middle school, and standardized test results, the research team also

concluded that self-control measures were better predictors of grades, but IQ was a

stronger predictor of standardized achievement tests. They explained their results by

suggesting "intelligence helps students learn and solve problems independent of formal instruction, whereas self-control helps students study, complete homework and behave positively in the classroom" (p. 439).

Self-control and academic performance in college students. The relationship between self-control and academic performance has also been studied at the college level, another time of transition. In a multiple regression study, $n = 201$ (78% females, 22% males) to predict college GPA in psychology students, Wolfe and Johnson (1995) considered high school GPA, SAT scores, and 32 personality variables assessed using the Jackson Personality Inventory; modifications of the Multidimensional Personality Questionnaire; the Big 5 Inventory; and a few additional variables. After accounting for high school GPA, self-control accounted for the most variability in college GPA (9%); SAT total score was next (5%).

Tangney, Baumeister and Boone (2004) conducted two studies investigating the relationship between self-control and multiple factors including college grades. The participants in their studies were undergraduates in a psychology course. In the first study ($n = 351$, 72% females, 28% male), the age of the participants ranged from 18 to 55 ($M = 20.07$, $SD = 4.99$); 49% were white, 20% African American, and 20% other. The sample in the second study ($n = 255$) was ethnically similar and had an even higher percent of females. Analyses in both studies showed a significant positive relationship between GPA and self-control. Thus, on average, the students with higher reported self-control had higher grades. The authors presumed this phenomenon was due to students with higher self-control being better at "getting tasks done on time, preventing leisure

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activities from interfering with work, using study time effectively, choosing appropriate courses and keeping emotional distractions from impairing performance" (p. 275).

Self-control and academic performance in engineering students. Research investigating lack of self-control and academic performance in engineering has been performed (Honken & Ralston, 2013b). This study involved 321 first-time, full-time engineering students (16% female, 84% male) and found a significant negative relationship, after controlling for ACT scores, between first semester GPA and the frequency with which a student engaged in actions that showed lack of self-control in high school.

The current study drew on these reviewed studies, but had some distinct differences. First, in the Wolfe and Johnson study and the Tangney et al. study, the participants were predominantly female. In the current study, the participants were predominantly male. Second, in the current study, all the participants were engineering students while students in the other studies were either in a psychology course or in the psychology test pool.

Measures of self-control. Multiple instruments have been developed to measure self-control such as the Self-Control Behavior Inventory (Fagen, Long, & Stevens, 1975); Self-Control Questionnaire (Brandon, Oesher, & Loftin, 1990); Barratt Inclusiveness Scale (Patton, Stanford, & Barratt, 1995); Self-Control Schedule (Rosenbaum, 1908); Low-Self-Control Scale (Grasmick, Tittle, Bursik, & Arneklev, 1993); the Self-Control Scale (Tangney et al., 2004); and the subscale of the California Personality Inventory (Gough, 1987). The measurements were specific to the developers' understanding of self-control in the context in which they were working. For example, the Self-Control

Questionnaire emphasized behavior health, such as eating habits, and the Self-Control

Schedule was designed to be used in a clinical setting (Tangney et al., 2004). Most of

these instruments are in the form of self-reported surveys while the Self-Control Behavior

Inventory is an observation checklist.

De Ridder and colleagues (2012) conducted a meta-analysis of studies on self-

control and limited inclusion to studies using instruments that had been widely used in

different domains. The other criterion for inclusion was that the instrument had to

measure the widely-accepted definition of self-control in the literature. As a result, they

analyzed studies using the Barratt Impulsiveness Scale ($k = 31$), the Low Self-Control

Scale ($k = 21$), and the Self-Control Scale or some variant of it ($k = 50$). In comparing

the three scales, they concluded that the Self-Control Scale, or variants of it, had been

used most frequently and had been used to relate self-control to a larger number of

behavioral outcomes. Use of the Self-Control Scale resulted in larger effect sizes than

the other two scales and better differentiated the relationship between level of self-control

in the different domains investigated.

The instrument used in the current study was the Brief Self-Control Scale

(Tangney et al., 2004). The creators of this scale state central to self-control is the

"ability to override or change one's inner responses, as well as to interrupt undesired

behavioral tendencies and refrain from acting on them" (Tangney et al., 2004, p. 275).

They believe self-control encompasses four domains: controlling thoughts, emotions,

impulse, and performance; thus these are represented in their scale. Their research in

self-control focused on the following domains: achievement and task performance

(school and work), impulse control, psychological adjustment (symptoms of anxiety,

depression, and obsessive-compulsive behavior), interpersonal relationships, and moral emotions (shame and guilt).

The Brief Self-Control Scale (Tangney et al., 2004) was built around the following concept:

> Regulating the stream of thought (e.g., forcing oneself to concentrate, altering moods or emotions) restraining undesirable impulses, and achieving optimal performance (e.g., making oneself persist) all constitute important instances of the self-overriding it responses and altering its states or behavior. More generally, breaking bad habits, resisting temptation, and keeping good self-discipline all reflect the ability of the self to control itself, and we sought to build our scale around them. (Tangney et al., 2004, p. 275)

Process used to create the Brief Self-Control Scale. The process to create the scale started with 93 items covering thought control, emotional control, impulse control, and performance regulation as well as breaking bad habits. All items were rated on a 5-point scale ranging from *Not at all like me (1)* to *Very much like me (5)*. The survey was administered to 351 undergraduate students consisting of 28% males and 72% females of which the ethnic distribution was 49% Caucasian, 20% Asian, 11% African American, and 20% Other. The average age of the participants was 20. Using exploratory factor analysis, the scale was reduced to 36 items. The 36-item survey was then administered to a second group of 255 undergraduates (19% male, 81% females, similar ethnic and age dispersion to study 1). A 13-item subset of the 36 items was evaluated at the same time. The correlation between the 36-item scale and the 13-item scale was high in both studies (study 1: $r = .93$ $n = 351$ and study 2: $r = .92$, $n = 255$). The Cronbach alphas for the two

studies were .83 and .85 which is considered very good internal consistency validity (Devillis, 1991). The three-week test-retest reliability was .87 ($n = 233$).

To determine if participants answered the survey questions based on what they thought were socially acceptable answers, the participants also completed the Marlowe Social Desirability Scale and the Balanced Inventory of Desirable Responding questionnaire. There was a strong correlation between the scores of social desirability and scores on the Self-Control Scale. The authors point to two potential explanations for this correlation: either participants' answers were swayed by the desire to represent themselves as conforming to socially approved norms, or people with high self-control act within the expected norms of society. When scores on the desirability scales were included in the analysis, the relationship between self-control and measures of performance were still significant.

During the development of the scale, analysis was performed to determine the relationship between the score on the scale and multiple outcomes. In addition to having a significant correlation with grades, scores on the scale had significant correlations with adjustment, binge eating and alcohol abuse, relationships and interpersonal skills, secure attachment, and emotional responses.

Findings from studies using the Brief Self-Control Scale. Both the total scale and the brief scale have been used in multiple studies. A review of the literature for a meta-analysis, found 50 studies (published and unpublished) that used the Self-Control Scale or the Brief Self-Control Scale (De Ridder et al., 2012). Sixty-one percent of the studies administered the brief scale, 20% used the full scale, and the remaining studies used an adapted version. The behaviors investigated in the studies included school and

work performance, eating and weight behavior, sexual behavior, addictive behavior, interpersonal functioning, affect regulation, well-being and adjustment, deviant behavior, panning, and decision making. The overall effect size of the 50 studies was .26. The meta-analysis contained a comparison of the effect size for different types of studies based on the type of research design, the behavioral domain, whether the study was published or not, which version of the scale was used, whether the act of self-control was to promote desirable behaviors or inhibit undesirable behaviors, and the time period. Of interest to this study is the analysis which showed that the largest effect size for the Self-Control Scale, or some version of it, was for work and school performance, which was .36. This effect size is considered between medium to large (Cohen, 1992). The effect size using the full scale was significantly higher than studies using the brief or adapted scales, but only for studies investigating the inhibition of undesired behaviors.

Summary

The issue of engineering student retention can be framed in the college retention theories or in theories from the college major and career choice literature. Part one of the current study was framed in expectancy value theory which, as previously discussed, has been used to frame other studies in career choice and engineering retention. The empirical studies outlined in Appendix A and discussed in this chapter show that a wide range of factors have been studied to try to understand students' decisions concerning whether to continue studying engineering. The review of this literature revealed an apparent gap: although research has shown that students left engineering due to lack of interest and poor performance, the interplay between these two variables has not been fully investigated.

Part two of the current study, which focused on factors related to academic performance for engineering students, was framed in the self-control literature reviewed in this chapter. Based on the studies in Appendix B, academic performance of engineering students is a complex issue and past research has not always come to the same conclusion on the significance of certain factors. Although self-control has been proven to have a significant relationship to academic performance with students in psychology courses, only one study was found that investigated self-control with engineering students. This study had a weakness in that the indicators used to measure the construct of self-control had not been validated with another sample. The current study used the Brief Self-Control Scale, which was described in this chapter and has been used in multiple studies, to measure self-control.

CHAPTER 3

RESEARCH DESIGN

Introduction

This study was part of an ongoing effort to improve retention of engineering students and to increase research focused on engineering education at the University of Louisville (UofL). This chapter contains a review of the research questions, a statement on the protection of human subjects, a description of the population sampled for the study and the sample used for analyses, an explanation of the sources of data, and methods used to analyze the data. This is followed by an analysis of missing data and discussions of generalizability and threats to validity.

Research Questions

Research Question 1a: What is the relationship between the likelihood a student will be retained in engineering after one year and his or her first semester GPA and level of interest in engineering at the end of first semester?

Research Question 1b: What are the gender differences in the relationship between the likelihood a student will be retained in engineering after one year and his or her first semester GPA and level of interest in engineering at the end of first semester?

Research Question 2: What is the relationship among first semester GPA, academic ability and engineering student's level of self-control at the beginning and the end of their first semester of college?

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Protection of Human Subjects

This study was approved by the University of Louisville (UofL) Internal Review Board. IRB 11.0358 covered the administration of the pre- and post-surveys and the use of the de-identified data for research purposes. IRB 11.0305 covered the use of de-identified student data in conjunction with the survey data. Due to the nature of the study and the use of de-identified data, both proposals were approved and given exempt status by the UofL Internal Review Board.

Population

The population sampled for this study was engineering students from the J. B. Speed School of Engineering (Speed School) at UofL, a large public research institution. UofL is located in the state of Kentucky, which is in the lowest quartile of states for the percentage of engineers per employee and for the percentage of higher education degrees that are awarded in science and engineering (National Science Foundation, 2010).

The Speed School is accredited by the Accreditation Board of Engineering and Technology (ABET) and offers degrees in bioengineering, chemical engineering, civil engineering, computer engineering and computer science, electrical and computer engineering, industrial engineering, and mechanical engineering. In the past five years, an average of approximately 500 bachelor's, master's and doctoral degrees were awarded by the college each year, representing approximately 11% of the graduates from the university. This study took place in a year of growth. According to university data, the 2012 freshman engineering cohort was 17% larger than the 2011 freshman engineering cohort and 35% larger than the 2010 cohort.

Sample

Cohort

All the data in the datasets used in this study were gathered from the 2012 first-time full-time freshmen cohort at the Speed School. According to official university data, there were 434 first-time full-time students in the 2012 cohort. Four of these students had a 0.0 first semester GPA, were not enrolled in spring 2013 semester, and had no record of taking any surveys administered to this cohort. They had no records of attending calculus class, and they did not live in university housing. According to university official data, these students were part of this cohort, but all indicators point to them being no-shows; they were not included in any future calculations in this study.

The 2012 cohort was 22% female and 78% male, and 84% of the cohort attended high school in Kentucky. Eighty-five percent of the cohort was Caucasian, and no other ethnic group represented more than 4%. All but five students were traditional students who were attending college directly out of high school. Approximately 79% of the students lived on campus. The average ACT composite score for the cohort was 28.5, and the average individual ACT test scores were 28.6 for English, 29.2 for math, 28.8 for reading and 28.8 for science. Thirty-eight percent of the students had a high school GPA of 4.0 or greater. A comparison of the cohort to national data appears later in the chapter.

The average first semester GPA for the cohort was 2.71 ($SD = .98$). *Figure 1* shows the frequency distribution of first semester GPA for males and females in the 2012 engineering cohort, $n = 430$. Although the average GPA for females, $M = 2.81$ ($SD = .88$) was higher than the average for the males, $M = 2.69$ ($SD = 1.01$), the difference was not statistically significant, $t(428) = -1.114$, $p = .266$. A higher percentage of males had

GPAs equal to or less than 2.0 (22%) compared to females (16%). Seventy percent of the cohort was still enrolled in engineering after one year, which was 8% lower than the 2011 cohort.
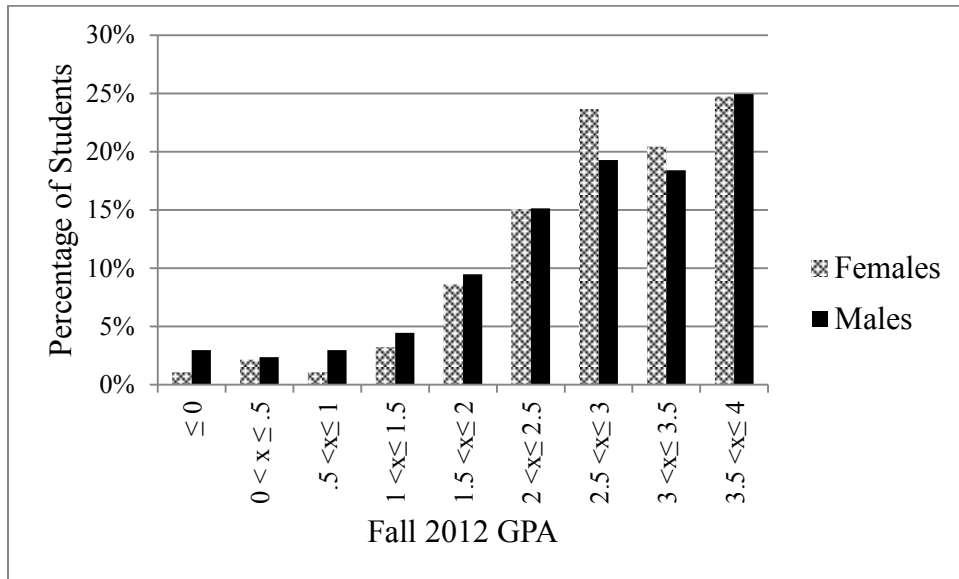
Figure 1. Distribution of first semester GPA for all males ($n = 337$) and females ($n = 93$) in 2012 engineering cohort.

Participants

Eighty-two percent of the 2012 cohort ($n = 352$) completed the post-survey, and their data were used in analysis of Research Questions 1a and 1b. Seventy-nine of the participants were female and 273 were male. The ethnic and gender distribution of the participants mirrored that of the cohort. Based on completed surveys, data from 392 students (91% of the cohort) were included in the analysis using self-control scores from the pre-survey, and 333 students (77% of the cohort) were used in analysis using the self-control scores from the post-survey. Again, the ethnic and gender distribution of the sample mirrored that of the 2012 cohort. More descriptive data on the participants in

located in Appendices C and D. Analyses on the differences between the students who did and did not participate in the study are in the section on missing data.

