DISSERTATION

PRE-COLLEGIATE FACTORS INFLUENCING THE SELF-EFFICACY OF FIRST-YEAR COLLEGE ENGINEERING STUDENTS

Submitted by:

Todd Donovan Fantz

School of Education

In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Spring 2009

UMI Number: 3374645

INFORMATION TO USERS

COLORADO STATE UNIVERSITY

March 31, 2009

WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY TODD DONOVAN FANTZ ENTITLED PRE-COLLEGIATE FACTORS INFLUENCING THE SELF-EFFICACY OF FIRST-YEAR COLLEGE ENGINEERING STUDENTS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate work

James E. Folkestad, Ph.D

Wade O. Troxell, Ph.D

Michael A. De Miranda, Ph.D, Advisor:

Thomas J. Siller, Ph.D, Co-Advisor:

Timothy G. Davies, Ph.D., Director, School of Education

ABSTRACT OF DISSERTATION

PRE-COLLEGIATE FACTORS INFLUENCING THE SELF-EFFICACY OF FIRST-YEAR COLLEGE ENGINEERING STUDENTS

High attrition rates in engineering schools and a decrease in the number of students pursuing engineering degrees has led to concerns of a shortage of engineering trained professionals. A shortage would threaten national security, economic competitiveness, and social conditions in the United States. Outreach programs consisting of pre-engineering classes, multi-day engineering programs (camps), school-sponsored engineering extra-curricular programs, and single-day engineering workshops have been funded and designed to recruit and prepare K-12 students to study engineering in college.

The purpose of this study was to determine the effectiveness of pre-collegiate engineering outreach programs to recruit and prepare future engineering students. Data was collected from 332 first-year engineering students at one university. Students were asked to list and rate their personal engineering experiences and influences to study engineering and their self-efficacy in their engineering courses. Correlation analysis was used to explore linear relationships among demographic factors, pre-collegiate exposure to engineering content, and engineering self-efficacy. Effectiveness of formal and informal pre-collegiate outreach programs and differences between demographic characteristics were examined through regression, ANOVA, and t-test analysis.

Results from this research indicate experiences from technology and pre-collegiate engineering programs are a significant source of motivation for students to study engineering. Exposure to engineering content during the pre-collegiate years was also shown to have a positive effect on the students' engineering self-efficacy. In particular, students with formal K-12 technology and pre-engineering coursework had higher self-efficacy scores than those who did not. In addition, students who had hobbies involving computers and programming showed higher self-efficacy scores than the students who did not. Males were found to have statistically significant higher engineering self-efficacy and significantly greater number of pre-collegiate engineering experiences than females.

This research adds to the breadth of knowledge about pre-collegiate engineering and technology outreach programs. The data and research findings in this study can inform engineering educators in assessing the effectiveness of pre-collegiate engineering outreach programs to recruit students into engineering programs and prepare them for success.

Todd Donovan Fantz
School of Education
Colorado State University
Fort Collins, CO 80523
Spring 2009

ACKNOWLEDGEMENT

The dissertation process would be difficult, if not impossible, to accomplish on one's own. I would like to thank the individuals that were most helpful with my dissertation journey and doctoral degree.

I could have never completed this without the support of my advisors. Dr. Michael DeMiranda provided me with the guidance and insight needed to survive the process. From the time I set foot on the campus until graduation, he has been instrumental in my success at Colorado State University. I would also like to acknowledge my co-advisor, Dr. Tom Siller, for providing valuable engineering insight to a very education-based study. Our weekly meetings were a source of learning and motivation.

I would like to acknowledge Dr. Carole Makela for her assistance throughout the proposal and instrument development process. She provided clarity to and direction for my writing. The members of my dissertation committee, Dr. James Folkestad and Dr. Wade Troxell, were instrumental in providing insight, guidance, and expertise.

My gratitude also goes out to my family, whose support has allowed me to explore avenues of interest instead of income. My parents have shown me the value of education and have given me the foundation on which to build. My daughter Maggie unknowingly sacrificed daddy time and provided an inspiration that I didn't know was possible. And last but by no means least, I would like to thank my wife and partner, Erin Jordan. She was my staunchest supporter throughout the process. It was her love, patience, and sense of humor that enabled me to see this process through to the end.

DEDICATION

To Erin, the love of my life, who had to sacrifice so much for me to pursue my dreams. I couldn't have done it without you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Introduction

Recent interest in engineering education can be attributed to the declining number of high school graduates pursuing science, technology, engineering, and mathematics (STEM) careers and a growing need for engineering professionals (Noeth, Cruce, & Harmston, 2003). Compounding this concern, less than half the freshmen who start in an engineering major will finish with an engineering degree, and at least half of students who do not persist leave the program during their freshman year (Besterfield-Sacre, Atman, & Shuman, 1997). Additionally, there is an underrepresentation of female, African American, Hispanic, and Native American students in U.S. engineering programs (French, Immekus, & Oakes, 2005).

The potential shortage of engineers in the U.S. has gained much attention since the year 2000. Participants of the National Academy of Sciences and the National Academy of Engineering are concerned about social and economic conditions in the U.S. rapidly declining if the nation's ability to perform in science and engineering weakens (Committee on Science, Engineering, and Public Policy, 2007). The National Science Board warned of a U.S. science and engineering workforce jeopardized from global competition and a shortage of scientific and engineering trained professionals (National Science Board, 2003).

To help prevent an engineering shortage, K-12 education has increased efforts to include engineering in the curriculum. Individuals involved believed their efforts would increase the number of students choosing to pursue engineering and provide the skills necessary to succeed in a college engineering program (Brophy, Klein, Portsmore, &

Rogers, 2008). Work has been done to develop and establish classroom and online materials, outreach programs, professional development programs, engineering contests, activities at school, engineering standards and classes, and service learning programs in both formal and informal settings (Jeffers, Safferman, & Safferman, 2004). As a result, engineering exposure in K-12 classrooms has increased from the year 2000.

Another method used to increase the number of U.S. engineers is to understand the high attrition rate in college and add measures to address retention. Several attempts have been made to understand the high attrition rate of college engineering students and to identify factors common to students who persist (Astin, 1971; Levin & Wyckoff, 1990; Mendez, Buskirk, Lohr, & Haag, 2008; Reys, Anderson-Rowland, & McCartney, 1999; Zhang, Anderson, Ohland, Carter, & Thorndyke, 2004). Some significant factors predicting persistence among engineering students included high school grade point average (GPA), Scholastic Aptitude Test (SAT) math and verbal scores, number of math and science courses taken in high school, and sex.

There have also been several studies showing a positive link between self-efficacy and persistence among engineering students (Brainard, Laurich-McIntyre, & Carlin, 1995; Multon, Brown, & Lent, 1991; Sandler, 2000; Sax, 1994). According to Bandura (1986, 1997), self-efficacy beliefs are developed and modified through four main sources: personal performance accomplishments, observation of other people's performance attainments, social persuasion from significant others, and physiological states and reactions.

While much is known about the positive effects of high self-efficacy and general sources of it, little research has been done with regard to how students develop their self-efficacy beliefs through the four defined sources in the subject of engineering. In particular for this study, research is needed to determine how engineering integrated into the K-12 curriculum and related activities and opportunities available to youth affects the development of self-efficacy beliefs. Brophy, Klein, Portsmore, and Rogers (2008) expressed the need:

> With regard to issues of efficacy and impact, P-12 engineering education programs need to conduct research on the extent to which they are reaching all students with respect to acquiring content and skills for problem solving, and in developing a sense of self as a learner and as a potential STEM professional. Are these programs truly developing new and diverse talent interested in pursuing engineering? Or are these programs simply capturing the hearts and minds of students already interested in pursuing STEM learning tied to other influencing factors (role models, parents, enrichment programs, hobbies)? More needs to be understood about how such programs provide for the inclusion of all students with participation in genuine engineering experiences that create opportunities and support for development of an interest in STEM related careers. (pp. 380-381)

Efforts have been made to prevent a shortage of engineers in the U.S. These efforts are aimed at increasing the number of students choosing to pursue engineering, providing students with the skills needed to succeed in engineering programs, and providing underrepresented groups the opportunities to explore engineering. However, research is needed to determine if the efforts are meeting the desired goals.

Purpose of the Study

The purpose of this study was to add to our understanding of how self-efficacy beliefs of engineering students may be developed during their pre-collegiate years. In particular, this study examined self-efficacy development through exposure to engineering content from K-12 coursework, after-school programs, work experience, field trips, toys and hobbies, summer programs, and relationships that influenced the choice to study engineering. The information gained from this study will assist in recruiting and retaining engineering students by evaluating the effectiveness of current pre-collegiate engineering programs, student self-efficacy, identifying the existing demographic discrepancies (e.g., sex, ethnicity, engineering program, etc.), and providing guidance when determining college engineering admission.