<p align="center">**Source of Data**</p>

Data used in this study fell under three categories: survey responses, official university records, and data from a calculus course. All the data for the proposed study were collected prior to this study and were contained in output files produced by Institutional Effectiveness, a department within the Office of Institutional Research at UofL. The primary survey data used in this study were drawn from the Pre-Engineering Fundamentals Survey (referred to as the pre-survey) and Post-Engineering Fundamentals Survey (referred to as the post-survey). Below are descriptions of each source of data.

Pre- and Post-Surveys

As part of an ongoing effort to improve freshman retention, the Department of Engineering Fundamentals at the Speed School started surveying freshman engineering students in 2010. Initially the survey was designed to determine students' perceptions of their knowledge of engineering topics at the beginning and end of their first semester of college, and included questions about factors that influenced the students' decisions to study engineering, their commitment level to engineering, their interest level in engineering, potential obstacles to completing an engineering degree, and a few questions on study and homework behaviors. The same survey was administered to the students in the Introduction to Engineering course at the beginning (pre-survey) and the end (post-survey) of fall semester. In fall 2012, both the pre- and post-surveys were modified to include the 13 items on the Brief Self-Control Scale (Tangney et al., 2004), additional questions on interest, and questions on homework behaviors and attitudes.

The 2012 pre- and post-surveys were administered by the Office of Institutional Effectiveness, which is under Institutional Research. For administration of both surveys, students received an email with a link to the survey and were informed that they would be given time during their Introduction to Engineering class to complete the survey. No rewards or credit toward a class grade were given to students to complete the survey. Student IDs were automatically attached to their responses when they opened the link. After an employee from the Office of Institutional Effectiveness replaced the student IDs with unique research IDs, the responses to all survey questions were given to the researcher in an Excel spreadsheet which was later read into SPSS. The pre-survey was administered during the first week of the semester and the post-survey was administered during the 13th week of the semester.

Official University Student Records

An employee from the Office Institutional Effectiveness supplied students' composite and individual ACT test scores, first semester GPAs, and retention status as of fall 2013. These data were extracted from university student records and the university's Official Enrollment File, which is generated at the end of each semester by the Office of Institutional Research.

Calculus Course Data

The final source of data was the course records for the freshmen calculus classes. The records included students' scores for multiple algebra readiness assessments. The scores on all three tests were accumulated by a calculus professor and given to an employee in the Office of Institutional Effectiveness along with student IDs and other

data from the students in the calculus class. Institutional Effectiveness personnel

substituted research IDs for the student IDs and returned the data in an Excel spreadsheet.

Measures for Research Questions 1a and 1b

Research Questions 1a and 1b were framed in the expectancy value theory;

therefore, the independent variables represented value and expectancy, and the dependent

variable represented a decision to persist at a task (to continue studying engineering).

The following sections describe the measures chosen to represent value, expectancy, and

continuation of study in engineering.

Value - Interest in Engineering

Multiple criteria were used to determine how to measure value. First, the measure

needed to be supported in the empirical research in career and college major choice and

engineering students' decisions to switch majors. This narrowed the options to good pay,

good job opportunities and interest. The second criterion was that the value, although

intrinsic, could potentially be influenced by course design, which meant that if found to

be a meaningful predictor the institution would potentially be able to impact this variable

with strategic changes. This criterion ruled out good pay and job opportunities since

these are controlled by the job market. The last criterion was the availability of data to

measure the value.

Based on these criteria, the value chosen was interest in engineering. The

decision to use interest to measure value is supported by the previously discussed

empirical research as well as Holland's theory of vocational choice. Interest also met the

second criterion since course design might have an influence on a student's level of

interest. Finally, data about student interest were available from surveys given to students.

The value used for interest in engineering was measured based on the response to the following question on the post-survey: "There are many reasons that affect people's decision on what to study. This question relates only to your interest level in engineering. Which of the following statements best describes your interest in engineering?"

The potential responses for this question were:

- *Very low interest - I'm not interested in engineering, I chose engineering for reasons other than interest.*

- *Low interest - I have an interest in engineering but stronger interest in another field(s).*

- *Medium interest - I am interested in engineering and equally interested in other fields(s).*

- *High interest - I am very interested in engineering, but also think I could be happy in another field.*

- *Very high interest - I am so interested in engineering that I could not imagine myself studying anything else.*

The same question was asked on the pre-survey. Although the responses were not used in the main analyses, they were used when investigating missing data and to help understand the results of the main analyses.

The responses were treated as categorical data with the following four categories and codes: *Very low* (1), *Low* and *medium* (2), *High* (3), and *Very high* (4). In the

analysis, the levels were dummy-coded with category 4 (Very high) being the reference category. The decision to combine *low* and *medium* was made due to the low number of responses in these two categories. Also both of these responses indicated a student had some interest in engineering but equal or more interest in another field. Other researchers have either condensed response categories or acknowledged this as an acceptable practice (Allen & Seaman, 2007; Osborne, 2015; Schwappach & Koeck, 2004). *Very low* also had a low number of responses, but was not combined with *Low* and *Medium* because a response of *Very low* was qualitatively different since it denotes the student had no interest in engineering.

Expectancy - First Semester GPA

First semester GPA was used as a measure of expectancy. This would be considered a measure of efficacy expectation, which is defined as the individual's belief that he can be successful in completing a given task (Bandura, 1997). Wiener (1976) found if an individual performed well on a task in the past, they expect to perform well on a similar task in the future. Most engineering students performed extremely well in high school. At the University of Louisville about 40% of students in the 2010 and 2011 cohorts had a high school GPA of 4.0 or above (Guild for Engineering Education Achievement, Retention and Success, 2011; Guild for Engineering Education Achievement, Retention and Success, 2010). Based on research done at UofL the students began engineering school with confidence their abilities and expectations that they would perform well (Honken & Ralston, 2013a). In the UofL research 88% of the 2010 cohort listed *Good and math and science* as a reason they choose to major in engineering. When asked to rate the top three factors of nine that they considered when

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choosing a career, 38% of the 2011 cohort selected *"Confident that I can be successful"* as one of the top three factors. Twelve percent chose it their most important factor.

Although the students started college with high expectancy for good performance, at the end of first semester many of these students had grades lower than they expected: only 44% of the 2011 cohort had a GPA of 3.0 or above, and only 26% had a 3.5 or above. The average first semester GPA of the 2011 cohort was over a point lower than their average high school GPA. According to Wiener (1976), this lower than expected performance would impact a student's belief that they could be successful. Based on the importance of GPA to students and empirical studies discussed in Chapter 2 that support the relationship between college GPA and retention in engineering (Besterfeld-Sacre et al., 1997; Seymour & Hewitt, 1997), first semester GPA was used as the measure of expectancy. First semester GPA at UofL is measured on a four-point scale and is typically determined by grades in the following classes: calculus (4 credits), chemistry (4 credits), introduction to engineering (2 credits), engineering graphics (2 credits), English (3 credits), and an elective (3 credits).

First-Year Retention

A student was considered retained in engineering after one year if, according to the data in the University's Official Enrollment File, the student was enrolled in classes in fall of 2013 and their academic unit equaled SS (Speed School). Throughout UofL, students who change academic units (for example, from engineering to business) complete an Intra-University Transfer Form online. The form is sent to admission personnel in the college into which the student is transferring. If the college decides to admit the student, the admission staff sends the information to the registrar's office where

the student's academic unit in the student's official university record is changed.
Students who leave the university show as "not enrolled" in the official university
records.

Data Analysis Research Questions 1a and 1b

The data for Research Question 1a investigating factors related to student
retention in engineering were analyzed using logistic regression in SPSS version 21.
Logistic regression can be used for two applications: to predict a dichotomous outcome
based on independent variables, or to understand the relationship between independent
variables and a dichotomous variable for the purpose of building or validating a theory
(Osborne, 2015). In this study, logistic regression was used to build theory about the
relationship among first semester GPA, interest in engineering, and retention in
engineering after one year

The dichotomous outcome (STATUS) was equal to "1" if the student was retained
in engineering at UofL, and it was set to "0" if the student left the university or switched
to another academic unit within the university. The variable for interest in engineering
(INTEREST) was treated as a categorical variable, and values for the INTEREST were
dummy-coded depending on the response to the survey question on interest. INTEREST
4 (very high interest) was used as the reference category. The equation resulting from
logistic regression had the following form:

$$\ln\left(\frac{p}{1-p}\right) = \beta_{constant} + \beta_{FALLGPA}FallGPA \tag{1}$$

$$+ \beta_{INTEREST(1)}INTEREST(1)$$

$$+ \beta_{INTEREST(2)}INTEREST(2)$$

$$+ \beta_{INTEREST(3)}INTEREST(3)$$

Results of the Wald test were used to determine the significance of GPA and INTEREST. The odds ratios for each independent variable were used to measure effect size.

A z-test was used to determine if there was a difference in the relationship among first semester GPA, interest in engineering, and retention in engineering for males and females. Equation 2 was used to calculate the z statistic (Altman & Bland, 2003; Paternoster, Brame, Mazerolle, & Piquero, 1998).

$$z = \frac{b_m - b_f}{\sqrt{SE_m^2 + SE_f^2}} \tag{2}$$

This study is correlational, therefore, only the size and direction of the relationships could be analyzed (Shadish, Cook, & Campbell, 2002). No cause and effect could be determined.

Measures for Research Question 2

The model for Research Question 2 was grounded in past research on self-control and was analyzed to understand the relationship among self-control, academic ability, and first semester GPA for engineering students. Since the purpose of the model was not to predict GPA, more variables from the research discussed in Chapter 2 were not included in the model for this study. The following are descriptions of the measures used followed by the methods used to analyze them.

Academic Ability

      ACT scores. The construct of academic ability had five indicators: scores on an algebra readiness test and ACT scores for math, English, reading, and science. Scores on standardized tests such as SAT or ACT have been used as a measure of cognitive or academic ability in multiple studies of engineering student performance and retention (Moller-Wong & Eide, 1997; Moses et al., 2011; Seymour & Hewitt, 1997; Zhang et al., 2004). Scores on the subject ACT tests range from 1 to 36. The ACT math test is a measure of reasoning skills to solve practical problems in mathematics. The math knowledge tested includes pre, elementary, and intermediate algebra; coordinate and plane geometry; and trigonometry. The ACT English test measures usage and rhetorical skills. The ACT reading test measures comprehension and use of referring and reasoning skills. Finally, the ACT science test measures skills in interpretation, analysis, evaluation, reasoning, and problem solving (ACT, 2012).

      Algebra readiness scores. Studies have also shown a relationship between calculus or algebra readiness, and first semester GPA of engineering students (Chariker et al., 2013; Levin & Wyckoff, 1988; Moses et al., 2011). Students in the 2012 cohort had three opportunities to take an algebra assessment test: (1) during summer orientation, (2) before fall semester started and after completing an online algebra review course, and (3) at the beginning of fall semester during their calculus class. The assessment given during summer orientation was titled the algebra readiness exam (ARE) and was designed by engineering professors at UofL to test basic algebra skills such as solving two equations with two unknowns and determining the equation for a line given a point and slope. The exam consisted of 25 multiple choice questions. If student did not do well, they were

encouraged to complete an algebra refresher course online or in person. Upon the completion of the online course, students were asked to take the Intervention Post Test (IPT). The IPT consisted of 25 multiple choice and open response questions that covered 22 of the principles covered on the ARE. The IPT was designed by UofL personnel from the Resource for Academic Achievement unit (REACH) which provides academic and support services to undergraduate students.

The ARE was also administered during the first week of the freshman calculus course. Students were given the option to take the test or use their scores from the summer. If students opted to drop freshmen calculus and instead take a calculus prep course, the scores on the tests were not counted toward their grade in the calculus class. Due to the way these data were collected, a score of 0 could indicate that the student did not take the test or that the student missed all the questions. For the purposes of this study, a score of 0 was considered a no-take.

Self-Control

Brief Self-Control Scale. The pre- and post-surveys contained the 13 items that make up the Brief Self-Control Survey. This scale is a subset of the Self-Control Scale which consists of 36 questions and was designed to measure an individual's level of self-control as defined by the creators of the scale as "the ability to override or change one's inner responses, as well as, to interrupt undesired behavioral tendencies and refrain from acting on them" (Tangney et al., 2004, p. 275). According to the creators of the scale, the scale measures an individual's ability to override his or her responses and alter his or her states and behaviors. The items focus around the ability to break bad habits, resist temptation, and keep good self-discipline. The 13 items are listed in Appendix E; an

example question is "I am good at resisting temptation." The potential responses were *Never* (1), *Seldom* (2), *Sometimes* (3), *Often* (4), and *Always* (5). Self-control scores were calculated by adding the 13 responses, as recommended by the creator of the scale. The potential range of scores was from 13 to 65; a higher score represents better self-control.

In a meta-analysis, authors found 50 studies (published and unpublished) that had used either the full, brief or modified version of the scale (De Ridder et al., 2012). In two studies conducted by the creators of the scale that used students in an introductory psychology course as participants, the scale had good internal consistency reliability (Cronbach alphas of .83 and .85) and good test retest reliability of .86 ($n = 233$).

Evaluation of scale with data from this study. The overall average self-control score (for all students, independent of whether they were used in the analysis) on both the pre-survey (46.75) and post-survey (43.01) were higher than the average scores (39.22 and 39.85) that were obtained in the two studies conducted by the designers of the scale. The standard deviation in the current study (6.51 on the pre-survey and 7.55 on the post-survey) were lower than standard deviations from those studies (8.58 and 8.61) (Tangney et al., 2004). The range of values in the pre-survey (27 – 64) was much lower than the range in Tangney's study (15 - 63), but the range from the post-survey (17 – 65) was closer to the range in Tangney's study. The participants in the study by Tangney and her colleagues (28% male and 72% female) were undergraduate college students taking a psychology course and their ages ranged from 18 to 55. The participants in the current study were engineering students (78% male and 22 % females) and 99% had just completed high school. Based on the difference in the populations between the current study and the studies by Tangney and her colleagues, there was reason to investigate

whether the scale performed as intended and whether the scale was in fact measuring one construct.

Internal consistency reliability. The Cronbach alpha for the responses on the pre-survey was .84, and .87 for the responses on the post-survey. According to Devillis (2003), these alphas indicate very good internal consistency reliability.

Convergent and discriminate validity.   The scale was also evaluated using confirmatory factor analysis (CFA) to investigate discriminate and convergent validity. All survey responses were used in this analysis independent of whether they were ultimately used in the analysis for Research Question 2. The results showed poor model fit based on Kline's (2011) criteria, $\chi^2(65) = 432.86$, $p \leq .001$; Tucker Lewis index (TLI) = .697; comparative fit index (CFI) = .748; root mean square error approximation (RMSEA) = .118. Two of the items ("I do certain things that are bad for me, if they are fun" and "I say inappropriate things*"*) had standard regression weights of less than .4. After these two items were removed and the CFA was re-run, the model fit improved (TLI = .847, CFI = .878 and RMSEA = .088), and one additional item ("I refuse things that are bad for me") had a standardized regression weight of under .4. After this item was removed, the fit indices still did not indicate good fit according to Kline (2011), but they were much closer ($\chi^2(35) = 113.73$, $p \leq .001$; TLI = .902, CFI = .924, RMSEA = .074). As a check, an exploratory factor analysis was run using principal axis factoring and oblimin with Kaiser normalization rotation. The analysis resulted in two factors with the three items removed in the CFA showing high factor loadings (.545 to .807) in the second factor, along with one other item ("I am good at resisting temptation") that had approximately the same loading (.330 and .365) in both factors. Since the factor loading

for this item (.492) was not much lower than the factor loadings for other the other nine

items in the CFA (ranged from .457 to .666), it was determined to leave this item in with

other nine and compute the self-control score based on 10 items. Confirmatory factor

analysis on responses on the 13 items of the self-control scale on the post-survey showed

similar results with poor model fit when all 13 items were included, and better model fit

(TLI = .920, CFI = .938 and RMSEA = .075) when only the 10 items were used. Since

no factor loadings were over .9, there was no reason to suspect discriminate validity

issues.