Statement of Problem

Concerns of an impending shortage of trained engineering professionals stem from recent trends in decreasing engineering enrollment, high attrition rates at engineering schools, and large growth in technology (Noeth, Cruce, & Harmston, 2003; Besterfield-Sacre, Atman, & Shuman, 1997; Shuman et al, 1999; Zhang et al, 2004). The literature suggests that engineers are critical to the United States' economic success and national security (Committee on Science, Engineering, and Public Policy, 2007; Popper & Wagner, 2002; National Science Board, 2003; Committee on Science, 2007). In responding to these concerns, research regarding engineering students' success and persistence and K-12 pre-engineering outreach programs has gained attention and funding. Two common goals among K-12 pre-engineering programs and engineering outreach programs are to motivate students to pursue engineering in college and provide knowledge and skills to help the students succeed once they get there. Little research has been done on the effectiveness of the K-12 pre-engineering programs and engineering outreach programs in meeting their long-term goals.

Research Questions

The purpose of this study was to gain knowledge about factors that affect the self-efficacy of engineering students at Colorado State University (CSU). In particular, the variables of pre-collegiate exposure to engineering content, influencing factors to study engineering, and demographics were assessed for relationships to self-efficacy of CSU first-year engineering students. The following research questions guided this research:

1. What are the primary influences for students at Colorado State University to study engineering?
2. How efficacious are first-year engineering students toward their engineering coursework at Colorado State University?
3. What is the relationship between exposure to engineering content before entering college and first-year engineering students' engineering self-efficacy?
4. Are some types of engineering exposure (e.g., class, field trip, summer camp, etc.) associated with higher self-efficacy than others?
5. What effect do the primary influences for major and career decisions have on a first-year engineering students' engineering self-efficacy?
6. Are there differences among first-year engineering students' engineering self-efficacy related to demographics (e.g., age, sex, residency, ethnicity, engineering program)?

Significance of the Study

This study is significant because the results can be used to examine the effectiveness of pre-collegiate engineering programs and exposure to engineering content in developing engineering self-efficacy. Pre-collegiate programs that are effective in developing engineering self-efficacy should be recognized and modeled. Non-effective programs and events should be examined and terminated or improved. Demographic knowledge gained from this study can be used to identify what pre-collegiate programs assist underrepresented groups in developing engineering self-efficacy. This information can be used by pre-collegiate programs to identify students who would most benefit from participating.

Further, the results from this study can provide persons in charge of admission into the College of Engineering at CSU variables that can be used to help predict an applicant's engineering self-efficacy and persistence. Accurately determining admission based on desire and ability of a student should lessen the current high attrition rate of engineering students.

Limitations and Delimitations

This study was conducted with a sample consisting solely of first-year engineering students at Colorado State University during the 2008-2009 academic school year. Therefore, this study is limited in its ability to generalize results to engineering students at other colleges and universities or students who may transfer into engineering at CSU.

Data were collected through questionnaires administered to engineering students at Colorado State University. The completion of the questionnaire was voluntary and did not include the entire population of engineering students. Any inferences to the population of engineering students at Colorado State University are limited due to the lack of a random sample.

Assumptions

This study examined the relationship between self-efficacy and pre-collegiate engineering exposure. It was assumed that the students' self-efficacy beliefs were not significantly altered by the experiences from the beginning of the 2008 fall semester until the questionnaire was given. It was also assumed the students answered the questionnaires truthfully and to the best of their ability.

Definition of Terms

To provide a common basis for interpreting and understanding, the following definitions of terms used in this study are included.

ABET: Accreditation Board for Engineering and Technology, Inc. A federation of engineering and technological societies with a goal of promoting and advancing engineering, technology, and applied science education.

CSU: Colorado State University. A land-grant institution located in Fort Collins, Colorado. It was founded in 1870 with about 25,000 students.

Engineering content: Subject matter requiring the application of scientific and technical knowledge to the design, analysis, or construction of an artifact.

First-year engineering students: Students who have not completed any collegiate engineering coursework, but are enrolled in engineering courses. This group includes students in their first year of college after high school, non-traditional students, transfer students from other colleges within Colorado State University, and transfer students from other colleges and universities provided they did not take engineering coursework.

GPA: Grade point average. The calculated mean of a student's high school or college grades for a given time period

IRB: Institutional Review Board. A committee responsible for reviewing research projects for protection of human subjects.

Leavers: A term used in previous research to indicate students who either dropped out of college or switched out of a program of study.

MSLQ: Motivated Strategies for Learning Questionnaire. An instrument designed to measure motivation and learning strategies for college students.

NSF: National Science Foundation. An independent federal agency concerned with promoting engineering science at the Kindergarten to12th grade level and higher-education.

Persistence: Refers to a student's continued enrollment in a college program.

Pre-collegiate exposure: Any content received or experienced before the first day of classes of the students' first year of enrollment in an engineering program.

SAT: Scholastic Aptitude Test. A common normal referenced aptitude exam taken by high school students applying to college.

Stayers: A term used in previous research to indicate student persistence to graduation; earning a degree.

Self-efficacy: The degree in which a people believe they can perform a certain task or attain certain goals.

SME: Science, mathematics, and engineering.

STEM: Science, technology, engineering, and mathematics.

Researcher's Perspective

As with any research, the perspective of the researcher is important. The following is the researcher's story as it pertains to this research project. He was not exposed to engineering in any way, shape, or form until deciding to try a class during his junior year while attending college. The researcher's perceived self-efficacy toward engineering and subsequent grades were very low. While he persisted to obtain a degree in civil engineering four years later, the struggle was the hardest he had ever faced. The desire to conduct this research resulted from a retrospective examination of his experience versus that of his peers in engineering. Some students had a confidence level (self-efficacy) he was unable to obtain. These students were familiar with the terminology, knew what a career in engineering would be like, and had a sense of belonging to the engineering world. Many had parents or other family members who were engineers. Some had spent time in the construction industry working side by side with engineers in the field. Were these past experiences related to their self-efficacy in engineering? After being involved in an engineering outreach program for middle and high school students, the researcher questioned whether or not the students believe more in their own abilities if and when they enter a college engineering program due to participating in the program. These questions and concerns were the driving force behind this study.

Organization of the Study

This study is organized into five chapters. Chapter one presents an introduction, the purpose of the study, statement of the problem, research questions, significance, the limitations and delimitations, assumptions of the study, definitions of terms, and organization. Chapter two describes the review of literature surrounding college freshman engineering persistence, self-efficacy, K-12 engineering education, underrepresented populations in engineering programs, and persons influencing college engineering students. Chapter three describes the methodology of the study through an explanation of the research design, participants and site, the conceptual framework, instrumentation, analysis of study validity and reliability, data collection procedures, and data analysis. The results of the data analysis are described in Chapter four. To conclude, Chapter five focuses on an overall summary of the data analysis with conclusions, implications for the field of engineering education, and recommendations for further research

CHAPTER 2: LITERATURE REVIEW

Importance of United States Engineers

Since the Industrial Revolution, economic prosperity in the U.S. can be largely attributed to engineering endeavors (Committee on Science, Engineering, and Public Policy, 2007). Almost every aspect of life today can be credited to the investment in scientific research and engineering. Evidence of prosperity from this investment can be seen in the areas of transportation, communication, agriculture, education, health, defense, and jobs (Popper & Wagner, 2002). Since the early 1900s, the U.S. has been considered by countries around the world to be the leader of science and engineering activities. With only 5% of the world's population, the U.S. has about 30% of the world's scientists and engineers, accounts for 40% of the world's research and development spending, publishes 35% of the engineering and scientific articles, and houses 17 of the world's top 20 universities (Freeman, 2005).

Over the past two decades, the world has witnessed large growth in global competitiveness. The growth threatens the dominance of the U.S. in science and engineering. In a paper provided to the National Bureau of Economic Research, Freeman (2005) gave four examples that showed how the changes in the global job market are undermining U.S. dominance in engineering and science. He stated the following:

1. Of the world's science and engineering graduates, the percentage representing the United States has decreased at every degree level. This is due, in part, to an unchanging number of U.S. graduates and rapidly increasing college enrollments in other countries.

2. The job market for U.S. scientists and engineers has deteriorated compared to other high-level occupations. Additionally, rewards are large enough to attract immigrants to study in the U.S.
3. Due to the increase of scientists and engineers in large population, low-income countries, such as China and India, the traditional pattern of trade in which more advanced countries specialize in high-tech and less advanced in manufacturing is threatened.
4. Without a high-tech advantage in the U.S., more jobs will be outsourced to other countries, research and development facilities will relocate to developing countries, and there will be limited growth in high-tech productions and exports (pp. 2-3).

A supply of engineers capable of keeping pace with the growth in technology is needed for the U.S. to remain competitive in the world market and nationally secure. The changing global market requires the U.S. to not only produce enough engineers, but produce the quality of engineer needed to be worldwide leaders in the industry.

Declining Number of United States Engineers

A projected shortage of U.S. trained engineers has gained much attention from corporate, government, national scientific, and technical leaders over the past five years. In 2003, The National Science Board warned that the U.S. science and engineering workforce was in jeopardy from global competition and a shortage of scientific and engineering trained professionals. This sentiment was echoed by participants of the National Academy of Sciences and the National Academy of Engineering when they stated concerns about social and economic conditions in the United States rapidly declining if the nation's ability to perform science and engineering weakens (Committee on Science, 2007).