As a means of testing potential consequential validity threats by using the shorter

10-item scale vs. the initial 13-item scale, analyses were performed using both the 10 and

13 item scores for self-control. The results showed no difference in coefficient estimates

when rounded to the 100th place, which offers strong evidence against any consequential

validity threat by using the shorter scale. Therefore only the results for the most

parsimonious instrument (the 10-item scale) were included in Chapter 4. For

comparison, the results using the 13-item scale are in Appendix F.

Model for Research Question 2

The specific model being tested is in Figure 2. In the model, academic ability and

self-control are assumed to be correlated. The residual errors of ACT reading and ACT

English are correlated because analysis with a high number of test results ($n > 100,000$)

showed high correlation ($r = .91$) between these two tests (Dorans, 1999).
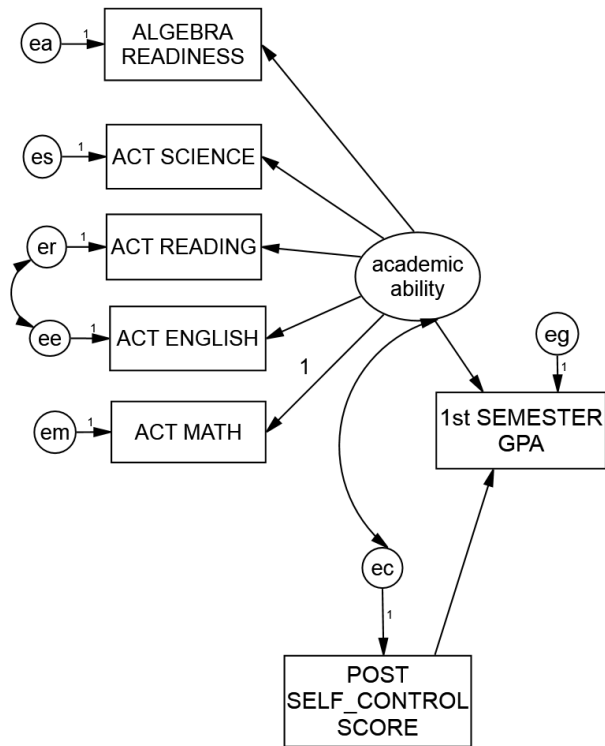
Figure 2. Structural Equation Model (SEM) used for Research Question 2.

Data Analysis for Research Question 2

To investigate the factors related to first semester performance, data were analyzed using structural equation modeling (SEM) which was performed in IBM[®] SPSS[®] Amos revision 21.0.0, Build 1178. SEM can be used to confirm that a hypothesized model is supported by the data. With SEM, both observed and latent variables can be analyzed, and, unlike with regression, no assumptions are made about the predictor variables having measurement error (Kline, 2011).

The two-step modeling approach, recommended by Anderson and Gerbing (1988), was used to test the hypothesized model shown in *Figure 2*. The first step was to

evaluate the measurement model and to make re-specifications as warranted theoretically and supported by the data. The second step was to evaluate the structural model. Within the literature there is an ongoing discussion on which fit indices should be reported (Kline, 2011). The following four indices were used to evaluate model fit: model chi-square, CFI, TLI, and RMSEA. The model chi-square tests the exact-fit hypothesis that the covariance matrix predicted by the model equals the actual covariance matrix. The chi-square has some limitations, especially with larger sample sizes (greater than 400) (Kline, 2011). Kline recommends the measure is reported along with other fit indices. The CFI is a comparative model fit index as is the TLI. In both of these fit indices, the χ^2 for the null model (all observed variables are uncorrelated) is compared to the target model (Hu & Bentler, 1999). The TLI is calculated by subtracting the degrees of freedom from the χ^2 value and the CFI is calculated by dividing the χ^2 values by the degrees of freedom. RMSEA index captures measurement residuals and is an absolute fit index based on only the χ^2 of the model, its degrees of freedom, and the sample size.

There has also been discussion within the literature on what values of these indices represent good fit and, over time, the values have become more stringent (Hooper, Coughlan, & Mullen, 2008). The criteria used to determine good fit in this study were taken from Kline (2011): χ^2 not significant at $p \geq .05$, RMSEA $\leq .05$ for good fit and RMSEA $\geq .10$ for poor fit, CFI $\geq .95$. Since Kline does not discuss TLI, the criteria from Hu and Bentler (1999) of TLI $\geq .95$ was used. These are the most stringent criteria in the literature.

Missing Data

Missing data were analyzed for two reasons: (1) to determine if any missing data could be imputed from other data, thus allowing inclusion in the analyses, and (2) to evaluate for potential threats to validity due to data not missing randomly. No data for gender, GPA, or retention status were missing since these were drawn from university records. Data were missing for ACT individual test scores, algebra readiness scores, self-control scores, and interest scores. ACT scores could be imputed based on submitted SAT scores, but no other variable was a candidate for imputation. The following is a discussion of the imputation method used for missing ACT scores, which is followed by an analysis of missing self-control scores, interest scores, and algebra readiness scores.

Imputed Data for Missing ACT Scores

Twenty-three students in the 2012 cohort had not submitted ACT test scores when they applied to the university, but instead submitted SAT scores. The university converted their composite SAT scores into composite ACT scores and stored this value in student records. ACT math, science, English and reading scores were imputed based on these calculated ACT composite scores in the following manner. First, means and standard deviations were calculated for the math, reading, English and science test scores for each ACT composite score. Analysis showed that for the students in the sample with ACT subject scores, the average score on each of the individual tests was within one standard deviation of their composite score except for the science score for the composite score of 22 and the math score for the composite score of 23. Of the 23 students without ACT subject test scores, only two students had an ACT composite score of 22 or 23.

Thus the ACT composite score was substituted as a proxy for the individual test scores for these 23 students.

Some of the students without ACT subject test scores were eliminated from analysis because they did not have algebra readiness scores or were also missing data from the pre- and post-surveys. In the analysis that used data from the pre-survey, imputed ACT subject scores were used for 19 students (5%), and in the analysis using the post-survey results, 21 (6%) of the students had imputed ACT subject scores. The low percentage of students missing ACT scores (less than 10%) lessens the imputation threat of lowering the variability of scores and potentially impacting the correlations (Roth, 1994).

Analysis of Missing Data for Potential Impact on Validity

Research Question 1a and 1b. Seventy-eight students (18%) did not complete the post-survey and their data were not included in the analyses for Research Questions 1a and 1b. The following section describes the known differences between the group of students included and excluded from analyses of the Research Questions 1a and 1b.

ACT scores and first semester GPA. The group of students whose data were excluded from the analyses had a statistically lower average ACT math score, $t(428) = -2.964$, $p = .003$; ACT science score, $t(428) = -2.568$, $p = .011$; and first semester GPA, $t(428) = -5.724$, $p < .001$, compared to students included in analyses. The average GPA for students included was 2.84 ($SD = .87$) compared to 2.16 ($SD = 1.24$) for the students not included. The frequency distribution of GPAs for students included and excluded from analyses (see Figure 3) shows the students with lower GPAs are underrepresented (13% of the students who were excluded had a GPA of 0, compared to 0.3% of the

71

included students) and students with higher GPAs were overrepresented (12% of the students who were excluded had a GPA greater than 3.5, compared to 28% who were included).
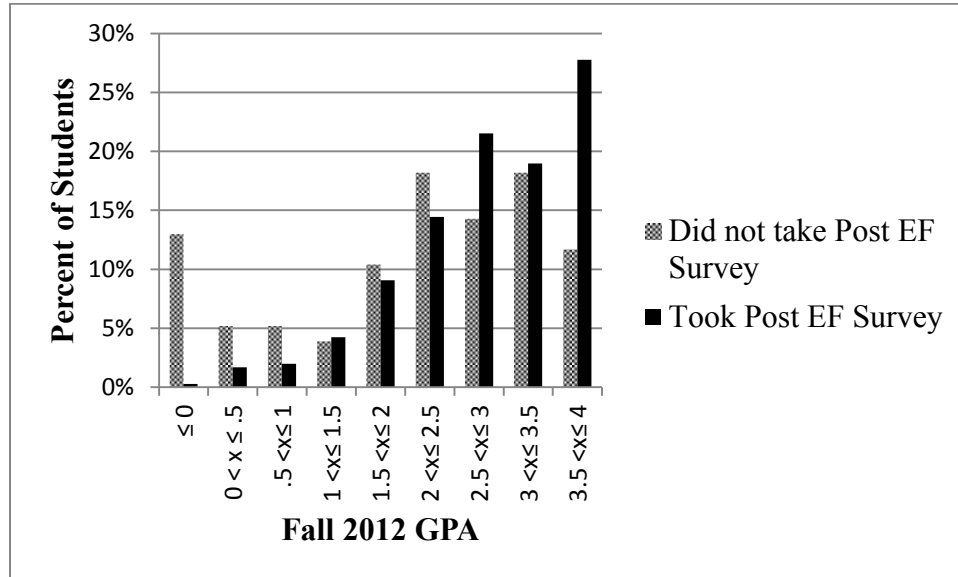
Figure 3. Distribution of GPA for students included ($n = 352$) and excluded ($n = 78$) from analyses for Research Questions 1a and 1b due to missing survey data

Interest at the start of the semester. Students were asked the same question about their interest in engineering on the pre- and post-surveys. The groups of students whose data were included and excluded from the analyses had similar distributions of interest in engineering at the start of their first semester of engineering school. Using the four point scale, 15% of the students' responses indicated an increase in interest, 64% indicated no change, and 21% indicated a decrease in interest. Note*: 10 students who took the post-survey did not take the pre-survey

Figure 4 shows the distribution of the responses to the interest in engineering question on the pre-survey for the students who did and did not take the post-survey.
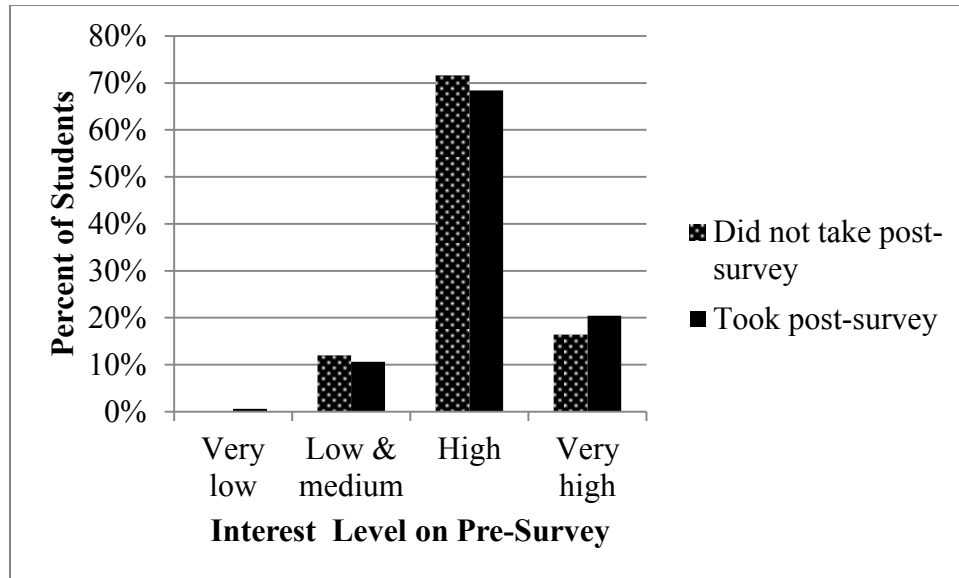
Note: 10 students who took the post-survey did not take the pre-survey

Figure 4. Distribution of responses from the pre-survey question on interest in engineering for students who did (*n* = 352) and did not take the post-survey (*n* = 68)

Retention. The retention rate of students included in analyses, 74%, was higher than the retention rate for excluded students, 56%. The overall first-year retention in engineering rate for the cohort was 70%; 12% of the students switched majors and 18% of the students left the university. Table 1 shows the retention status for students included and not included in the analyses of Research Questions 1a and 1b. Twenty-six percent of the students who were not retained (*n* = 34) were not included in the analyses. Thus, students who were retained were overrepresented in the analyses and students who left the university were underrepresented.

Table 1

Fall 2013 Status for Student Included and Not Included in Analyses for Research

Questions 1a and 1b

	Included *n* (% of included)	Not Included *n* (% of excluded)
Switched out of engineering, but stayed at the university	41 (12%)	13 (17%)
Not enrolled at the university	51 (14%)	21 (27%)
Still enrolled in engineering at the university	260 (74%)	44 (56%)

Research Question 2. Analysis for Research Question 2 included the self-control scores from the pre- and post-surveys, ACT scores, algebra readiness score, and GPA. As previously discussed, missing ACT scores were replaced with the composite score. Students who had no recorded algebra readiness scores were not included in the analysis. Students missing responses on the self-control questions on the pre- or post-survey were not included in the respective analysis, but were included in analysis for which they had scores.

Pre-survey data. For analyses using responses from the pre-survey, 15 students were excluded due to having no self-control score, and 23 were eliminated for having no algebra readiness score. These exclusions resulted in a sample size of 392 which represented a 91% participation rate, well above the 85% response rate at which the National Center for Education Statistics requires analysis on nonresponse bias data (Chen, 2013). Of the 23 students who were excluded for not having an algebra readiness score, nine had a GPA of less than 0.5. This resulted in a statistically significant

difference in the average GPA for students who were and were not included in the analysis using the data from the pre-survey, $t(40) = 3.428$, $p = .001$ (using the t-test equal variances not assumed based the results of Levene's test for equality of variances $F(1, 428) = 34.65$, $p < .001$) . There was also a statistically significant difference in the average ACT math score, $t(428) = 4.898$, $p < .001$, and ACT English scores, $t(428) = 2.211$, $p = .028$.

Post-survey data. For analysis using responses from the post-survey, 85 students were excluded for not having a self-control score, and 12 were excluded for not having algebra readiness score. This resulted in a final sample size of 333 which represented 77% of the cohort. When comparing the average ACT subject scores and average first semester GPAs for the 333 students in the analyses for Research Question 2 using data from the post-survey and for all 430 students in the 2012 cohort, there was a statistically significant difference in the average GPA, $t(761) = 2.116$, $p = .035$. This difference caused some concern given the inclusion rate of less than 85%, and presented a potential threat to internal validity.

As with analyses for Research Questions 1a and 1b, the students with the lowest GPAs are underrepresented and the students with the highest GPAs are overrepresented. There was a statistically significant differences when comparing participants and nonparticipants in the average ACT math, $t(428) = 3.333$, $p < .001$; and average ACT science scores $t(172) = 2.186$, $p = .030$; as well as, in the variances for the ACT science scores, $F(1, 428) = 7.250$, $p = .007$ and GPA, $F(1, 428) = 32.779$, $p < .001$.

Conclusion on missing data. Based on these analyses of missing data, the most important threat to internal validity was the lack of representation of students at the

lowest GPA level. Exclusion of over one in four of the students who left engineering also poses threat to statistical validity as it lowers the number of data points in a retention category that already had fewer students.