Those concerned about a potential shortage of U.S. trained engineers identified the declining number of high school graduates pursuing engineering degrees and a growing need for engineering professionals as evidence (Noeth, Cruce, & Harmston, 2003). A twelve year comprehensive study (1991-2002) of data from over 750,000 ACT tests demonstrates the decrease in the percentage of students who chose to study engineering (Noeth, Cruce, & Harmston, 2003). Figure 1 provides a re-creation of the graph with the data from the study. Further, less than half the freshmen who begin with an engineering major will finish with an engineering degree, and at least half of students who do not persist leave the program during their freshman year (Besterfield-Sacre, Atman, & Shuman, 1997). Additionally, there is an underrepresentation of female, African American, Hispanic, and Native American students in U.S. engineering programs (French, Immekus, & Oakes, 2005).

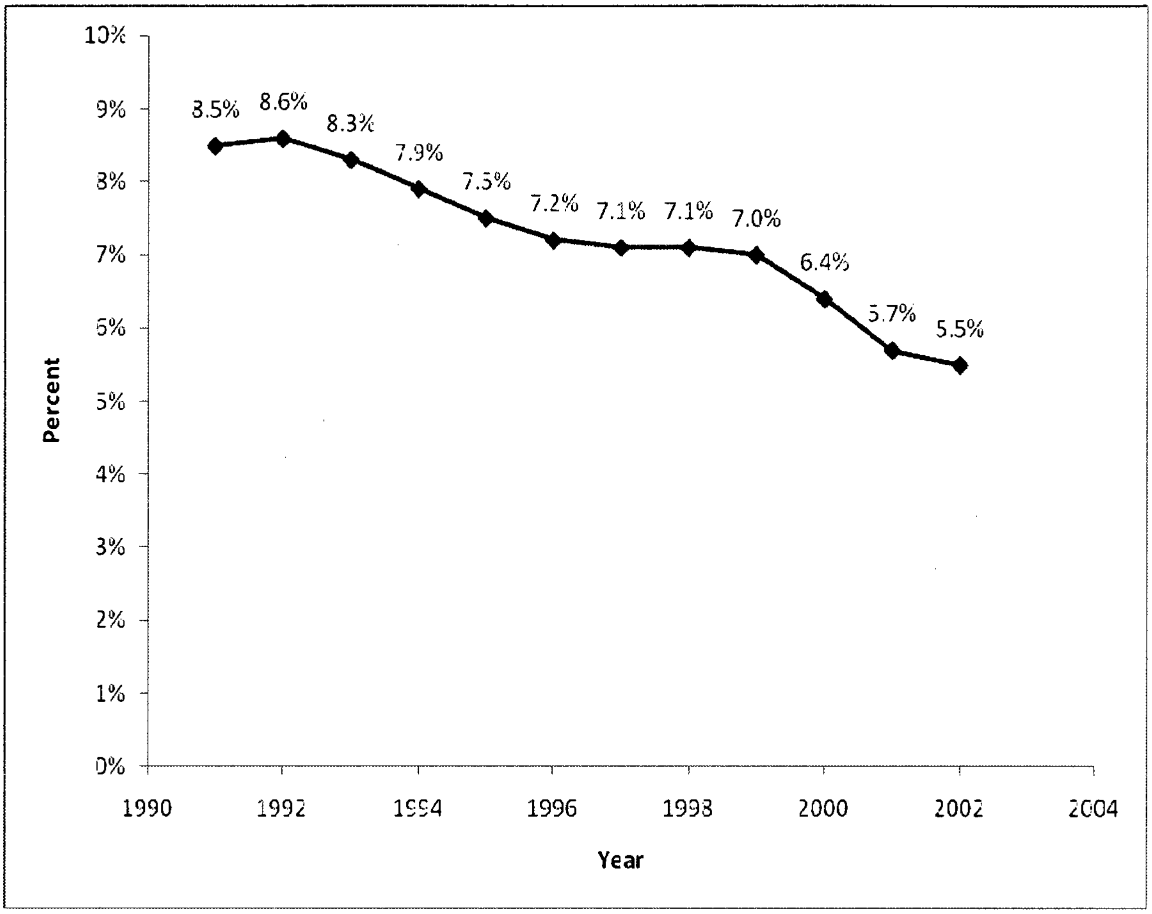

Figure 1. Percentages of ACT participants choosing to pursue engineering in college

Attrition in Engineering Schools and Colleges

In the engineering sciences, there is an exceptionally high attrition rate. Of the students who begin studying engineering, only 25 to 50 percent finish with an earned engineering degree (Shuman et al, 1999; Zhang et al, 2004). To determine methods to decrease the high attrition, researchers have studied reasons why students leave engineering. One such study involves students leaving engineering at the University of Pittsburgh (Shuman, Delaney, Wolfe, Scalise, & Besterfield-Sacre, 1999). The researchers created a survey containing open-ended questions for students to identify reasons they chose to leave engineering. The instrument was administered by academic advisors to every student who transferred out of the engineering program over a seven-year period. The reasons were analyzed by grouping responses based on common themes. The two most common themes from the participants (n = 115) were the loss of interest in engineering (72%) and developing a dislike for the subject (66%). The number of students claiming these reasons exceeded those leaving due to academic problems (25%). The authors argue that less focus should be placed on academic support and more on a change in structure and culture within engineering programs to decrease the high attrition rate.

In a study of 335 students over a three-year period involving seven four-year institutions, Seymour & Hewitt (1997) examined attrition of male versus female students in different science, mathematics, and engineering (SME) majors. One aspect of their study involved the reasons the students chose to leave SME majors. The researchers found about one-third of students who switched out of a SME major decided to pursue a career outside of SME. The most common factor in the decision to switch majors was "lack of/loss of interest in SME" (43%). The next most common factor was "non-SME major offers better education/more interest" (40%). In particular, a desire to teach at the K-12 level was commonly stated. Participants pursued teaching despite negative feedback from faculty, friends, and peers and lower material rewards associated with the decision. The results agree with the University of Pittsburgh study that academic problems are not the primary reason students leave engineering. This is contrary to the common assumption that students switch out of engineering due to an inability to handle the academic challenge.

Studies have also been conducted to determine how to decrease the high attrition associated with engineering programs. A study of the retention of minority and non-minority students was conducted by the National Action Council for Minorities in Engineering, Inc. (NACME). After interviewing administrators at institutions with the lowest dropout rate in the country, they recommended six key actions to lesson attrition. They included the following:

1. Exhibit strong institutional commitment as measured by attitudes of faculty and staff, integral minority engineering programs, and allocation of resources
2. Remove barriers to student success
3. Involve the corporate community
4. Precollege development of potential engineering students
5. Offer/sponsor summer bridge programs
6. Attend to early success of first-year students. (Morrison, Griffin, & Marcotullio, 1995)

Institutions interested in decreasing attrition in their engineering programs were advised to follow the six key actions that were successful at other institutions. However, the study did not account for additional factors contributing to student drop-out such as admission requirements or school location.

Factors That Predict Persistence and Success in Engineering Programs

Predictor Variables

Extensive research has been conducted to examine why some students persist in engineering and others do not. Much of the research is focused on predicting factors for incoming engineering students. One of the first studies of this nature was by Astin in 1971. After examining 36,581 students, he concluded that the high school academic record was the best indicator of future performance in college (Astin, 1971).

In 1990, Levin and Wyckoff developed three models to predict success and persistence in engineering programs. The independent variables in the models included high school GPA, SAT math, SAT verbal, algebra score, engineering foundation GPA (calculus I and II, physics I and II, and chemistry I), calculus I and II grades, physics I and II grades, chemistry I grade, gender, attitude towards high school math, attitude toward high school physics, attitude toward high school chemistry, college study hours, non-science points (consistency of major choices), reason for engineering choice (a dichotomous variable with either genuine (intrinsic) or superficial (extrinsic) reasons), certainty, and knowledge of intended major. After entering the data of 1,043 freshmen into the models and tracking them for two years, they found the pre-enrollment factors that best predicted success were high school GPA ($\chi^2 = 14.63$, $p < 0.0001$), algebra score ($\chi^2 = 10.97$, $p = 0.0009$), gender ($\chi^2 = 10.07$, $p = 0.0015$), non-science points ($\chi^2 = 8.85$, $p = 0.0029$), chemistry score ($\chi^2 = 6.82$, $p = 0.009$), and reasons for choosing engineering ($\chi^2 = 5.93$, $p = 0.0149$) (Levin & Wyckoff, 1990).