Generalizability of Results

This study was conducted in a period of growth in the engineering program at UofL. The retention rate for the 2012 cohort was unusually low when compared to the past four cohorts that had all trended to increased retention. Still, the results of this study should be generalizable to the population of engineering students who started or will start college at UofL within a few years of the study.

Those interested in applying the results of this study to a group of students outside of UofL must first determine if their group of students is similar to the one used in this study as the sample does not mirror the national population of engineering students. The sample in this study was less ethnically diverse and had a higher percentage of females than the national population of engineering students (see Table 2).

Table 2

National and UofL Ethnic and Gender Distribution of Freshman Studying Engineering

Group	National 2010 Freshman Intending to Study Engineering [a] (%)	National 2009 Freshman Studying Engineering [b] (%)	UofL 2012 Freshman Engineering Cohort (%)
Caucasians	74	68	85
Asian/Pacific Islander	13	10	4
Hispanic	11	6	4
African American	8	10	3
American Indian /Native Alaskan	2	1	< 1
Unknown / other	3	n/a	3
Temporary resident	n/a	6	< 1
United States citizen	n/a	94	100
Temporary resident	n/a	6	< 1
Male	n/a	82	78
Female	n/a	18	22

[a]Data from NSF Science and Engineering Indicators 2012. Data were gathered by the Higher Education Research Institute. [b]Data from NSF Women, Minority and Personas with Disabilities in Science and Engineering. Data were gathered from the Engineering Workforce Commission, *Engineering Enrollment Fall 2009*.

Longitudinal data from the National Science Foundation show that, since 1995, the group of students intending to major in engineering has become more diverse, resulting from a decrease in the percentage of Caucasian students and an increase in the percentages of Asian and Hispanic students (NSF science indicators, 2010). This shift in

diversity has not been realized at UofL where Caucasians represented 85% of the 2012 cohort and no other ethnic group represented more than 4%. This is consistent with other cohorts at UofL.

<div align="center">**Threats to Validity**</div>

Within the study, there were multiple threats to validity to consider when interpreting outcomes. Some of the threats were inherent in all studies using survey data or instruments to measure constructs. Other threats were a result of the sample used in the study. The following discussion on the threats to validity is categorized by type of validity.

Threats to Construct Validity

The two constructs, self-control and interest in engineering, were measured using survey questions. As with all studies based on self-reported survey data, there was a potential for multiple interpretations of the questions and misrepresentation which can be a threat to construct validity. The responses to the survey questions could have been influenced by a recent event such as an interesting lecture or a less-than-interesting assignment.

Threats to Convergent Validity

The instrument used to measure self-control, the Brief Self-Control Scale, has been used in at least 30 studies (De Ridder et al., 2012), but no evidence could be found where the scale had been used with a sample of engineering students. Although the internal consistency reliability for the scale was good, the CFA on the items did not have good fit and some of the factor loadings were less than .7 which is the criteria for good convergent validity recommended by Kline (2011).

Although the Brief Self-Control Scale has been widely used, there have been critics of the scale. A published article by Maloney, Grawitch and Barber (2012) questions its uni-dimensionality and the validity of the scale.

Construct validity also was an issue in the SEM model used to analyze data for Research Question 2. Not all factor loadings for academic ability were over .7 and the fit statistics did not show good fit according the most stringent published criterion (Kline, 2011). These issues are not a great concern since the model was not intended to be used for prediction.

Threats to Internal Validity

This study was limited by the inability to gather data from non-responders. Participation rate for analysis for both Research Questions 1a and 1b was 82%. For Research Question 2, the participation rate was 91% for analyses using responses from the pre-survey and 77% for analyses using responses from the post-survey. Although these response rates are respectable, both self-selection and attrition were threats to internal validity. The response rate on both surveys was higher for the students who were retained after one year than for students who were not.

Threats to Statistical Conclusion Validity

When using both males and females, the sample size was appropriate for all analyses. There were problems with scarcity of data when trying to perform logistic regression using just female students. Modifications were made by condensing two categories of interest with few data points into one category. Due to results discussed in Chapter 4, there is still a potential threat to statistical conclusion validity. Also

throughout the study, there were many *t*-tests performed between groups with vastly different sample sizes. This too could have been a potential issue.

Threat to External Validity

The current study investigated one cohort of students from one university in which 85% of the students were Caucasian and no other ethnic group represented over 4% of the sample. This was a less diverse population than the national population of engineering students. A more diverse group of students might have different results. The overwhelming majority of the students in the study attended high school within the state of Kentucky. Readers of the study need to determine if the results of the study are applicable to a specific group of students based on the demographics of that group.

CHAPTER 4

RESULTS

This chapter contains the results of the analyses and is divided into two sections

based on the research questions. Details of the descriptive statistics for dependent and

independent variables for all questions appear in Appendices C and D. Discussion of the

results and their potential applications are in Chapter 5.

Research Questions 1a and 1b

Research Questions 1a and 1b investigated the relationship among interest in

engineering, first semester GPA, and retention in engineering after one year, and whether

this relationship varied for males and females. The sample size for this analysis was 352

which represented 82% of the cohort.

Results of Logistic Regression

Table 3 summarizes the variables used in the logistic regression analysis and

includes the variable type, potential values, and the sample size for the categorical data.

The variable STATUS was coded as a "0" if the student left the university or switched

academic units and "1" if the student remained in engineering after one year. In the

analysis, the variable INTEREST (4; very high interest) was treated as the reference

variable.

Table 3

Information on Variables for Research Question 1 Analyses

Variable		Type	Potential values	*n*
Retention status (outcome variable)	(STATUS)	Categorical	0 = No 1 = Yes	92 260
Fall 2012 GPA	(GPA)	Continuous	0 to 4.0	
Interest in engineering	(INTEREST)	Categorical	1 = Very low 2 = Low and medium 3 = High 4 = Very high	10 64 197 81

Model fit. Although the purpose of the analysis was exploratory and the main emphasis of the analysis was to investigate the significance of the odds ratios, the fit statistics for the model still warranted review. The chi-square test comparing the fit between the model with no predictors and the hypothesized model indicated that INTEREST and GPA help the model fit the data significantly better than no predictors, $\chi^2(4) = 126.271$, $p < .001$, . Cox and Snell R^2 was .301 and Nagelkerke R^2 was .441, which gave a sense of the magnitude of percent variance explained by these predictors. Overall the model correctly predicted the status of 83% of the students, which was better than the null model that correctly predicted status for 74% of the students. The model correctly predicted 95% of the students who were retained, but only 50% of the students who did not continue to study engineering. The lower percentage predicted for non-retained students is most likely driven by the substantially smaller sample size for that group.

Analysis of the 46 cases that were incorrectly predicted to stay in engineering showed 26 students (57%) switched majors and 20 students (44%) left the university.

The model correctly identified 61% of the students who left the university, but only 37% of the students who switched majors. This will be discussed further in Chapter 5. As discussed in Chapter 3, if the purpose of the model was to predict status with high accuracy, more variables that have been shown to relate to retention such as those discussed in Chapter 2 would have been included in the model.

Odds ratios. Table 4 contains the coefficient estimates and the Wald statistic for each variable, along with the odds ratio and upper and lower confidence intervals of the odds ratio. Each of the coefficients were significant at $p = .001$, except for INTEREST(3). Thus, the data did not support a significant difference in the likelihood of retention for students who indicated they had high or very high interest in engineering, given the same GPA.

Table 4

Results from Logistic Regression Analysis

Variable	β	S. E.	Wald	Sig.	Odds Ratio	Odds Ratio 95% CI
GPA	1.52	.20	55.25	< .001	4.566	[3.059, 6.814]
INTEREST(1)	-3.76	1.16	10.62	.001	.023	[.002, .222]
INTEREST(2)	-1.84	.46	15.90	< .001	.160	[.065, .394]
INTEREST(3)	-.39	.41	.90	.342	.678	[.304, 1.512]

Based on the odds ratio for GPA, students in this data set were approximately 4.6 times more likely to be retained if their GPA was 1 point higher than another student, given the same interest level. Based on the 95% confidence interval of the odds ratio for

GPA, one would expect the odds to be between 3 and 6.8 in other samples drawn from the same population.

Since INTEREST was treated as a categorical variable, the odds ratios are interpreted relative to the reference variable (category 4) which was a response of *Very high*. Based on the confidence intervals of the odds ratio for INTEREST(1), one would expect a student with very low interest would be between 4.5 (= 1 / .222) and 500 (= 1 / .002) times less likely to be retained than a student with very high interest. The range of this confidence interval is large due to the high standard error compared to the other estimates, which is in part a result of a lower sample size ($n = 10$) for INTEREST(1). Based on the confidence intervals of the odds ratio for INTEREST(2), a student with low to medium interest would be between 2.5 (= 1 /. 394) and 15.4 (= 1 /. 065) times less likely to be retained than a student with very high interest. Since the confidence interval for INTEREST(3) includes 1 and $p > .05$, the data do not support a difference in retention status between students who responded *High* (3) or *Very high* (4) interest.

Outlier analysis. Outlier analysis was performed to determine if certain data points exerted disproportional influence on estimates. When the top five suspected outliers were excluded from analysis, the model became unstable since two of the data points were in the lowest interest category; exclusion of these points created a situation where too few data points were in the *Very low* category. Therefore, analysis was re-run, condensing the interest responses into three categories; *Very low*, *Low* and *Medium* (INTEREST(1)), *High* (INTEREST(3)), and *Very high* (INTEREST(4)). The results of the logistic regression model with three interest categories also showed no significant difference in status for students who selected *High* or *Very high* interest. There was a

significant difference between students who indicated they had *Very low, Low* or *Medium* interest and those who indicated they had *Very high* interest. There was considerable overlap in the confidence intervals for the odds ratio for GPA and the *High* interest variable from the analyses using four and three levels of interest.

Results Related to Differences between Males and Females

The model created using all students correctly predicted retention status of 85% of the males, but only 77% of the females. The lower rate for female students might be due to the smaller sample size (79 versus 273) which makes accurate prediction less obtainable, or it could indicate that different models are needed for male and female students. Twenty percent of the females were incorrectly predicted to remain in engineering versus only 11% for the males. Of the 16 females incorrectly predicted to stay in engineering, 44% left the university and 56% switched units. The 30 males incorrectly predicted to remain in engineering had similar percentages of those who left the university, 43%, and those who switched units, 57%. Only three percent of the females and 4% of the males stayed in engineering, but were predicted to leave.

To answer Research Question 1b about gender differences in the relationship among interest, GPA, and retention, the research design called for running separate logistic regression analyses for males and females. Since there were only four *Very low* responses for females and only six for males, there were not adequate data to support analysis with four interest categories (Osborne, 2015). Instead, the interest responses were compressed into three categories of variables: INTEREST(1) which contained responses of *Low*, *Very low* and *Medium*, INTEREST(3) with the response of *High*, and INTEREST(4) with the response *Very high*. As discussed in Chapter 3, compressing

response category is an accepted practice (Allen & Seaman, 2007; Osborne, 2015; Schwappach & Koeck, 2004). Table 5 shows the number of responses in each category for males and females.

Table 5

Sample Size for Each of Three Categories of Interest for Males and Females

	Males	Females
Very low, *Low and Medium* - INTEREST(1)	53	21
High - INTEREST(3)	154	43
Very high - INTEREST(4)	66	15

Using these levels of interest, separate models were run for males and females, and the results are in Table 1. The model for males successfully predicted the status of 84% of the male students; the model for females still only correctly predicted the status for 77%. This might be due in part to the small sample size of females. It is a possibility that accurate prediction of female engineering student retention is more complex, as the decision to remain in engineering for females might be based on more factors than it is for males (Goodman et al., 2002).

Table 6

Results from Logistic Regression Analyses with Three Categories of Interest and Z-Statistic Comparing β_{Male} and β_{Female}

Variable	β	S. E.	Wald	Sig.	Odds Ratio	Odds Ratio 95% CI	z Statistic
GPA							
Male	1.66	.24	46.23	< .001	5.266	[3.262, 8.500]	.54[a]
Female	1.40	.42	10.90	.001	4.048	[1.785, 9.284]	
INTEREST(1)							
Male	-1.75	.50	12.13	< .001	.174	[.065, .465]	1.06[a]
Female	-3.11	1.17	7.05	.008	.045	[.005, .443]	
INTEREST(3)							
Male	-.02	.46	<.01	.958	.976	[.399, 2.387]	1.43[a]
Female	-1.73	1.11	2.45	.118	.177	[.020, 1.548]	

Note. [a] not significant at *p* = .05

The odds ratio for INTEREST(3) for males is very close to 1.0 which signifies no difference between the odds of being retained for male students with *High* or *Very interest*. This was confirmed by the non-significance of $\beta_{INTEREST(2)}$ (*p* = .958). Although $\beta_{INTEREST(2)}$ was also not significant in the model of female students (*p* = .118), investigation of the odds ratio point estimate and the large standardized error suggests future research with a different and larger sample would be necessary to be confident in the conclusion that there was no difference in retention rate for female students indicating they had high or very high interest in engineering, given the same GPA.

Using a z-test statistic in Equation (2), there was not a significant difference between any of the βs for the males and females as all z statistics were under 2. As a secondary check, the model with three levels of interest was run with gender as a categorical value, and gender was not found to be significant ($p = .104$).

Research Question 2

Research Question 2 investigated the relationship among the constructs of self-control, academic ability, and first semester GPA. The descriptive statistics for the variables are located in Appendix D. On both the pre- and the post-surveys, students completed the 13 items that comprise the Brief Self-Control Scales. As discussed in Chapter 3, the items of the scales had better model fit when three of the items were eliminated from the scale. The average self-control scores on the pre- and post-surveys were statistically different (see Appendix D), but highly correlated, $r = .76$.

Separate analyses were performed using both the data from the pre- and the post-surveys. The sample size for analysis using data from the pre-survey was 392 students (91%), and 333 students (77%) were included in analysis using data from the post-survey.

Correlation Matrices

Tables 7 and 8 display the correlation matrices for data used in the SEM analysis. Table 7 displays the correlations for data from the pre-survey, and Table 8 displays correlations for data from the post-survey. All variables in both tables were statistically significantly correlated with GPA at $p < .001$. ACT math scores had the strongest correlation with GPA, followed by the algebra readiness score. The correlation between self-control scores (both 13 item survey scores and 10 item survey scores) from the post-

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survey were more strongly correlated with GPA than the self-control scores from the pre-survey. The items used to create the construct of academic ability were all significantly correlated with each other ($p < .001$) and ranged from .281 to .669 for the pre-survey data and from .285 to .689 for the post-survey data. Interestingly, ACT math scores were more strongly correlated with ACT science scores than with algebra readiness scores. Self-control scores were not significantly correlated with scores on the ACT tests in either the pre- or post-survey data, which supports the SEM conceptualization of self-control as an independent construct from academic ability in the model (see Figure 2)

Table 7

Correlation Matrix for Data from the Pre-Survey (n = 392)

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
ACT English (a)	1							
ACT math (b)	.554[*]	1						
ACT reading (c)	.645[**]	.449[**]	1					
ACT science (d)	.557[**]	.669[**]	.619[**]	1				
Algebra readiness (e)	.372[**]	.525[**]	.281[**]	.399[**]	1			
Self-control (13 items) (f)	.005	.007	-.029	.007	.129[*]	1		
Self-control (10 items) (g)	-.008	-.020	-.028	-.008	.129[*]	.948[**]	1	
Fall 2012 GPA(h)	.353[**]	.461[**]	.287[**]	.352[**]	.402[**]	.223[**]	.206[**]	1

Note. * $p \leq .05$, ** $p \leq .001$

Table 8

Correlation Matrix for Data from the Post-Survey (n = 333)

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
ACT English (a)	1							
ACT math (b)	.581**	1						
ACT reading (c)	.638**	.469**	1					
ACT science (d)	.570**	.689**	.643*	1				
Algebra readiness (e)	.390**	.523**	.285**	.406**	1			
Self-control (13 items) (f)	.043	.026	-.031	.009	.154*	1		
Self-control (10 items) (g)	.043	.022	-.025	.006	.183**	.959**	1	
Fall 2012 GPA(h)	.388**	.433**	.277**	.345**	.410**	.353**	.353**	1

*Note. * p ≤ .05, ** p ≤ .001*

There was a low but significant correlation between both the 13 and 10 item survey self-control scores and the scores on the algebra readiness test. The correlation might be due to the nature of how the algebra test was administered: twice during the summer and once in class with students having an opportunity to take a review course during the summer. Although in principle the correlation could indicate a problem with discriminate validity, the correlations were quite low (.129 to .183).

Measurement Model Results

In the measurement model, all direct effects were replaced with correlations and all exogenous variables were correlated. For comparison, four separate measurement models were run; two models with self-control scores from the pre-survey based on 10 and 13 items and two models using self-control scores from the post-survey based on 10 and 13 items. Results from the analyses with the 10 item survey scores are discussed in this section. Results using the 13 item survey scores and comparison to results using the 10 item scores are in Appendix F.

The factor loadings for the items in the construct of academic ability were the same for both the pre- and post-surveys scores when rounding to two decimal places (ACT math = .84, ACT reading= .62, ACT English = .67, ACT science= .80, algebra readiness = .57). Since all values were less than .9, discriminate validity appears unproblematic (Kline, 2011). The score on the algebra readiness test had the lowest standardized regression weight which was well below the .7 recommended by Kline (2011) for convergent validity. Due to the difference in delivery method, format and timing between the algebra readiness test and the ACT tests, it is understandable why the factor loading for the algebra readiness scores are lower than the ACT tests. Research discussed in Chapter 2 (Chariker et al., 2013; Levin & Wyckoff, 1988) supports that the skills represented by the algebra readiness test score are important for success in engineering, so these scores were not removed.

The modification indices indicated that correlating the residual error between ACT reading and ACT science would improve model fit. However, there was no evidence in the literature that these scores are more strongly correlated than any other ACT test scores, so no changes were made.

In analyses using the pre- and post-survey data, the correlation between academic ability and the residual error of GPA was significant ($p < .001$), as were the correlations between the residual error of the self-control score and the residual error of GPA. The correlation between academic ability and the residual error of the self-control score was not significant ($p = .479$ for post-survey data and $p = .974$ for pre-survey data). The lack of significant correlation between academic ability and self-control is supported by

previous work on self-control by Duckworth (2012) who concluded that self-control was not related to scores on standardized tests, but was related to grades.

The fit statistics for the measurement model using the pre-survey data were χ^2 (12) = 76.40, $p <. 001$; TLI = .882; CFI = .933; RMSEA = .117, 95% CI [.093, .143]. The fit statistics for the model using the post-survey data, χ^2 (12) = 72.61, $p <. 001$; TLI = .873; CFI = .927; RMSEA = .126, 95% CI [.100, .154]. These statistics do not show good fit for either model (Kline, 2011) which is not surprising due to the simplicity of the model.

Structural Model Results

Coefficient estimates. Analyses of the structural models did not include the correlation between the error of the self-control score and academic ability since that correlation was determined to be not significant in the measurement model. Table 9 includes the results of the analyses which indicated a significant relationship between self-control score and academic ability with GPA. The self-control coefficient estimate using the post-survey data was higher than calculated with the pre-survey data; however, when using Equation 2, there was no significant difference in the two values ($z = 1.19$). Nor was there a difference in the coefficient estimates for academic ability using the pre- or post-survey data ($z = 1.06$).

Table 9

Regression Coefficients and Estimates of Correlation

	β	Unstandardized Estimate	*SE*	*p*	95% CI
Effects					
Academic ability on First semester GPA					
10 item pre self-control	.519	.169	.016	<.001	[.038, .200]
10 item post self-control	.487	.145	.016	<.001	[.113, .176]
Self-control on First semester GPA					
10 item pre self-control	.206	.035	.007	<.001	[.021, .049]
10 item post self-control	.338	.046	.006	<.001	[.034, .058]
Correlation					
Residual error of ACT English with residual error of ACT Reading					
10 item pre self-control	.394	3.824	.625	<.001	
10 item post self-control	.342	3.093	.633	<.001	

Using the date from the pre-survey, the expected difference in GPA is .035 given

a 1 point difference in self-control score (sum of the all 10 responses), with academic

ability held constant. Based the standardized coefficient for the self-control variable for

the pre-data, the expected difference in GPA would be .206 standard deviations give a

one standard deviation change in the self-control score, with academic ability held

constant.

Based on the unstandardized coefficient for academic ability, the expected

difference in GPA for two students who had a 1 point difference in academic ability and

equal self-control would be .169. A student with a one standard deviation higher score

for academic ability would be expected to have a GPA that was .519 standard deviations

higher than another student with the same self-control score. Since academic ability is a

construct measured with five indicators, to make sense of this result the factor loadings

must be investigated. All five indicators, ACT math, science, reading and English scores

and the score on the algebra readiness test contribute to the value of academic ability.

Therefore, the value of academic ability is increased when a student scored higher on one

of these tests. Since the factor loadings for the ACT math and ACT science scores had

the highest factor loadings, an increase in these scores would increase the value of

academic ability by more than an increase in one of the other indicators. Therefore these

scores have the highest impact on the value of academic ability.

Model fit. As expected, the model fit statistics for the parsimonious model

chosen for analyses did not show good fit according to the standards set by Kline (2011).

The fit statistics for the structural model with the pre-survey data were χ^2 (13) = 76.40, p

<. 001; TLI = .893; CFI = .934; RMSEA = .112, 95% CI [.088, .137] and for the post-

survey data were χ^2 (13) = 76.16, p <. 001; TLI = .884; CFI = .928; RMSEA = .121, 95%

CI [.095, .148]. Poor model fit is a result of too much covariance between exogenous

variables that is not explained by the model. This poor model fit may be due to omission

of a variable that could explain the covariance, or a parameter in the model that was

incorrectly specified. As discussed previously in Chapter 2, many variables have been

found significant in models to predict academic performance in freshmen engineering

students. The intent of this study was to investigate a parsimonious model evaluating the

relationship between self-control, academic ability, and academic performance. The

intent was not to predict academic performance with a high amount of accuracy. Most

likely there are variables that have been shown to be significant in other studies, but were

not included in this study, that could improve model fit.

CHAPTER 5

DISCUSSION, CONCLUSIONS, AND FUTURE RESEARCH

Retention, GPA, and Interest

Whether or not a shortage of qualified STEM employees, particularly engineers, currently exists or will exist in the future, understanding factors related to retention of STEM students is important. Although this study specifically investigates retention of engineering students, the results might be applicable to other fields within STEM with similarly challenging curriculum and dynamics.

Improving engineering retention is not only related to the effort to ensure an adequate supply of engineers, but also to helping increase college retention and graduation rates that currently are being used to rate universities and in some states determine state funding to universities (Deangelo et al., 2011). Engineering retention might also indirectly relate to student debt. Students who do not graduate are less likely to pay back their student loans (Nguyen, 2012) and students who switch majors might take longer to graduate and might accrue more loans.

By framing the issue of engineering retention in the expectancy value theory (Wigfield & Eccles, 2000) and drawing on past research on students' motivations to study engineering or leave engineering, interest and academic performance became obvious variables to investigate. Although there are different types of value and different ways to measure expectancy, using interest as a measure of value and GPA as a measure

of expectancy are supported by research that has shown two of the top reasons students decide to student engineering are interest in engineering, science and math, and being good at math and science (Anderson-Rowland, 1997; Honken & Ralston, 2013; McIlwee & Robinson, 1992). Research on why students leave engineering has shown the top reasons are loss of interest in engineering (or more interest in some other field) and poor academic performance (Besterfield-Sacre, et al., 1997; Seymour and Hewitt, 1997).

Specifically, Research Question 1a investigated the relationship between interest in engineering at the end of the first semester, first semester GPA, and retention in engineering after one year. Logistic regression analyses showed first semester GPA had a significant relationship with retention (see Table 4). Students with higher GPAs were more likely to stay in engineering given the same amount of interest. This finding is supported by previous research (Bundy et al., 1998; Hartman & Hartman, 2006) that showed first semester GPA was significantly related to retention in engineering.

Interest was initially measured with four categories: (1)*Very low* defined as "not interested in engineering,"(2) *Low* to *Medium* interest defined as "equally or more interested in a field other than engineering," (3) *High* interest defined as "very interested in engineering, but could be happy in another field," and (4) *Very high* as "not interested in a field other than engineering." Due to scarcity of data after outliers were removed, an analysis was also run with the two lowest categories of interest combined, resulting in only three categories of interest. Logistic regression models with both three and four levels of interest showed a significant difference in retention between students with very high interest and students with very low, low, or medium interest, given an equal GPA. There was not a significant difference in retention between students with high or very

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high interest. This finding is important as it indicates that students do not need to be

interested only in engineering to have a higher probability of being retained, as long as

their interest in engineering is stronger than their interest in another field. Previous

research of students who have left engineering showed loss of interest as a main reason

for leaving along with poor academic performance (Besterfeld-Sacre et al., 1997;

Seymour & Hewitt, 1997). In the current study, 50% of the students with equal or more

interest in a field other than engineering were retained compared to 82% of the students

with more interest in engineering than any other field.

Step-outs to Stars Engineering Retention Framework

Based on the results of analysis for Research Question 1a, a synthesized

framework was created through which to consider engineering retention. The framework

titled "Step-outs to Stars engineering retention framework" consists of four quadrants

based on first semester GPA and interest in engineering after one semester (see Figure 5).

GPA was divided into two sections, "above average" (high) and "less than average"

(low). The two classifications of interest are "equally or more interested in a field other

than engineering" (low) and "more interested in engineering than any other field" (high).

The division was made at this point since the analyses in this study showed no difference

in probability of being retained for students with high or very high interest, but a

significant difference between very high and very low, low and medium interest.

		GPA	
		Below average (Low)	Above average (High)
Interest	Equal or more interested in another field (Low)	STEP-OUTS ($n = 38$, 11%) Retained 21% Switched units 29% Left university 50%	SEARCHER ($n = 36$, 10%) Retained 67% Switched units 25% Left university 8%
	More interested in engineering than any field (High)	STRUGGLERS ($n = 102$, 29%) Retained 61% Switched units 15% Left university 24%	STARS ($n = 176$, 50%) Retained 94% Switched units 3% Left university 2%

Figure 5. Step-outs to Stars engineering retention framework

Stars. In the framework, the students in the quadrant with high GPA and high interest were named the Stars. Based on the odds ratio from the model for Research Question 1a, the Stars would be expected to have the highest retention rate. The actual retention rate for the students from the 2012 cohort in this quadrant was 94%, which was the highest of all the quadrants. Based on the simplicity of the framework and the exclusion of factors such as finances and commitment to UofL, the accuracy of prediction in this quadrant was high. It was not surprising that these students had the highest

retention rate as they seem to have found a good fit between interest and ability. Fifty percent of the students in the 2012 cohort were in this quadrant.

At the start of the semester 21% of the Stars indicated they had very high interest in engineering and the percentage increased to 27% at the end of the semester. Post hoc analysis showed a significant positive change in interest for the Stars (see Appendix G).

Step-outs. The students in the opposite quadrant with low GPA and low interest, referred to as the Step-outs, would be predicted to have the lowest retention rate based on the logistic regression results. This group represented 11% of the 2012 cohort and their retention rate of 21% was the lowest of any quadrant. Half of the Step-outs left the university and 29% switched to another unit.

The Step-outs had a significant change in their responses to the interest in engineering question from the pre- to post-survey (see Appendix G). On the pre-survey, 76% of the Step-outs selected a higher interest category than they did on the post-survey. It is unknown if the students in this quadrant chose engineering as a major not knowing much about the field or the curriculum, if they lost interest due to their lackluster performance, or if their interest changed for some other reason. Future research could be conducted to determine the reasons that these students chose to study engineering and if better career advising could have helped them make a better decision that was more related to their interest and abilities. It would also be interesting to determine if their poor performance impacted their interest level in engineering.

Searchers. Based on the logistic regression model, the two remaining quadrants – the one with high GPA and low interest called the Searchers and the quadrant with low GPA and high interest called the Strugglers – would be the hardest to predict since the

variables suggest opposite relationships with the likelihood of being retained in engineering. The Searchers (10% of students) had the second-highest retention rate and the highest rate of switching to other units. Based on their responses to the interest question of the pre-survey, 57% of the Searchers indicated a higher level of interest in engineering at the start of the semester than in week 13 of the same semester. Their shift in interest was significant (see Appendix G).

The Searchers have the ability to do above-average work in engineering, but might not be interested enough to continue to study engineering. The Searchers most likely would benefit from career advising or activities that help them maintain interest in engineering. Future research could investigate if students from this group switch units later in their studies. Another interesting study would be to investigate why these students indicated lower interest levels at the end of the semester than at the beginning considering they were performing above-average.

Strugglers. The third highest retention rate was for students with low GPA and high interest. The Strugglers represented 29% of the 2012 cohort. The percent of students in this group who left the university was less than half the percent that of Step-outs (low interest, low GPA) who left, even though their average GPA was not statistically different, $t(138) = 1.365, p = .171$. The percent of this group that switched to another unit was 46% less than the percent of the Searchers who switched units.

At the beginning of the semester 30% of the Strugglers indicated they had very high interest in engineering. At the end of the semester the percentage had increased slightly to 33%, which was higher than the percentage of Stars that had indicated they

had very high interest. The data did not show a significant shift in interest between the

pre- and post-surveys for the Strugglers (see Appendix G).

The Strugglers may benefit the most from tutoring and mentoring. Future

research could investigate Strugglers to determine what led to their low performance.

<h3 style="text-align:center">Difference between Males and Females</h3>

Within this study, multiple analyses were performed to investigate the difference

in the relationship between GPA, interest, and retention for males and females.

Adjustments were made to the research plan due to sparse data in certain categories of

interest. The four interest categories were reduced to three by combining the *Very low*

category with the *Low* to *Medium* category. Regardless of the analysis performed,

retention status of females was much harder to accurately predict. As mentioned

previously, this difficulty is due in part to the smaller sample size, but there also might be

more factors that influence females' decisions to stay in engineering. As discussed in

Chapter 2, multiple research studies have investigated retention of females in engineering

and other STEM fields. Within these studies is evidence that certain factors, such as the

high threshold for acceptable grades and school climate, might be related more strongly

to females' decisions to leave engineering (Goodman et al., 2002; Seymour & Hewitt,

1997).

Figure 6 shows the Step-outs to Stars engineering retention framework for males

and females. Females represented 22% of the sample, yet they represented 36% of the

Searchers. Their percentage in the other categories was representative of their proportion

of the sample. The retention rate of the female Searchers was 32% lower than for the

male Searchers. Again, caution must be taken due to the small sample of females; but it

appears that females with low interest and high GPA are much more likely to switch out

of engineering than males in the same category. Future research could focus on the

Searchers to determine if this difference truly exists and why males in this quadrant are

more likely to stay in engineering than females in this quadrant.