One of the most comprehensive studies of factors that predict engineering graduation and retention was conducted in 1994 by Zhang, Anderson, Ohland, Carter, and Thorndyke. The researchers examined data that spanned 10 years and included 9 universities. This data included 39,277 students enrolled for at least one semester in one of the nine universities. The six predictor variables of ethnicity, sex, high school GPA, SAT math score, SAT verbal score, and citizenship status were used to determine a multiple logistic regression model of persistence. Similar to previous studies, the results indicated that high school GPA and math SAT scores were the strongest predictors of both academic success as defined by graduation from the institution and retention (Zhang et al., 2004). The Wald chi-squared statistics (χ^2) and associated p-values were reported individually for the nine universities. Each university's data resulted in a statistically significant high school GPA with χ^2 values ranging from 21.82 ($p < 0.0001$) to 533.22 ($p < 0.0001$). Similarly, each university had statistically significant SAT math scores with χ^2 values ranging from 4.97 ($p = 0.02$) to 217.98 ($p < 0.0001$). Findings indicate the probability that high school GPA and SAT math scores do not predict retention is less than 0.01%.

Most recently, a group of researchers used the method of Classification Trees and Random Forests to determine predicting persistence variables for science and engineering majors at Arizona State University. Factors in this studies include gender, ethnicity, citizenship, high school GPA, SAT scores, living on campus, student work, scholarships, loans, athletics, state of residency, first-time freshman, freshman-year calculus, number of STEM courses, total credit hours enrolled, cumulative college GPA, and age. While it was a different analysis method, the results were similar to previous studies. The researchers found that high school GPAs and quantitative SAT scores are most likely to influence persistence (Mendez, Buskirk, Lohr, & Haag, 2008). In particular, engineering students with a high school GPA of 3.5 or greater were almost five times more likely to persist than engineering students with a high school GPA of 2.5. The odds of persistence were also shown to increase by a factor of $1.051 = (1.005)^{10}$ for every ten point increase in quantitative SAT score. The number of science and engineering courses taken the freshman year was also found to be an important indicator of success.

Student Attitudes

Another method in determining persistence and success is by examining student attitudes toward engineering. In a study of 417 students over a three year period at the University of Pittsburgh, researchers compared students in three groups; students in good academic standing who left engineering, students who stayed in engineering, and students in poor academic standing who left engineering (Besterfield-Sacre, Atman, & Shuman, 1997). The researchers found statistically significant differences between the attitudes of the students who left engineering in good academic standing and the other two comparison groups. They concluded that success and retention are not only related to academic ability, but also to the attitudes of the students toward engineering, predominantly in the freshman year. Of particular interest to the current study, the between-group students differed in their self-perceived ability to succeed (self-efficacy) in engineering. The self-perceived ability was comprised of questions about confidence in chemistry, communication skills, basic engineering knowledge and skills, and engineering skills.

A similar study was done in Georgia at Mercer University. Analysis of university data revealed that GPAs and SAT scores, while predictors of persistence, only accounted for 25% of why students do not persist (Burtner, 2004). Through a survey of 116 first-year engineering students in fall, 2000, Burtner measured the students' attitudes and self-assessment in the area of engineering. Thirteen attitudes and beliefs were obtained from the students through the use of the Pittsburgh Freshman Engineering Attitudes Survey

(PFEAS). The students were tracked one year and categorized as "stayers" if they remained for two years, "leaverF" if they left before the end of the first year, and "leaverSJ" if they left before the two year period. The three levels of persistence were compared by a series of ANOVA one-way analyses. A Bonferroni adjusted α of 0.005 was used to lessen the chances of a Type I errors. The analysis led to the conclusion that significant differences exist between stayers' and leavers' attitudes. Specifically, there were differences in confidence of study habits ($F(2, 133) = 5.56, p = 0.05$) and general impressions of engineering ($F(2, 113) = 13.81, p < 0.000$). Students who had statistically significant lower confidence in their study habits and general impressions of engineering did not persist with the engineering program beyond the first or second year. The results did not show a statistical significant difference between the groups with respect to parental influence to study engineering ($p = 0.202$).

In a study of Rowan University's College of Engineering (located in Glassboro, NJ), Hartman & Hartman (2006) compared students who left engineering (leavers) to those who persisted (stayers). Their findings contradicted that of the study done at the University of Pittsburgh and Mercer University. Hartman and Hartman found no statistically significant difference between stayers and leavers in self-confidence in engineering academic ability. They also did not find a difference between stayers and leavers in terms of parental characteristics; siblings in science, engineering or math; support from significant others; perceived social usefulness of their degree; number of pre-collegiate science/mathematics activities; or their math SAT score. The researchers, however, did find differences in self-confidence in the ability to stick with engineering until graduation; involvement in engineering activities; and general versus specific declaration of an engineering major. One limitation of this study is the ability to make inferences based on the limited number of leavers (N = 33) involved with the survey. This could explain the contradictory self-confidence results when compared to previous studies.

Self-Efficacy

Definition and Background of Self-Efficacy

The concept of self-efficacy developed through social cognitive theory. The concept was first stated by Bandura (1977) in his publication "Self-Efficacy: Toward a Unifying Theory of Behavioral Change." Self-efficacy can be defined as "people's judgment of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). It is an individual's level of confidence in his/her ability to organize and implement actions needed to effectively perform the task at hand (Schunk, 1989). Since the introduction of self-efficacy in 1977, the concept has been used in a variety of fields. Some applications include analyzing self-efficacy with phobias, depression, social skills, assertiveness, smoking behavior, pain performance, and in educational research, primarily with academic motivation (Pajares, 1996).

According to Bandura (1977), efficacy perceptions are gained through four major informational sources:

1. Personal performance and accomplishments – one's patterns of past successes and failures
2. Vicarious learning - comparing oneself to the performance of others

3. Social persuasion - encouragement or discouragement one receives from significant others
4. Physiological states and reactions - pleasant or unpleasant emotional or physical reactions (anxiety, fatigue, happiness, etc.)

All four sources are believed by Bandura to act simultaneously and interactively in the development of one's perception of self-efficacy. The three behavioral consequences of the perceived self-efficacy were also described by Bandura (1977) as:

1. Approach versus avoidance - what one is willing to try and what one stays away from
2. Performance - ability demonstrated on any form of assessment
3. Persistence- not giving up the pursuit of one's goals

The development of one's self-efficacy can be self-perpetuating. For example, an individual with a high self-efficacy will perform better on assessments, which leads to an increase in perceived self-efficacy because of comparisons to how others performed on the same assessment and received positive consequences (Bandura, 1977; 1982).

Link between Self-Efficacy and Success in Engineering

Studies have examined the correlation between self-efficacy beliefs and achievement. Bandura (1982) posited "In causal tests, the higher the level of induced self-efficacy, the higher the performance accomplishments and the lower the emotional arousal" (p. 122).

In 1991, studies linking self-efficacy to academic success were combined into a meta-analytic synthesis by Multon, Brown, and Lent. Across a wide variety of subjects, experimental designs, and assessment methods, the researchers found a statistically significant positive relationship between self-efficacy beliefs and academic performance and persistence (Multon et al., 1991). More specifically, when researchers looked at engineering self-efficacy among college engineering students, they found that students were significantly affected by their self-efficacy beliefs in their choices to pursue and persist in engineering (Bandura 1977, 1997; Pajares, 1996).

Pajares and Miller (1994) used path analysis techniques to determine relationships between self-efficacy and mathematical problem-solving. The study compared the mathematical self-efficacy to math self-concept, math anxiety, perceived usefulness of mathematics, prior experience with mathematics, and gender in the ability to predict problem-solving ability. The results from the 350 participants showed self-efficacy to be a stronger predictor of mathematical problem-solving ability than math self-concept, perceived usefulness of mathematics, prior experience than mathematics, or gender. The results further supported the high correlation between self-efficacy and academic achievement.

While the research indicates a strong relationship between self-efficacy and academic success, attention needs to be given to the measurement of self-efficacy. The participants need to relate the self-efficacy scale to the topic of interest. As stated by Pajares (1996), "...judgments of self-efficacy are task and domain specific, global or inappropriately defined self-efficacy assessments weaken effects" (p. 547). The students' general self-efficacy may not be applicable to all areas of their studies or life. Therefore, the instrument measuring self-efficacy needs to apply directly to the engineering coursework to determine the students' engineering self-efficacy.

With the research demonstrating a high correlation between self-efficacy and academic achievement and persistence, Santiago and Einarson (1998) suggested persistence literature can be used to determine antecedents of academic self-efficacy. Therefore, the literature reviewed in this section suggests academic self-efficacy in engineering stems from the students' high school GPA, gender, and SAT scores (Astin, 1971; Levin & Wyckoff, 1990; Mendez, Buskirk, Lohr, & Haag, 2008; Zhang, Anderson, Ohland, Carter, & Thorndyke, 2004; Levin & Wyckoff, 1990; Zhang, Anderson, Ohland, Carter, & Thorndyke, 2004).

Development of K-12 Engineering Education

National standards have been established pertaining to the skills and knowledge students should gain from an engineering and technology education curriculum. These documents include the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), the *National Science Education Standards* (National Research Council, 2003), and *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000). While these documents do not directly address engineering in their titles, engineering content is found in each. For example, a version of the engineering design process is described under the *Science and Technology* section of the *National Science Education Standards* (p.190). In the *Designed World* section of the *Benchmarks for Science Literacy* standards, engineering topics such as materials, manufacturing, energy sources, communication, and information are described.

There have been several efforts to create K-12 engineering curriculum based on the developed national standards. The efforts range from something as small as designing a one-time engineering experience to comprehensive programs of instruction taking place over several years (e.g., Project Lead the Way). A review of existing engineering outreach programs by Jeffers, Safferman, and Safferman (2004) revealed 14 programs dedicated to creating and delivering classroom materials. Seven additional programs offered teachers online resources to incorporate into their classrooms. All 59 of the programs the researchers listed were associated with a college or university, demonstrating the perceived importance of K-12 engineering programs to higher education. The authors grouped the outreach programs into six categories; those which:

1. Develop classroom materials
2. Conduct outreach activities on the college campus
3. Conduct outreach activities at the K-12 school
4. Conduct or sponsor engineering contests
5. Sponsor teaching fellows or service-learning courses
6. Offer professional development for K-12 teachers

(p. 102)

While the programs are approaching engineering education from different perspectives, they share common themes of active learning through hands-on activities, inquiry-based learning, curriculum supplements, engaged role models, younger student focus, and K-12 teacher involvement. The large list of programs demonstrates two things; there is a strong interest in developing K-12 engineering resources and there is a wide variety of approaches in incorporating engineering into the K-12 curriculum.

The Massachusetts Department of Education provides a model for states aspiring to developing K-12 engineering-specific standards. Many of the same elements are found when comparing the *Standards for Technological Literacy* and the standards created in Massachusetts. For example, at the elementary level, students focus on materials, tools, and machines. Middle school and high school students work on progressively more complex engineering topics such as understanding the engineering design process (Brophy, Klein, Portsmore, & Rogers, 2008). Massachusetts showed its commitment to engineering and science education by requiring that all high school students be competent in one or the other. Beginning in 2010, all students in the state of Massachusetts must pass one of the four competency exams in science or engineering to graduate from high school (Selingo, 2007).

Influences Toward the Study of Engineering

Rarely is an individual's choice of career determined by a single incident or factor. The decision is more likely a culmination of a series of events that contribute to how an individual views possible careers as capable of meeting their needs, hopes, and expectations. Borg (1996) stated "[Choice of career] is a process that stretches back into childhood, where basic personality characteristics begin to be formed" (p. 6). The research suggests influences on career choice develop from family, peers, schooling, information from work visits, personal work experience, demand for jobs, geographical location, and personal characteristics such as age, sex, and ethnicity (Borg, 1996; Healy, O'Shea, & Crook, 1985; Larson, Butler, Wilson, Medora, & Allgood, 1994; Seymour & Hewitt, 1997).

Several studies determined that parents are one of the primary influences for students' choice of career (Reagor & Rehm, 1995; Reyer, 2007). According to Young (1994), parents aid in the career decision process of their children by providing security and assistance in career exploration. Young asserts, "Because career choice is one of the primary development tasks of adolescence, it represents an important means for constructive parent-adolescent engagement" (p. 196). In a dissertation studying factors that influenced students' choice of construction management as a career in one Midwestern State, Koch (2006) found the father to be the top influential person with a mean of 2.89 on a 1-5 scale. From a review of literature, Splete and Freeman-George (1985) suggested the family influence factors that affect decisions about career are:

1. Geographic location
2. Genetic inheritance
3. Family background
4. Socioeconomic status
5. Family composition
6. Parenting style
7. Parental work-related attitudes

(p. 56)

Influence from peer groups has also been shown to affect the career decisions of science and engineering students. In a study by Astin and Astin (1992), 27,000 freshmen who were studying science were surveyed. The researchers found a positive relationship between the number of peers majoring in science, mathematics, and engineering and the likelihood of the individual choosing to study science, mathematics, or engineering.

At one large, Midwestern university, 1,240 freshmen participated in a study of influences and persistence. The researchers found that social relationships significantly influence decisions to stay in college (Bank, Slavings, & Biddle, 1990). In particular, more than three-quarters of the participants rated their peers' and parents' opinions of them as very important or extremely important. When analyzed further, the parents received slightly higher importance ratings.

In a three-year study of 335 students from seven four-year institutions, Seymour and Hewitt (1997) examined attrition of male versus female students in different science, mathematics, and engineering (SME) majors. Part of their study involved the reasons students chose to study in a discipline. The researchers found the number one reason given by SME majors was "Active Influence of Others" (18%). Open-ended follow-up questions revealed the primary group described by the participants within the "Others" was family. Also included were peers, high school teachers and counselors, college advisors, and family friends. Other major reasons were given as "Intrinsic Interest" (17%), "Pragmatism/Materialism" (16%), and "Good at Math and/or Science in high School" (12%) as the second, third, and fourth most common responses given, respectively.

In a qualitative study involving a state university and technical college by two semi-independent research teams, researchers examined perceived influences of career decisions. The results were similar to previous studies with social support from friends and family members as a significant support factor. In particular, all 12 students from the technical college stated support enabled them to pursue their career choice (Lent, et al., 2002).

Other Exposures to Engineering

Beyond K-12 engineering education and personal influences to study engineering, students can be exposed to engineering through various other experiences. Examples of these experiences include outreach programs, youth organizations, personal exploration through toys and/or hobbies, and work experiences.

Colorado Outreach Programs

The Integrated Teaching and Learning (ITL) Program through the College of Engineering at the University of Colorado evolved in the mid 1990s with the intention of introducing hands-on, project-based learning for undergraduate engineering students in the college (CU College of Engineering). The ITL program was later expanded by the development of a pre-engineering summer outreach program for K-12 teachers and students. The first summer in 1999 consisted of three teacher workshops and six student workshops with topics such as "How Do Things Work?" and "Too Hot to Handle" exploring electromechanical systems and thermodynamics, respectively (Poole, deGrazia, & Sullivan, 1999). The program has continued to provide outreach programs to K-12 students and teachers as well as offering classroom materials, web-based resources, and partnering with several schools in the area for active K-16 collaboration (Jeffers, Safferman, & Safferman, 2004).

The Colorado School of Mines created the Center for Engineering Education (CEE) in January 2000 in an effort to improve the learning of science and engineering (Streveler, Moskal, Miller, & Pavelich, 2001). From 2003-2007, a series of middle-school outreach programs involving 11 school districts in Colorado were developed. The intent of the programs was to expose middle school students to engineering through the use of hands-on activities using mathematics and science in their classrooms (Moskal, et al., 2007). Results from pre-post tests and other qualitative measures led researchers to conclude the programs are effective in providing middle school teachers with resources they will use in classrooms and increased engineering knowledge in participating middle school students.

The Rocky Mountain Middle School Math Science Partnership (RMMSMSP) is comprised of four Colorado school districts: Adams County 14, Englewood, Elizabeth, and Gilpin County; and five universities and colleges: University of Colorado at Denver, the University of Denver, Metropolitan State College of Denver, Colorado State University, and Fort Lewis College (MSPnet, 2008). Through the course of the five-year project, it is estimated that 26,400 students in grades 6-12 will be impacted. The purpose of the partnership is to increase student achievement in science and mathematics and provide professional training for middle school teachers.

Youth Organizations

Youth organizations often include engineering content in their programs. For example, the Boy Scouts of America offer a merit badge in engineering. In 2007 alone, 5,733 Boy Scouts received a merit badge in engineering (Boy Scouts of America, 2008). The Girl Scouts also offer several programs centered on engineering content. Some examples include FIRST Robotics, Lighten UP- Discovering the Science of Light, Girls Go Tech, and collaboration with NASA and Lockheed Martin to increase interest and participation in engineering (Girl Scouts of the United States of America, 2008). Additionally, the 4-H Youth Development Program has the goal of preparing one-million new young people to excel in science, engineering, and technology by the year 2013 (National 4-H Council, 2008). The 4-H Program works directly with 106 land-grant universities' and colleges' through the Cooperative Extension System. This partnership allows content to be developed and delivered to the 4-H program participants.

Toys and Hobbies

Often exposure to engineering results from individual discoveries, such as personal interests in toys or hobbies. For many engineers, the decision to pursue engineering developed from tinkering with technology during childhood (Kleif & Faulkner, 2002). The connection between toys and engineering can be seen at the university level as well. For example, an engineering course at the University of Iowa used LEGO® MINDSTORMS™ robots to teach students C programming and introductory embedded systems design (Williams, 2003).

Work Experience

Through part-time and full-time employment, some students are exposed to the engineering environment. In a qualitative study involving two different colleges/universities by two semi-independent research teams, researchers examined influences and impedances of career decisions. The results produced six categories of career influences with moderate frequency that the participants listed as reasons they choose their career path. Two of the six were "direct exposure to work-relevant activities" and "vicarious exposure to work-relevant activities" (Lent, et al., 2002).

In her dissertation study, Koch (2006) found previous work or volunteer experience was the sixth most common response for students to choose construction management as a career. Construction management and engineering share similar attributes such as hands-on activities and project-based work.

Summary

The literature suggests that engineers are critical to the United States' economic success and national security. Recent trends in decreasing engineering enrollment, high attrition rates at engineering schools, and large growth in technology have resulted in concerns about an impending shortage of engineers.