STEP-OUTS				SEARCHER		
	M (30)	F (8)			M (23)	F (13)
Retained	20%	25%		Retained	78%	46%
Switched units	30%	25%		Switched units	13%	46%
Left university	50%	50%		Left university	9%	8%
STRUGGLERS				STARS		
	M (79)	F (23)			M (141)	F (35)
Retained	63%	52%		Retained	94%	94%
Switched units	14%	17%		Switched units	3%	6%
Left university	23%	30%		Left university	3%	0%

Figure 6. Step-outs to Stars engineering retention framework for males and females

One potential explanation for the difference in retention rate of male and female

Searchers is that females might have a different perception of what is an acceptable

grade. In the Goodman (2002) study, some female students with A's and B's indicated

they were discouraged by grades. In the Seymour and Hewitt study (1997) females who

switched out of engineering had a higher average GPA than the males who switched out.

This in part might be due to the impact on self-esteem of receiving a poor or a good grade

on assignments. A study found, when comparing male and female engineering students who indicated that academic competence was a source of their self-esteem, that the female engineering students let a poor grade have a larger negative impact on their self-esteem and a good grade have a smaller positive impact (Croker et al., 2003). This is another area that could be investigated in the future.

GPA, Self-Control, and Academic Ability

Due to the significant relationship between first semester GPA and retention, the analyses on GPA were particularly important. The second part of the study that investigated the relationship between self-control, academic ability, and first semester GPA was grounded in past research on self-control. The resulting model fit statistics were not optimum. Based on the simplicity of the model, this was expected and was not of great concern since the purpose was not to produce a model to predict GPA.

The SEM model using self-control scores from the pre-survey explained 31% of the variability in first semester GPA; the model using self-control scores from the post-survey explained 35% of the variability. The increased percentage might be due to the difference in sample or the time in the semester the surveys were administered.

The results confirmed previous research with middle school students (Duckworth et al., 2012; Hofer et al., 2012) and with college students taking a psychology course (Tangney et al., 2004; Wolfe & Johnson, 1995) that showed self-control was related to grade attainment. The results also confirmed the lack of a significant relationship between self-control and academic ability (Duckworth et al., 2012; Hofer, et al, 2012).

The results of this study also confirmed previous research with University of Louisville engineering students that showed a negative relationship between lack of self-

control and first semester GPA, and a positive relationship between academic ability and GPA (Honken & Ralston, 2013). In Honken and Ralston study and the current study, the magnitude of the self-control variable and the academic ability variable were similar, even though self-control was measured differently in the two studies. In the Honken and Ralston (2013) study, self-control was measured by the frequency of performing illegal or irresponsible acts in high school, as reported by students on a survey taken the summer before starting college. The measure of academic ability in the Honken and Ralston study included the individual ACT scores, but did not include algebra readiness test scores.

Duckworth and Seligman (2005) speculated that lack of self-discipline and focus on short term goals is a major cause of students not reaching their intellectual potential. Some are concerned that due to the increased distractions created by technology, such as smart phones, the need to develop self-control is now even more important to academic success (Elstad, 2008). To help individuals develop self-discipline, Duckworth, Seligman (2005), and Elstad (2008) promoted the inclusion of programs into the K-12 system that help students build self-discipline. Based on the findings in this study and other studies that have linked the ability to exercise self-control as a child with important factors later in life, (Mischel et al., 1989: Motiff, 2011), this seems like a reasonable approach.

The data in the current study showed a statistically significant decrease in average self-control scores from the beginning to the end of the semester. Universities and engineering colleges might be able to help students develop or keep higher levels of self-control. For example engineering colleges could provide more peer mentoring or give

guidance in environmental, behavioral or cognitive strategies that might improve self-control. They could also create wireless free zones to reduce the temptation to receive or send text messages.

Future research on the area of self-control and academic ability could focus on determining if students' levels of self-control are more strongly related to success in certain academic environments or majors. Another interesting line of inquiry might be to investigate if students with certain levels of self-control tend to select certain college majors or career paths. This type of research might help individuals when selecting a college major.

Application of Results

As government agencies, universities, corporations, and other organizations work to ensure an adequate supply of engineers to meet the demands of the workforce and colleges of engineering work to increase their retention and graduation rates, credible data are needed to make good decisions on where to invest limited resources. The Step-outs to Stars engineering retention framework provides a mechanism through which to view students and to develop potential programs to increase retention. The framework is particularly useful to colleges of engineering offering administrators another resource allocation tool.

For example, resources could be directed towards the Strugglers by offering tutoring or supplemental instruction, or in the form of helping students develop better self-control before attending college. Based on the participants in this study, this could impact approximately 29% of the students. Resources could be directed toward the Stars, about 50% of the students in this study, by creating more opportunities for them to

develop their interest and continue to excel. Or resources could be directed toward the

Step-outs and the Searchers, each representing around 10%, by investigating ways to

increase interest in engineering or providing more opportunities to learn about

engineering and the engineering curriculum before deciding to study engineering.

The findings presented herein can also be of value to students considering

engineering as a college major. The more students know about the skills and personal

characteristics of successful engineering students, the better equipped they will be to

make their college major choice.

The Step-outs to Stars engineering retention framework can also be used by

researchers investigating retention in engineering. Since academic performance and

interest are the top reasons students switch out of engineering (Besterfield-Sacre et al.,

1997: Seymour & Hewitt, 1997), investigation of other factors related to retention could

be viewed based on the student's quadrant. By viewing gender with respect to the

framework, it quickly became obvious that the discrepancy in the retention rate between

males and females in this sample was with students in the Searchers quadrant.   There

was a higher percentage of female students in this quadrant and they were more likely to

leave engineering than male students in this quadrant.

Viewing other factors through this framework might help explain some of the

inconsistencies found in the previous research on engineering retention. For example,

samples with more Searchers may have a difference in retention rate between males and

females, while samples with more Stars may have the same retention rate for males and

females. Examples of other variables that could be investigated through this framework

include the following: self-esteem; attainment value of being an engineer; social

integration into engineering; factors that influenced students to study engineering; time spent on classwork and studying; participation in science, math and engineering related camps and extracurricular activities in high school; when students became interested in engineering; and beliefs on effort and intelligence. If the relationship between these variables and retention in engineering is different for students in different quadrants, the potential for understanding and improving student retention in engineering might be greatly improved.

Future Research

New questions and areas of inquiry have surfaced as a result of this research. Before the Step-outs to Stars engineering retention model can be used to guide resources to improve engineering retention, more must be known about the students in each quadrant. The Guild for Engineering Education Achievement, Retention and Success (GEARS) at the UofL is currently investigating multiple factors that might be related to retention. Factors include test anxiety, study and time management, beliefs on effort and intelligence, collaboration frequency, and factors considered when selecting a career. Once scores for these factors are included in the framework, interventions for each quadrant might become more obvious. Interventions could then be designed specifically for students in each quadrant.

Other factors not currently being investigated by the GEARS could also help to better understand the students in each quadrant. For example, having a better understanding of the differences between teaching styles and expectations in engineering versus what the students experienced in high school.

Another area that needs to be addressed is increasing the amount of data from females. Having data for more females will increase the confidence in the results of the study, particularly the results dealing with the likelihood of retention between a female with high and very high interest. As part of the long term research goals for the GEARS, this information is being collected on additional cohorts and can be analyzed when retention information becomes available.

All participants in this study were from the engineering college where no ethnic group other than Caucasian represented more than 4% of the cohort. It would be interesting to determine if the percentage of students in each quadrant was similar for engineering cohorts at other universities, especially universities with more ethnic diversity or an all-female student body.

In this study, average GPA was chosen as the break point between high and low GPA. There are other options for this break point. Research currently being done by the GEARS is trying to determine what grade students consider acceptable. If each student defines success differently, then using the difference between the student's defined acceptable grade and the student's actual grade might be a better break point than using the average for the entire cohort. Another option is to use 3.0 as a break point since many scholarships and co-op jobs have a 3.0 minimum.

Finally, over half of the Step-outs and Searchers reported lower interest at the end of the semester than at the beginning. As part of the approved study by the UofL Internal Review Board, all data was stripped of personal identifiers and therefore the students in these quadrants cannot be contacted to gather more information on what caused their change of interest. Future study designs could include an opportunity for students to

identify themselves as being willing to participate in interviews or focus groups to discuss changes of interest. This information would be valuable in determining if the student had misconceptions of engineering or if something in the engineering culture or teaching style impacted their interest.

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APPENDICES

Appendix A. Studies of Engineering Retention

Authors	Dependent variable	Variables considered that were not significant	Significant variables
(Burtner, 2004)	Beginning of 4th year	Belief that engineers improve society, prefer math/science of liberal arts, belief engineering is an exact science, parental influence to study engineering, confidence in speaking, writing, computers, preference to work in groups, confidence in creative thinking and problem solving abilities, technical and mechanical identity	High school (HS) GPA, 1st yr. GPA, confidence in study habits, degree to which students likes the study of engineering, perception of high pay
(Mendez et al., 2008)	Graduation persistence	Gender, SAT verbal	Freshman college GPA, HS GPA, ethnicity, SAT math, citizenship
(Besterfeld-Sacre et al., 1997)	1st year retention Looked at students who left in good standing separate from students who leave in poor standing	Perception of the work engineers do, engineering perceived as a precise science, engineering compare positively to other fields, confidence in chemistry, communications skills or engineering skills, basic engineering knowledge, adequate study habits, working in groups	Students who leave in poor standing versus all other retention groups - SAT math, HS Rank, Impact program and financial influence, students who leave in good standing – HS Rank, like engineering, like math/science, family influence

(Besterfeld-Sacre et al., 1997)	Students who left (does not say when)		Survey of students who left – 1/3 who left in good standing said disliked engineering and had lost interest in studying it, 1/3 wanted to pursue another field of study, 1/3 poor perception of their academic abilities
(Shuman et al., 1999)	Left engineering freshman – senior yr.		Loss of interest/developed new interest,, academic problem, disliked engineering/studying engineering, financial issues
(Bundy et al., 1998)	Just says engineering retention		SAT math, high school rank, first semester
(Moses et al., 2011)	1st yr. retention (non-retainers included students who switched majors, universities or dropped out of college all together)	Measures from Nowicki-Duke Locus of Control Scale, Neuroticism, Extraversion, Agreeableness and conscientiousness scores from the NEO Personality Inventory NEO-FFI, SAT verbal, SAT math	Score on the Assessment and Learning in Knowledge Spaces (ALEXS) which is a calculus readiness test, HS GPA, Openness Although SAT math, neuroticism and locus of control had significant correlations, they did not enter the model
(Zhang et al., 2004)	Graduation rate	Varied by school	Involved students from 9 schools, investigated variables by school. Independent variables investigated were ethnicity, gender, HS GPA, SAT Quantitative, SAT verbal and citizenship status. HS GPA and SAT quantitative were significant in all schools, significance of other variables varied by school

(Marra et al., 2009)	Surveyed students when they left engineering		Poor teaching and advising, curriculum difficulty, lack of belonging (used principal factor analysis on survey results from students who left)
(Veenstra, 2010)	First-year retention	Quantitative skills, study habits, commitment to enrolled college, family support	High school achievement, confidence in quantitative skills, financial needs and social engagement
(Leslie et al., 1998)	Becoming an engineer		Self-concept/self-efficacy, peer influence, goal commitment, having a parent as an engineer
(Eris et al., 2010)	Retention throughout program	Many factors from the Persistence in Engineering survey	Parental and high school mentor, confidence in math and science skills, intention to complete an engineering degree
(Hartman & Hartman, 2006)	Retention throughout program	Satisfaction with aspects of the program or relationships with faculty and peers, confidence in engineering or academic abilities, or communications skills	SAT verbal scores, For males (SAT scores, math and science achievement in high school, amount of study and organizational activities, fall GPA, spring GPA, engineering GPA), general major (versus specific engineering majors), involvement in academia enrichment and counseling activities, confidence in major

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Appendix B. Studies Investigating Performance in Engineering

Reference for study	Dependent variable	Variables not significant	Significant variables
(Levin & Wyckoff, 1988)	GPA in required math, physics and chemistry	Attitude towards HS math, physics and chemistry, certainty in major, knowledge of intended major	HS GPA, SAT math, SAT verbal, algebra readiness test, gender, anticipated study hours, chemistry placement test, reason for studying engineering, interest in science
(Besterfeld-Sacre et al., 1997)	Fall GPA	SAT Verbal, participated in program, impressions of engineering, perception of what engineers do, confidence in chemistry, communications, engineering skills and basic engineering knowledge and skills, working in groups, gender, value of scholarship, engineering perceived as being precise science, engineering compare positively to other fields, family influence to study engineering	If student had a scholarship, HS rank, SAT math, study habits, enjoyment level of math/science, financial influence to study engineering
(French et al., 2005)	GPA after eight and six semesters	Motivation, integration, class orientation	SAT verbal, SAT hath, HS rank, gender
(Bernold et al., 2007)	1st semester and end of each year GPA	Learning type measure	Learning type measure

(Gonzalez-Barreto & Gonzalez-Quevedo, 2005)	1st year GPA	Gender, type of high school, geographical location of high school	College entrance exams, HS GPA
(Schuurman et al., 2008)	Graduating GPA	Work experience, gender	Pre-work GPA, civil engineering, computer engineering, Electrical engineering
(Lackey et al., 2003)	1st year GPA	SAT verbal, total SAT, SAT math (for females)	Critical thinking notebook score, HS GPA (SAT math for males, but not females)
(Vogt, 2008)	Does not specify, just says GPA		Faculty distance, self-efficacy, academic confidence, academic integration
(Felder et al., 2002)	1st year GPA		Myers-Brigg Type Indicator score
(Jin et al., 2011)	1st year GPA	Did not give statistical significance of variables, but looked at affect measures (leadership, expectancy, major decisions, meta-cognition, deep-learning, self-efficacy, surface learning, team and motivation) and high school history (SAT/ACT scores, HS GPA, grade and number of semesters in HS math, science and English	In multi-outcome model most important were SAT math, HS GPA and then some measures of motivation In single-outcome model- SAT math, semesters of English, overall GPA, core GPA and a motivational measure
(Cummings & Knott, 2001)	1st semester GPA	race	SAT math. SAT verbal, credit hour load, gender

(Dewinter & Dodou, 2011)	1st year GPA (a few degrees that would not be considered engineering in the U.S., but are in the Netherlands, were included in this study)	Gender, high school exam score in languages	High school exam scores in liberal arts, natural sciences and mathematics,
Ting, S. R.(2001)	1st semester GPA	For males and females – SAT Math, SAT Verbal, self-appraisal system, coping with racism, a strong support person, demonstrated community service, acquired knowledge in the field. In addition for males – leadership experiences In addition for females – preference for long term goals	All students – Sat total, positive self-concept, leadership experiences, preference for long term goals. For males – SAT total, positive self-concept, preference for long term goals For females – SAT total, leadership experiences, positive self-concept
Ting, S. R. (2001)	2nd semester GPA (not clear in the article if this is cumulative)	SAT Verbal, SAT Total, self-appraisal system, coping with racism, a strong support person, demonstrated community service, and acquired knowledge in the field. When looking at males and females separately – leadership experiences	All students – SAT math, positive self-concept, leadership experiences For males and females separately – SAT Math, positive self-concept

(Veenstra, Dey, & Herrin, 2008)	1st year GPA	Commitment to enrolled college, financial needs, family support, social engagement	High school achievement, quantitative skills (as measured by ACT Math and ACT Science or SAT Quantitative, and math and chemistry placement tests), commitment to career/educational goals, confidence in quantitative skills
(Hacket et al., 1992)	Cumulative GPA (1st and 2nd yr., students)	Gender	Academic milestone self-efficacy, SATM, faculty encouragement, HS GPA, Faculty discouragement, interest, support, perceived strain
(Honken & Ralston, 2013b)	1st semester GPA		Self-control Academic ability measured by ACT Math, Science, Reading and English test scores

Appendix C. Research Questions 1a and 1b Descriptive Statistics

This appendix contains the information about the variables used in analysis for Research Question 1a and 1b: first semester GPA, interest in engineering at the end of the first semester and retention status at the end of the first year. The reported statistics are for the participants in the study and have been separated by males and females students.