Responding to these concerns, research regarding engineering students' success and persistence has gained attention and funding. The results of the research indicate high school GPA, SAT scores, performance in math and science courses, and students' attitudes determine engineering academic success and persistence.

Engineering self-efficacy is one aspect of student attitudes shown to largely influence students' success and persistence in engineering. Bandura (1977) asserts that a high self-efficacy would result in higher academic achievement and persistence. Research in various academic settings has confirmed the positive self-efficacy relationship to success and persistence (Multon, Brown, & Lent, 1991; Pajares & Miller, 1994). Similar relationships regarding the specific content of engineering have also been shown to exist (Bandura 1977, 1997; Pajares, 1996).

Two common goals among K-12 pre-engineering programs and engineering outreach programs are to motivate students to pursue engineering in college and provide knowledge and skills to help the students succeed once they get there. Other sources of motivation for students to pursue engineering are individuals (parents, friends, teachers, etc.), youth organizations, and toys and hobbies.

The research demonstrates the link between engineering self-efficacy and success in engineering programs. Therefore, a measure of success for the influences of K-12 pre-engineering programs, engineering outreach programs, individual persuasion, youth organizations, and toys and hobbies to study engineering is their ability to foster the students' self-efficacy.

CHAPTER 3: METHODOLOGY

Introduction

This study analyzed possible associations of demographic information, pre-collegiate engineering exposure, and influential factors of the participants to engineering self-efficacy of first-year engineering students at Colorado State University. The following research questions guided this study:

1. What are the primary influences for students at Colorado State University to study engineering?
2. How efficacious are first-year engineering students toward their engineering coursework at Colorado State University?
3. What is the relationship between exposure to engineering content before entering college and first-year engineering students' engineering self-efficacy?
4. Are some types of engineering exposure (e.g., class, field trip, summer camp, etc.) associated with higher self-efficacy than others?
5. What effect do the primary influences for major and career decisions have on a first-year engineering students' engineering self-efficacy?
6. Are there differences among first-year engineering students' engineering self-efficacy related to demographics (e.g., age, sex, residency, ethnicity, engineering program)?

The first purpose of the research questions was to give a description of the influential factors for students at Colorado State University to study engineering and their self-efficacy. The next purpose was to find relationships between the students' self-efficacy and engineering experiences. The final purpose was to determine any effects due to demographic characteristics.

Research Design

The purpose of this cross-sectional study was to examine the pre-collegiate engineering experiences, influences to study engineering, and self-efficacy of first-year engineering students at Colorado State University. A survey was the preferred type of data collection methodology due to the ability to make inferences about the population, quick turnaround time in data collection, ability to reach a large group, and economy of the design.

This study was framed in a quantitative research perspective. A quantitative design is used to objectively test theories by examining relationships between variables (Creswell, 2009). The decision to use a quantitative design was based on the researcher's training and experience, research questions addressed, and for comparison to studies of a similar nature.

Data were primarily collected through close-ended questions on self-administered questionnaires. The questionnaires surveyed students about their previous experiences with pre-collegiate engineering classes, extra-curricular programs, work experiences, multi-day programs focused on engineering, single-day workshops or field trips, engineering related toys and hobbies, and influences to study engineering. In addition to the close-ended questions, participants were given the opportunity to write additional experiences and influences for their choice to study engineering.

Participants and Site

The sample for this study was drawn from first-year engineering students enrolled at Colorado State University (CSU). The College of Engineering at CSU contains five departments: Atmospheric Science, Chemical & Biological Engineering, Civil & Environmental Engineering, Electrical & Computer Engineering, and Mechanical Engineering. Atmospheric Science does not offer an undergraduate degree program and was not included in this study.

Colorado State University is a land-grant institution founded in 1870 in the northern Colorado city of Fort Collins, a midsized city of about 131,000 residents. At the time of this study, there were about 25,000 students enrolled in the university and about 1,520 undergraduate students and 500 graduate students in the College of Engineering (Colorado State University, 2008). The population for this study was the 449 students enrolled in the first-year College of Engineering course sequence in the fall semester, 2008.

Conceptual Framework

The concept of engineering self-efficacy for this study is understood as the level at which students feel academically confident in their engineering classes (e.g., successfully complete assignments and earn passing grades). This definition is based on the work done by Bandura (1977; 1986; 1997) where he describes academic self-efficacy as the students' belief that they have the abilities to succeed when faced with academic challenges. Bandura asserts self-efficacy beliefs are at the center of social cognitive theory of motivation and will determine the choices students make. For example, a student will choose to begin an assignment over watching television based on the level of self-efficacy beliefs. Bandura also suggests that self-efficacy dictates students' level of persistence and the amount of effort given to academic tasks. He claims that students' beliefs about their abilities will be better indicators of academic success than their actual knowledge and skills levels as indicated by students' grade point averages (GPAs) (Bandura, 1997).

Engineering exposure can be conceptualized as the extent to which students have experience with engineering concepts. Throughout the K-12 grades, there are a variety of ways students can be exposed to engineering. The exposure can be in the form of a middle school or high school course specific to engineering (e.g., Project Lead the Way). Often, these courses have fully developed curriculum and grading rubrics. Additionally, numerous summer or out-of-school engineering programs are offered to stimulate interest in the topic of engineering. These programs typically span a few days to a few weeks and do not go into great depth of engineering content, but rather focus on generating excitement and exposure to a broad audience. Some students find work in engineering, technology, or construction with direct contact with engineering professionals in the field. These students are exposed to a real-life engineering environment. Through engineering learning laboratories (e.g., Integrated Teaching and Learning Program at the University of Colorado), elementary, middle, and high schools participate in single-day field trip activities. Students receive a small amount of exposure to engineering degree programs, engineering design, and engineering careers.

Another form of engineering exposure for students is through personal relationships with current engineering students or engineering professionals. These students are exposed to engineering in a variety of ways such as work visits or conversations about engineering.

The final source of engineering exposure for this study is through the use of toys or hobbies by the students. Many toys and hobbies were directly developed from engineering principles. Some relationships of engineering to toys include civil engineering and LEGO® building blocks and Lincoln Logs™, mechanical engineering and Erector Sets®, aerospace engineering and Estes Rockets® and model airplanes, biological engineering and microscopes, electrical engineering and electronic sets, and computer engineering and video game production.

This study explored how engineering exposure, personal influences to study engineering, and demographics are related to engineering self-efficacy of first-year engineering students at CSU. Figure 2 is a graphical representation of the concepts and hypothesized connections to each other. The research question connected with each concept is shown within a box adjacent to the corresponding arrow.