First Semester GPA Statistics

Figure 7 shows the frequency distribution of GPA for the 273 male and 79 female students who were included in the analysis to answer Research Question 1a and 1b. The overall average GPA was 2.84 ($SD = .87$). There was not a statistically significant difference between GPA between the males, 2.83 ($SD = .87$) and females, 2.86 ($SD = .86$) included in the analysis.
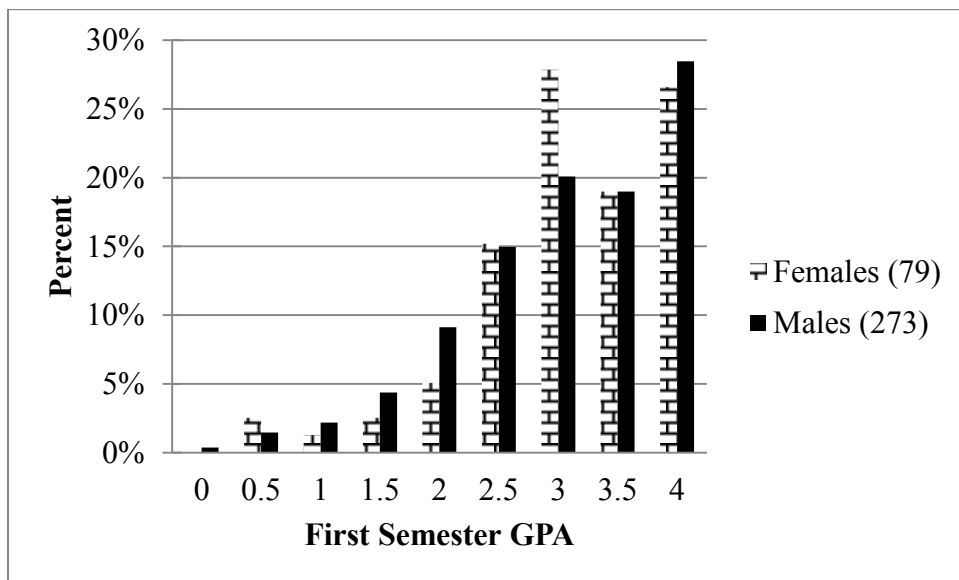

Figure 7. Distribution of first semester GPA for males and females included in analysis for Research Questions 1a and 1b.

Interest in Engineering Score Statistics

Figure 8 shows the distribution of the responses to the following question on the post-survey: "There are many reasons that affect people's decision on what to study. This question relates only to your interest level in engineering. Which of the following statements best describes your interest in engineering?" The highest percentage of students responded *High* (56%) and the lowest responded *Very low* (3%). The percentage of males who responded *High* and *Very high* were slightly higher than the females, and the percentage of males who responded *Very low* or *Low* were slightly lower than the percent of females.
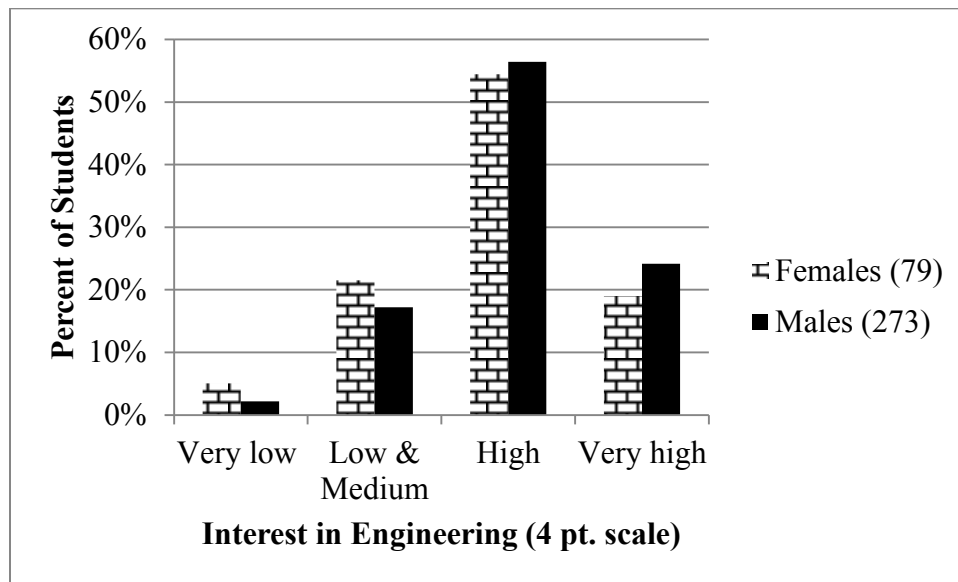

Figure 8. Distribution of responses from males and females to the post-survey question on interest in engineering.

Retention Status Statistics

Official university data showed that 304 (70%) students in the 2012 engineering cohort returned to study engineering in fall of 2013, 54 (12%) switched to a different academic unit, but remained at the university and 76 (18%) left the university. The

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retention rate was 67% for females and 72% for males. The retention rates was down from the 2011 cohort where 78% of all students and 79% of females were retained in engineering after one year.

Of the 352 students that were used in the analysis for Research Question 1a and 1b, 260 (74%) were retained in engineering, 51 (15%) were no longer enrolled in the university and 41 (12%) had switched academic units. Seven-nine females were included in the analysis, 53 (67%) were retained, 14 (18%) changed academic units and 12 (15%) left the university. Of the 273 males used in the analysis 207 (76%) were retained, 27 (10%) switched units and 39 (14%) left the university.

Appendix D. Descriptive Statistics for Variables Used in Research Question 2

This appendix contains the information about the variables used in analysis for

Research Question 2: first semester: self-control scores, ACT scores and algebra

readiness scores. As with the data in Appendix C, the reported statistics are for the

participants in the study. Since the analysis for Research Question 2 was completed with

data from the pre- and post-surveys, there are two different samples discussed in this

appendix. The appendix concludes with a comparison of the pre and post self-control

scores.

ACT, Algebra Readiness, and Self-Control Scores for Analysis Using Data from the

Pre-Survey

Table 10 displays the average and standard deviation of the variables used in

analysis for Research Question 2 when the self-control scores were taken from the pre-

survey. There was a statistically significant difference between males and females for the

scores on the ACT English, $t(390) = -2.422$, $p = .016$, ACT Reading, $t(390) = -2.393$, $p =$

.017, self-control (13 items), $t(390) = -2.852$, $p = .005$, and self-control (10 items), $t(390)$

$= -2.572$, $p = .010$. Females scored higher on all four of these measures. There was also

a significant difference between males and females in the standard deviation of the ACT

Math scores, $F(1,390) = 1.603$, $p = .010$, with females having a lower standard deviation.

Table 10

Mean and Standard Deviation of Variables in Analysis Using the Data from the Pre-

Survey for Males and Females

	Males (*n* = 305)		Females (*n* = 87)	
	M	*S. D.*	*M*	*S. D.*
ACT English score	28.29	4.01	29.46	3.82
ACT math score	29.43	3.40	28.79	2.83
ACT reading score	28.49	4.28	29.70	3.71
ACT science score	28.80	3.68	28.29	3.29
Algebra readiness score	61.28%	20.21%	58.33%	21.72%
Self-control score (13 items)	46.33	6.37	48.54	6.48
Self-control score (10 items)	35.29	5.24	36.93	5.30
Fall 2012 GPA	2.77	.92	2.83	.82

ACT, Algebra Readiness and Self-Control Scores for Analysis Using Data from the Post-Survey

Table 11 displays the average and standard deviation of the variables used in analysis for Research Question 2 when the self-control scores were taken from the post-survey. There was a statistically significant difference between males and females for the scores on the algebra readiness test, $t(331) = 2.446$, $p = .015$, and self-control (13 items), $t(331) = -2.118$, $p = .035$. Females had higher self-control scores and males had higher scores on the algebra readiness test. There was also a significant difference between males and females in the standard deviation of the ACT math scores, $F(1,331) = 1.565$, $p = .015$, with females having a lower standard deviation.

Table 11

Mean and Standard Deviation of Variables in Analysis Using the Data from the Post-Survey for Males and Females

	Males (*n* = 257)		Females (*n* = 76)	
	M	*SD*	*M*	*SD*
ACT English score	28.30	4.01	29.08	3.77
ACT math score	29.49	3.44	28.82	2.86
ACT reading score	28.49	4.28	29.47	3.77
ACT science score	28.98	3.78	28.17	3.37
Algebra readiness score	62.42%	19.87%	55.90	22.20%
Self-control score (13 items)	46.47	6.34	48.96	6.713
Self-control score (10 items)	35.38	5.25	37.13	5.503
Fall 2012 GPA	2.85	.84	2.88	.83

Comparison of Self-Control Scores from the Pre- and Post-Surveys

Based on the results of a paired sample *t*-test using only students who completed both the pre- and post-surveys, on average both males and females reported statistically lower self-control scores on the post-survey than on the pre-survey (for males $t(262) = -10.93$, $p < .001$ and for females, $t(76) = -6.61$, $p < .001$). Figure 9 shows the frequency distribution of the self-control scores from the pre- and post-surveys for all students who took the surveys. Thirty-nine percent of the scores from the post-survey were 40 or below compared to only 16% on the pre-survey. Thirty-six percent of the student's self-control scores were within plus or minus 2 points of their score from the pre-survey, 7%

had scores of more than two points lower on the pre-survey and 57% of the students'

scores were more than two points lower on the post-survey. The shift in scores between

the pre-survey and the post-survey could be the result of an actual shift in the students'

perception of their self-control or the result of slightly different samples since more

students took the pre-survey than took the post-survey. Due to the differences, analysis

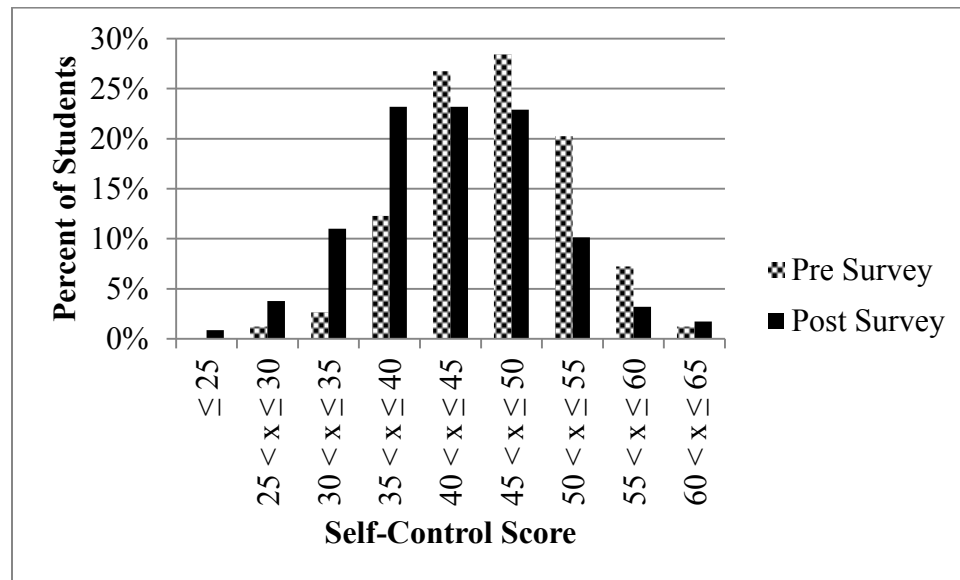for Research Question 2 was performed using both the pre- and post-survey results.

Figure 9. Frequency distribution for self-control scores from the pre- and post-surveys

Appendix E. Items in the Brief Self-Control Scale

This appendix contains the items that make up the Brief Self-Control Scale as they appeared on the Pre Engineering Fundamentals Survey. The potential responses were *Never*, *Seldom*, *Sometimes*, *Often* and *Always*, with *Never* in the left most column. No number was associated with the response on the survey.

With respect to school, how frequently does each of the following statements apply to you?

1. I do certain things that are bad for me, if they are fun.

2. I have a hard time breaking bad habits.

3. I am lazy.

4. I act without thinking through all the alternatives.

5. I am good at resisting temptation.

6. I refuse things that are bad for me.

7. I am able to work effectively towards long-term goals.

8. People would say that I have iron self-discipline.

9. Pleasure and fun keep me from getting work done.

10. I have trouble concentrating.

11. I wish I had more self-discipline.

12. I can't stop myself from doing something, even if I know it is wrong for me.

13. I say inappropriate things.

Appendix F. Results of 10 versus 13 Item Self-Control Scores

Although the Brief Self-Control Scale has been used in multiple studies, the CFA using data from this study did not show good model fit. The model fit improved when three items with low factor loadings were removed. For comparison, this appendix contains results of analysis using the 10 and 13 item self-control scores. Table 12 shows the model fit statistics from the measurement model, Table 13 shows the results of the structural model and Table 14 shows the structural model fit statistics. The statistics show very similar results for both the 10 and 13 item self-control scores. When rounded to two digits the standardized regression weights using the 10 or 13 item scores were identical for all factors.