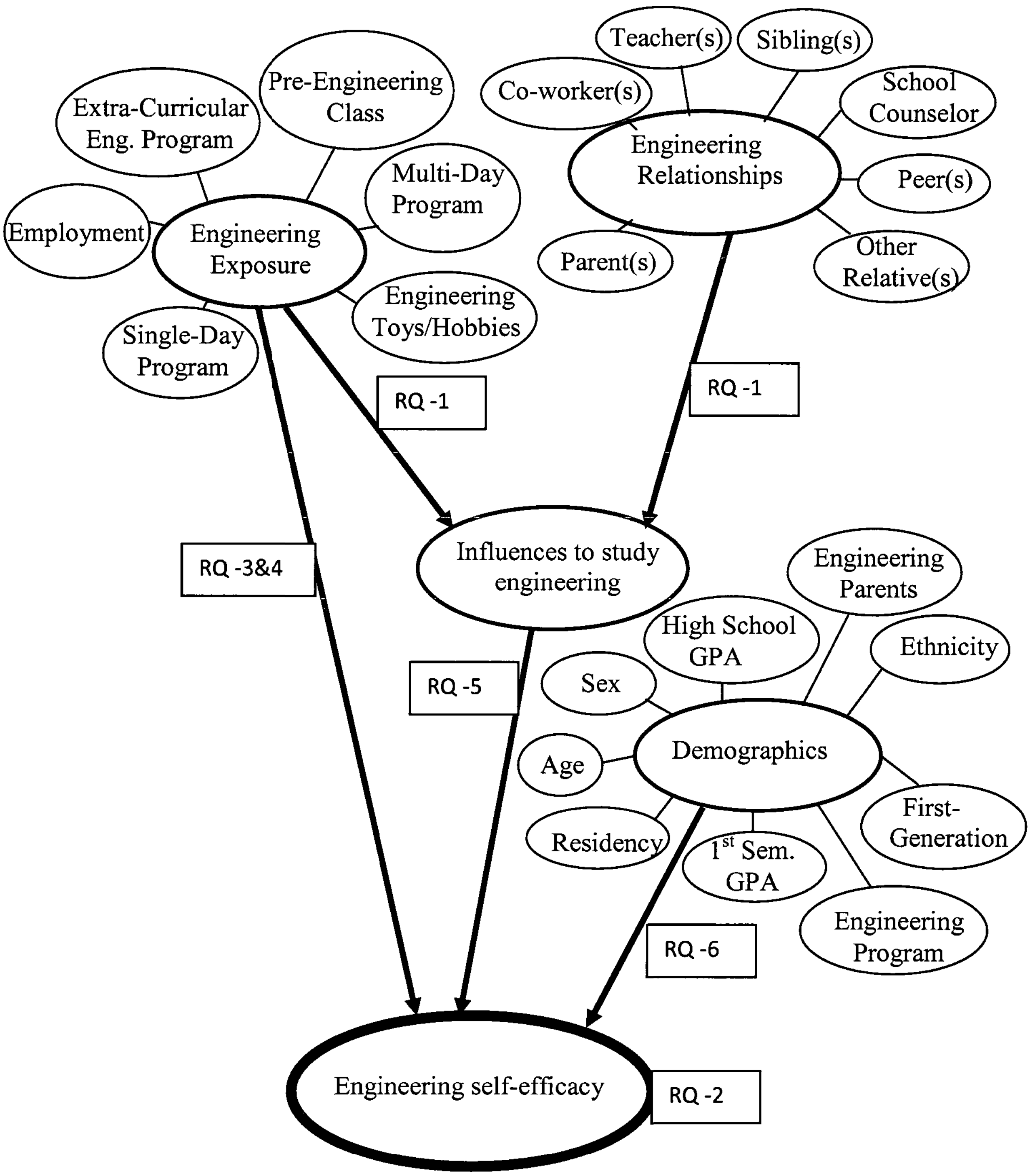

Figure 2. Concept map

Instrumentation

Initial Development

An instrument was developed to collect data on the participants' demographics, engineering exposure, extent of the engineering exposure, and identification of individuals who influenced the participants to study engineering. The instrument was evaluated by a graduate-level education class concerned with developing dissertation proposals. Revisions for the directions, layout, text style and size, question wording, and examples of engineering experiences were done based on suggestions from the class.

The revised instrument was evaluated by a graduate level education class concerned with developing dissertation instruments. Based on class and professor recommendations, changes were made to the wording of questions and directions; an open-ended question regarding other influences of the students to study engineering was added; sections for the participants to mark each type of engineering experience and the influence those experiences had on the students' choice to study engineering were added; Likert-style formatting was adapted to the sections of engineering experience as a influencing factor and individuals as a influencing factor; and the self-efficacy statement regarding assignments and tests was broken into two statements.

Pilot Testing

The third revision, as shown in Appendix A, was pilot tested with a group of third-year engineering students (n = 78). Parallel forms of the instrument were distributed to test for biases resulting from the order of the questions. Version A contained the following order: demographics, engineering experiences, influences to study engineering, and engineering self-efficacy. The parallel version B had the order: demographics, engineering self-efficacy, engineering experiences, and influences to study engineering. The goals of the pilot test were to determine the following:

- Understandable instructions
- Time to complete the instrument
- Readability
- Adequate engineering exposures to choose from
- Adequate personal influencing factors to choose from
- Order of the questions

There were no observable or statistically significant differences between the parallel forms of the questionnaire. Reliability measures using Cronbach's α were found to be $\alpha = 0.76$ and $\alpha = 0.91$ for version A and B, respectively. Based on the higher reliability measure, it was determined that the question order of version B would be used for the final instrument. The added engineering experiences were "shop class" to the list of pre-engineering classes, "firearms" to the list of hobbies and toys, and "air and space museum" to the list of single-day workshops. Some students listed non-engineering hobbies and toys (e.g., soccer) under the personal hobbies and toys section. The title of the section was changed to include engineering. In the demographics section, a student asked if the anticipated first-semester GPA question referred to an overall GPA or engineering major GPA. The wording of the question was changed to indicate an anticipated overall GPA.

To measure the students' engineering self-efficacy, the Motivated Strategies for Learning Questionnaire (MSLQ) was used. The MSLQ was developed by Pintrich, Smith, Garcia, and McKeachie (1991; 1993) and improved by VanderStoep and Pintrich (2003). The MSLQ was described as, "a self-report instrument designed to assess college students' motivational orientation and the use of different strategies for college courses" (Pintrich P. K., Smith, Garcia, & McKeachie, 1991, p. 3). The 81 item instrument measures 15 different scales, which can be used by researchers as a whole or independently. Each item is a statement with a seven-point Likert scale used for determining the students' agreement with the statement. For this study, the eight items relating to the self-efficacy for learning and performance were used. The items include statements such as "I believe I will receive an excellent grade in this class," and "I'm certain I can understand the most difficult material presented in the readings for this course." Permission to use the eight items from the MSLQ was granted by the University of Michigan. The granted permission is in Appendix C.

When researchers determine what they wish to study, they must modify the basic self-efficacy instrument to their chosen domain (Betz, 2000). Since the concept of personal efficacy began with Bandura (1977), many instruments have been created based on the domain the researcher was trying to measure. To this researcher's knowledge, there has not been an instrument created to measure self-efficacy specific to engineering. To measure the engineering self-efficacy of the students, the concept of engineering was integrated into the MSLQ. To add the domain of engineering to the instrument, the only modification was to replace the generic label of "class" and replace it with "engineering classes." The modified MSLQ self-efficacy survey is shown in Appendix B.

Validity and Reliability

Validity

Validity consists of the evidence that the use of an instrument is adequate for a particular setting with a particular population and for a particular purpose (Morgan, Gliner, & Harmon, 2006). Content validity and construct validity were tested through open-ended questions during the development and pilot study of the instrument. Students were asked about questions that were unclear or confusing and asked for additional questions that should be added to the survey to help measure influences to study engineering and self-efficacy. Construct validity was also checked through comparison to empirical research. DeVellis (2003) wrote, "The extent to which empirical correlations match the predicted pattern provides some evidence of how well the measure 'behaves' like the variable it is supposed to measure" (p. 53). Empirical data show students' high school GPA should be positively correlated to the students' first semester GPA and both high school GPA and first semester GPA should be positively correlated to their self-efficacy (Astin, 1971; Levin & Wyckoff, 1990; Mendez, Buskirk, Lohr, & Haag, 2008; Zhang, Anderson, Ohland, Carter, & Thorndyke, 2004). Results from the pilot test show a statistically significant correlation between high school GPA and anticipated first semester GPA, $r = 0.36$, $p = 0.003$ and anticipated first semester GPA and self-efficacy, $r = 0.25$, $p = 0.04$. While not statistically significant, there was also a positive correlation between high school GPA and self-efficacy, $r = 0.12$, $p = 0.32$.

Reliability

A measure of reliability for an instrument is the ability of the instrument to consistently determine the construct it is measuring (Field, 2005). The most common measure of reliability is Cronbach's α. For this study an accepted value of Cronbach's α of 0.70 or higher was considered acceptable. As stated by Morgan, Leech, Gloeckner, and Barrett (2007), "alpha should be positive and usually greater than 0.70 in order to provide good support for internal consistency reliability" (p. 129). The pilot instrument had a Cronbach's $\alpha = 0.88$ for the influences to study engineering and engineering self-efficacy scales. It was determined to consistently measure those scales and was unaltered for the final instrument. The final instrument produced similar results with a Cronbach's $\alpha = 0.83$ for the influences to study engineering and engineering self-efficacy scales.

The MSLQ has been shown to have both construct validity and internal consistency and reliability (Garcia & Pintrich, 1995). The reliability for the self-efficacy portion of the MSLQ instrument was determined to be strong with a measured Cronbach's $\alpha = 0.93$ (VanderStoep & Pintrich, 2003). The pilot instrument containing slightly modified self-efficacy questions resulted with a similar result with Cronbach's $\alpha = 0.90$. The pilot survey was determined to consistently measure the self-efficacy scale and unaltered for the final instrument. The final instrument resulted with a Cronbach's $\alpha = 0.92$ for the self-efficacy questions.

Data Collection

Data collection occurred in the month of December, 2008. The population of students majoring in the engineering disciplines of chemical and biological, civil, computer, electrical, environmental, mechanical, and engineering science at CSU were asked to complete the survey. Four introductory classes were determined to include every first-year engineering student following the prescribed course requirements. The classes were:

1. CBE 101: Chemical and Biological Engineering I
2. ECE 102: Digital Circuit Logic
3. CIVE 102: Introduction: Civil/Environmental Engineering
4. MECH 100: Introduction to Mechanical Engineering

Approval was obtained from Colorado State University's Institutional Review Board (IRB). The approval letter is shown in Appendix D. The researcher visited the classes and asked for student volunteers to help with distribution and collection of the surveys. A brief description of the study was given to each class with information that participation was voluntary, their responses would remain anonymous, and that they could contact the researcher any time after the survey was complete if they had any questions or concerns. Contact information was given on the cover sheet and verbally before the survey began. For students who did not wish to participate, a box was placed at the back of the classrooms to place their blank surveys.

Data Analysis

Descriptive statistics including means and standard deviations were performed for all demographic variables. The demographic data were compared to the known population data of first-year Colorado State University engineering students to check for proportionality. Descriptive statistics were also used to find the skewness and kurtosis of the variables to determine normality of the data. Descriptive statistics, residual plots, and scatterplots for each variable were performed and visually inspected for any violations. Violations lead to bias of the sample's ability to represent the population of Colorado State University engineering students.