Table 12

Measurement Model Fit Statistics

	TLI	CFI	RMSEA	[95% CI]	$\chi^2 (12), p<.001$
Pre-survey					
10 item self-control	.882	.933	.117	[.093, .143]	76.397
13 item self-control	.886	.935	.115	[.091, .141]	74.453
Post-survey					
10 item self-control	.873	.927	.126	[.100, .154]	72.605
13 item self-control	.879	.931	.123	[.097, .151]	74.453

Table 13

Regression Coefficients and Estimates of Correlation

	Standardized estimate	Estimate	SE	*p*
Effects				
Academic ability on First semester GPA				
Pre-survey - 10 item self-control	.519	.169	.016	<.001
Pre-survey - 13 item self-control	.516	.167	.016	<.001
Post-survey - 10 item self-control	.487	.145	.016	<.001
Post-survey - 13 item self-control	.487	.146	.016	<.001
Self-control on First semester GPA				
Pre-survey - 10 item self-control	.206	.035	.007	<.001
Pre-survey - 13 item self-control	.213	.030	.006	<.001
Post-survey - 10 item self-control	.338	.046	.006	<.001
Post-survey - 13 item self-control	.338	.037	.005	<.001
Correlation				
Residual error of ACT English with residual error of ACT Reading				
Pre-survey - 10 item self-control	.394	3.824	.625	<.001
Pre-survey - 13 item self-control	.393	3.807	.624	<.001
Post-survey - 10 item self-control	.342	3.093	.633	<.001
Post-survey - 13 item self-control	.342	30.88	.633	<.001

Table 14

Structural Model Fit Statistics

	TLI	CFI	RMSEA [95% CI]	χ^2 (13)
Pre-survey				
10 item self-control	.893	.934	.112 [.088, .137]	76.398
13 item self-control	.896	.936	.110 [.087 - .135]	74.625
Post-survey				
10 item self-control	.884	.928	.121 [.095 - .148]	76.157
13 item self-control	.889	.931	.118 [.092 - .145]	73.073

Appendix G. Post Hoc Analyses

After the Step-outs to Stars Engineering Framework was created, analysis was performed to determine if the interest level of the students in each quadrant had significantly changed from the pre-survey to the post-survey. Figures 10 to 13 display the frequency histograms for the variable INTEREST (the response to the question on interest in engineering). Since INTEREST was treated as a categorical variable the chi-square goodness-of-fit test was used to determine if there was a significant change in the distribution of responses. Equation 3 was used to calculate the chi-square value.

$$\sum \frac{(\text{INTEREST(post)} - \text{INTEREST(pre)})^2}{\text{INTEREST(pre)}} \qquad (3)$$

The analysis showed a significant negative change in interest for the Step-outs, $\chi^2(3) = 429.27$, $p < .001$, and the Searchers, $\chi^2(3) = 59.96$, $p < .001$, and a significant positive change in interest for the Stars, $\chi^2(3) = 12.12$, $p = .007$. The data did not show a significant change in interest for the Strugglers, $\chi^2(3) = 4.33$, $p = .228$. When the chi-square statistic was calculated for the Step-outs the *Very low* and *Low* responses were combined because there were no response of *Very low* on the pre-survey, but there were some on the post-survey. Combining these two categories prevented a zero in the denominator. Figures 10 through 13 show the frequency histograms for the INTEREST variable for students in each quadrant.
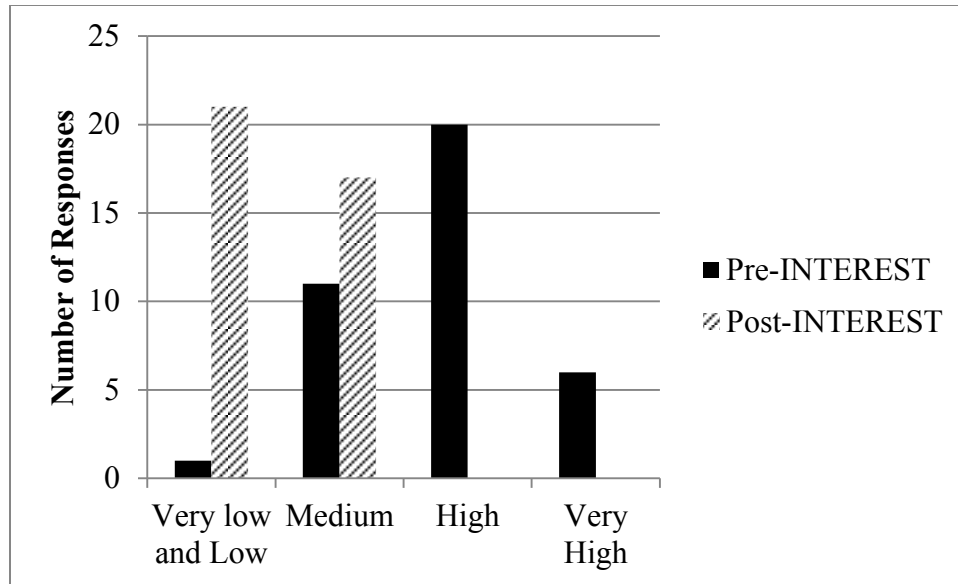
Figure 10. Interest responses for the Step-outs from the pre- and post-surveys (*n* = 38)
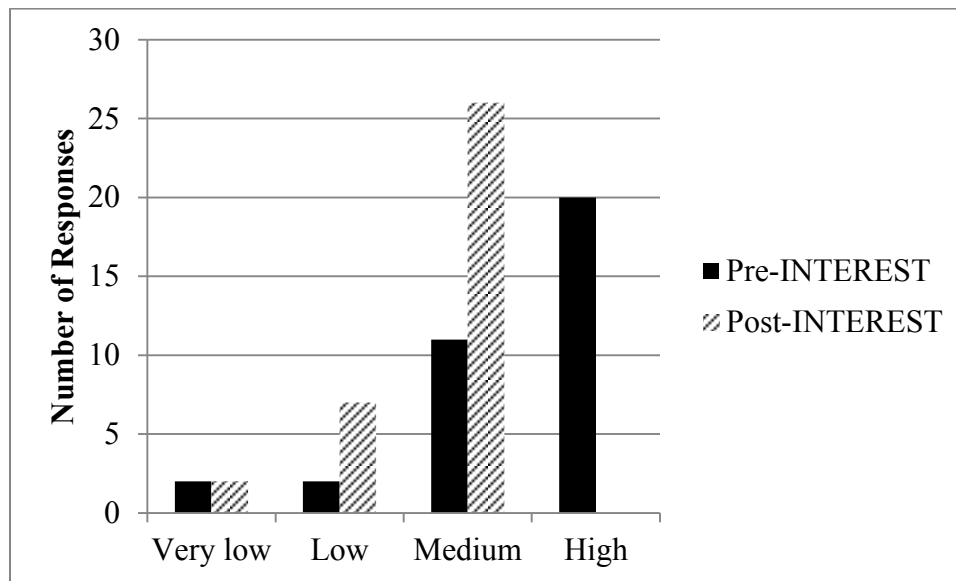

Figure 11. Interest responses for the Searchers from the pre- and post-surveys (*n* = 36)
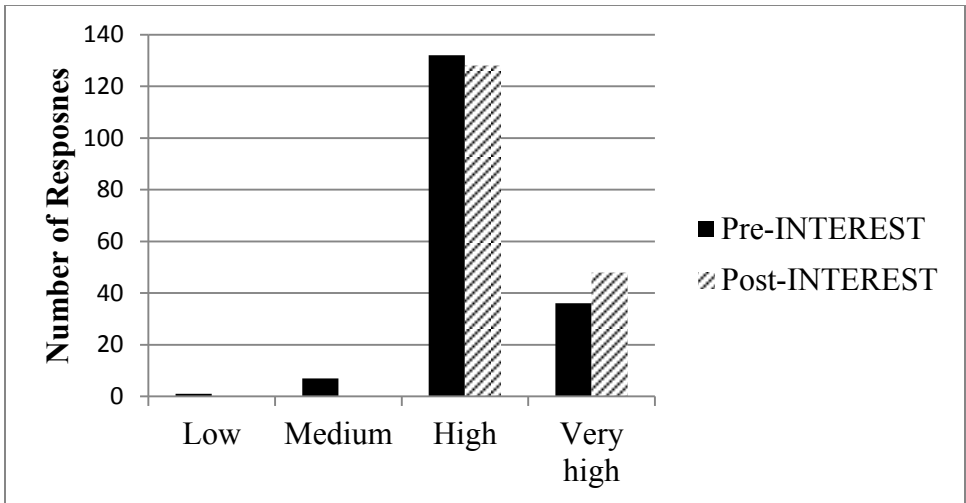
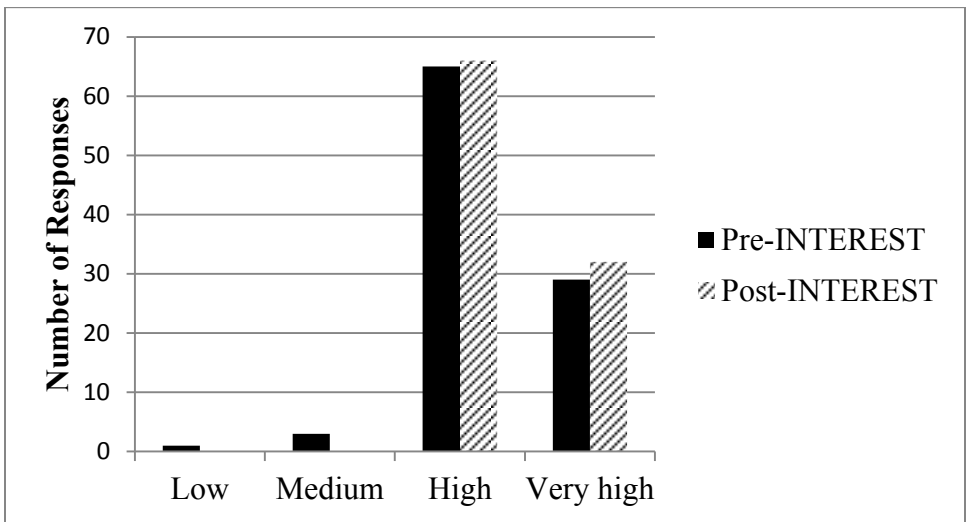*Figure 12*. Interest responses for the Stars from the pre- and post-surveys (*n* = 176)

Figure 13. Interest responses for the Strugglers from the pre- and post-surveys (*n* = 102)

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PUBLICATIONS

Peer Reviewed
Honken, N. & Ralston, P. (2013). Freshman engineering retention: A holistic look.
 Journal of STEM Education: Innovations and Research 14(2), 29-37.

Honken, N. B., & Ralston, P. A. S. (2013). High-achieving high school students and not
 so high achieving college students: A look at lack of self-control, academic ability
 and performance in college. *Journal of Advanced Academics, 24*(2), 108-124.

Not Peer Reviewed
Honken, N & Shuck, B. (2012). *"*Networking for People Who Hate to Network: A Field
 Guide for Introverts, the Overwhelmed, and the Underconnected by Devora Zack"
 book review. *Human Resource Development Quarterly*, *22*(3), 277-280.
 doi:10.1002/hrdq.21150

PRESENTATIONS

Peer reviewed and published in proceedings

Honken, N. B., Synder, K. E. & Ralston, P. A. (accepted). *Exploring Engineering Students' Beliefs on Effort and Intelligence.* Paper submitted to the 2014 121th ASEE Annual Conference, Indianapolis, IN.

Honken, N. B., & Ralston, P. A. (accepted). *Informal Peer-Peer Collaboration, Performance, and Retention for First Semester Engineering Students.* Paper submitted to the 2014 121th ASEE Annual Conference, Indianapolis, IN.

Honken, N. B. (June 2013). *Dreyfus five-stage model of adult skills accusation applied to engineering lifelong learning.* Paper presented at the 2013 ASEE Annual Conference, Atlanta, GA.

Honken, N. B., & Ralston, P. (June 2013). *Do attitudes and behaviors towards homework and studying change between high school and engineering classes.* Paper presented at the 2013 ASEE National Conference, Atlanta, GA.

Not peer reviewed

Honken, N. (2012) *Prediction of first semester GPA in engineering students using self-control and academic ability.* 2012 Spring Research Conference, University of Louisville, Louisville, KY.

TEACHING EXPERIENCE

University of Louisville: Introduction to Engineering, 2013 (Designed and taught fall 2013)

University of Louisville: Engineering Management, 2013 (Designed and taught 1/3 of course)

University of Louisville: Human Resource Management, 2013 (Designed 6 week online course)

Mesa Community College: Introduction to Quality, Mesa Community College, 1996 (Designed and taught)

In industry: Statistics for Engineers, 9000 ISO, Quality, Inventory Control, Manufacturing Lead Training (Designed and/or taught)

INDUSTRY EXPERIENCE

University of Louisville – Louisville, Kentucky
Research Assistant, Teaching Assistant, **J. B. Speed School of Engineering** – Designed and taught two sections of Introduction to Engineering to transfer and nontraditional students. Performed research on retention and performance of first-year engineering students. Wrote multiple article and conference papers. Assisted Engineering Fundamentals Department Chair in starting a cross-disciplinary research team including faculty from brain sciences and educational psychology.
Graduate Assistant, **Research Office College of Education and Human Development** – Assisted the Dean of Research on various projects. Chaired student research conference for University of Louisville, University of Kentucky and University of Cincinnati students. Worked on updating Graduate Student Handbook.

Axxess Technologies – Tempe, Arizona
Director of Quality - Managed the following departments: Incoming and Supplier Quality, Reliability Testing, Failure Analysis, Software Test and Control, Documentation, and Field Quality Reporting.
Implemented and/or refined quality systems as company grew from $17 to $82 million in sales (150 to 500 employees). Systems included quality reporting, documentation control, failure analysis reporting, engineering change control, field failure tracking, software change control and release, calibration. Created a collaborative climate by opened communications between sales, marketing, manufacturing, purchasing, field service and quality by hosting product line meetings. Set priorities on quality improvement efforts using data from quality tracking systems. Assisted in new product introduction as needed. Performed analysis and experiments as needed.

Varian Tempe Electronics Center – Tempe Arizona
Quality Engineer, Manufacturing Engineer - Responsible for implementing systems and improving quality.
Designed and implemented PPM (parts per million) system to facilitate quality improvement. Implemented a quality system, including SPC in the first high volume area. Experienced real improvements in quality on a variety of product lines by using quality data and working with factory workers to solve root causes of problems. Improved designs for manufacturability by opening communications between design and assembly. Conducted team training. Used team approach to relayout plant for a 50,000 sq. ft. expansion. Assisted in the Malcolm Baldridge National Quality Award Finalist site visit. Designed and implemented a radio frequency barcode system to reduce errors in the stockroom.

Honeywell Industrial Automated Controls **- Phoenix, AZ**
Honeywell - Arizona State University Industrial Fellow Designed and team-taught statistical techniques class to engineers. Wrote ISO 9001 department practices and divisional procedures for quality manual. Taught ISO 9001 classes. Performed statistical analysis on performance factors to determine effects on quality of service in the Technical Assistance Center. Wrote a white paper on future direction of technical customer support for third-party software.

Amoco Performance Products - Greenville, SC.
Production Supervisor - Responsible for supervising, training and evaluating production crew manufacturing carbon fibers.
While a supervisor, the department reduced scrap by 50% resulting in a savings of $1.8 million/year, reduced setup time by 26% resulting in a savings of $175,000/year and reduced downtime by 55% resulting in a savings of $450,000/year. Additional responsibilities included teaching Statistical Process Control and being a member of the Emergency Response Team.

Corning Incorporated - Greencastle, PA.
Industrial Engineer - Responsible for performing Industrial Engineering functions to support the shipping department.
Lead a team that designed and taught an inventory training class. Reduced costs through new line setups. Implemented a new system resulting in the elimination of 200 obsolete stock-keeping units in 8 months. Coordinated cross-functional implementation of a new pallet. Utilized SAS to determine optimal pick locations of finished product. Developed shipping department productivity measurement system. Improved area layouts. Additional responsibilities included coordinating the cost reduction program for the entire facility, facilitating the shipping department quality circle, overseeing the process management system and participating on the Inventory Corrective Action Team, Safety Committee and Ergonomics Team.

SERVICE TO THE PROFESSION

Louisville Leadership Team, Kentucky Girls STEM Collaborative (currently)
Chairperson 2012 Spring Research Conference (student research conference)
> College of Education and Human Development, University of Louisville.
> (2012)
Member, Research and Faculty Development Grant Committee (2011-2012)
Speaker, E-Discovery Day, East Oldham Middle School (2013)
Judge, E-Expo, University of Louisville (2013)

AWARDS

Fellow for 2012 National Data Institute on the datasets of the National Center for
  Education   Statistic (NCES) and the National Science Foundation (NSF)
University of Louisville Strategic Plan Tuition Award (2012-2013)
Arizona State University Industrial Fellowship
Virginia Polytechnic Institute and State University
    First place Institute of Industrial Engineer Local Student Technical Paper Contest
    Alpha Pi Mu, Industrial Engineering Honor Society
    Who's Who in American Universities and Colleges
    Outstanding Junior in Industrial Engineering
Certificate of Recognition from the President of Honeywell's Industrial Division for
work
    done for ISO 9001 certification
Honeywell Spot award for work done on ISO 9001
Corning Corrective Action Request of the Quarter
Corning Corrective Action Team of the Year