An engineering exposure score was calculated for each participant. The score was calculated by multiplying the number of engineering experiences (e.g., engineering class, field trip, multi-day camp, etc.) by an estimated number of eight-hour days the experience would involve and adding up the scores for each experience. The estimation for each experience was the following:

- Middle school or high school pre-engineering class = 15 days
- Multi-day program focused on engineering = 7 days
- Engineering hobbies or toys = 10 days
- Working in engineering related environments = 20 days
- Extra-curricular engineering school programs = 15 days
- Single-day workshop of fieldtrip that focused on engineering = 1 day

For example, a student who had two engineering hobbies and participated in one extra-curricular engineering school program would have an engineering exposure score of (2 X 10) + (1 X 15) = 35.

Correlations measure the linear relationship between variables. A Pearson product moment correlation coefficient was computed to standardize the results (Field, 2005). Pearson Product Moment Correlations were used to gain knowledge about intercorrelations between age, engineering program, sex, residency, first-generation college student, students with engineering parents, high school GPA, anticipated first semester GPA, ethnicity, engineering exposure, and engineering self-efficacy score.

In the cases of violation of normality by the data or categorical data, either Spearman's correlation coefficient, r_s, or Kendall's tau, τ were used. Scatterplots of the variables of interest were used to check for linearity of relationships between the variables. Internal consistency reliability (Cronbach's alpha) was analyzed and reported for the data as well.

Results with $p < 0.05$ were determined to have achieved statistical significance and indicated by means of a single or double asterisk. Caution should be used in interpreting the importance of these results. The nature of the statistical analysis allows for an inverse relationship between the sample size and the size of the coefficient needed for statistical significance (Morgan, Gliner, & Harmon, 2006). A large sample size can easily lead to trivial statistical significant results and a small sample size may not provide statistical significance where important results exist. Effect sizes were calculated and reported for all statistically significant results.

Comparison groups were created from the demographic information on age, engineering major, sex, residency, first-generation status, engineering parents, and ethnicity. Independent samples t-test analyses were used to compare the dichotomous variables sex, residency, first-generation status, and engineering parents. One-way independent samples ANOVA analyses were performed to find differences within the variables age, engineering major, and ethnicity. Table 1 lists the variables and procedures used to analyze each research question.

Table 1

Research Questions, Variables, and Analytical Procedures

Research Questions	Variables	Analytical Procedures
1. What are the primary influences for students at Colorado State University to study engineering?	Factors influencing students to study engineering	Influences were ranked based on the mean score from participants. Mean scores range from 3 for the most influential experience or person to -3 for least influential.
2. How efficacious are first-year engineering students toward their engineering coursework at Colorado State University?	Engineering self-efficacy	The levels of agreement were assigned a scoring number from 3 for Strongly Agree to -3 for Strongly Disagree with 0 for neutral. An individual student's score was the sum of the scores from the 9 self-efficacy statements. The score had a range of -27 to 27.
3. What is the relationship between exposure to engineering content before entering college and first-year engineering students' engineering self-efficacy?	Engineering exposure, engineering self-efficacy	An exposure score was calculated for each student. The score was calculated by adding an estimated number of days for each type of exposure checked on the questionnaire. The estimation was the following: • pre-engineering class = 15 days • multi-day program = 7 days • Personal hobbies or toys = 10 days • Working for engineering or construction company = 20 days • Extra-curricular engineering program = 15 days • Single-day workshop or field trip = 1 day A linear regression analysis was used to determine the power of pre-collegiate engineering exposure to predict engineering self-efficacy.

Research Questions	Variables	Analytical Procedures
4. Are some types of engineering exposure (e.g., class, field trip, summer camp, etc.) associated with higher self-efficacy than others?	Engineering exposure, engineering self-efficacy	Simultaneous multiple regression was used to find the best predictors of self-efficacy from the six categories of engineering exposure. T-tests were then used to evaluate differences of between participants who experienced the exposure versus those who did not for the fifty-three individual exposures.
5. What effect do the primary influences for major and career decisions have on a first-year engineering students' engineering self-efficacy?	Factors influencing students to study engineering, engineering self-efficacy	A multiple linear regression analysis was used to find the best predictor variables out of the seven "exposure" influences and eight "individual" influences.
6. Are there differences among first-year engineering students' engineering self-efficacy related to demographics (e.g., age, sex, residency, ethnicity, engineering program)?	Age, engineering major, sex, residency, first-generation, engineering parents, ethnicity, engineering self-efficacy	The participants were grouped based on the seven demographic questions. A one-way independent ANOVA analysis was used to find differences among the age, engineering major, and ethnicity groups. T-tests were be used to find differences between the sex, residency, first-generation, and engineering parents groups.

CHAPTER 4: RESULTS

Introduction

The purpose of this study was to explore associations of demographic information, pre-collegiate engineering exposure, and influencing factors of the participants to engineering self-efficacy of first-year engineering students at Colorado State University. The instrument consisted of five sections that align with the objectives of the study:

1. Student Demographics
2. Engineering Self-efficacy
3. Engineering Experiences and Events
4. Experiences and Events Influencing Students to Study Engineering
5. Individuals Influencing Students to Study Engineering

The variables were explored through descriptive and inferential statistics. A correlational analysis was used to investigate possible relationships between the demographic variables, engineering self-efficacy, and engineering exposure. Descriptive statistics and statistical analyses using t-tests, ANOVAs, and linear regressions were used to examine the research questions.

Treatment of Data

The data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 17 and Microsoft Excel software. Exploratory data analysis with descriptive statistics and graphs were used to determine the following:

1. Problems with the data such as missing values, non-normal distributions, errors during data entry, and outliers.
2. Check the assumptions needed for the inferential statistics used in the analysis of the data. This included normally distributed data, homogeneity of variance, interval data, and independence of the data (Field, 2005).
3. Gain information about the demographics of the sample for comparison to the CSU first-year engineering population.
4. To examine relationships between variables to aid in understanding results. (Morgan, Leech, Gloeckner, & Barrett, 2007)

The data were examined using intercorrelations, linear regressions, t-tests, and ANOVAs. Each investigation was determined to have met the assumptions of the general linear model.

Demographic Data

Upon completion of all questionnaires, 332 students participated in the study. The majority of students were white (81%), male (81%), between the ages of 18 and 19 (85.5%), residents of Colorado (79.5%), and not first-generation students (80.7%). The demographic characteristics of the sample are shown in Table 2.

Table 2

Demographics of the Study's Sample

Demographic	N	Percent
Sex		
Male	269	81.0%
Female	62	19.0%
Ethnicity		
White	269	81.0%
Multi-racial	17	5.1%
Hispanic/Latino	15	4.5%
Other	8	2.4%
Prefer not to respond	7	2.1%
Asian American/Asian	6	1.8%
African American/Black	3	0.9%
American Indian/Alaskan Native	3	0.9%
Native Hawaiian/Pacific Islander	1	0.3%
Age		
18	164	49.4%
19	120	36.1%
21-24	22	6.6%
20	14	4.2%
25 years or older	5	1.5%
17 years or under	4	1.2%
Engineering major		
Mechanical	111	33.4%
Civil	88	26.5%
Chemical and Biological	38	11.4%
Environmental	32	9.6%
Electrical	27	8.1%
Computer	22	6.6%
Other	6	1.8%
Engineering Science	5	1.5%
Undeclared/undecided	2	0.6%
Residency		
Resident of Colorado	263	79.5%
Non-resident of Colorado	68	20.5%
First-Generation		
No	268	80.7%
Yes	63	19.3%

Intercorrelations

To examine the data for linear relationships, intercorrelational analysis was used. Table 3 presents the means, standard deviations, and correlations between all student demographic variables, student engineering self-efficacy scores, and student engineering exposure scores. Age was significantly correlated to the variables of Sex, $r = -0.14$, $p < 0.01$, and High School GPA, $r = -0.15$, $p < 0.01$. With male students represented with a 1 and female students with a 2, these results indicate as the age groups increase, students were more inclined to be male than female. The correlation between Age and High School GPA demonstrate a decrease in High School GPA with an increase in Age. According to Cohen's (1988) interpretation of the strength of a relationship, both of these correlations are small.

Engineering Major was significantly correlated to the variables of Sex, $r = -0.11$, $p < 0.05$, and Anticipated First Semester GPA, $r = -0.15$, $p < 0.01$. Specifically, the percentage of females was greatest in the engineering majors of environmental engineering (41%), chemical and biological engineering (37%), and engineering science (20%). The average anticipated first semester GPA was highest in the engineering majors of chemical and biological engineering (mean = 3.19), computer engineering (mean = 3.08), and civil engineering (mean = 2.98).

The demographic variable Sex was significantly correlated to the variables of engineering self-efficacy, $r = -0.21$, $p < 0.01$, and engineering exposure, $r = -0.39$, $p < 0.01$. The statistically significant correlation signifies females experienced less engineering content and had lower self-efficacy for their engineering coursework than their male counterparts. The correlation between sex and engineering self-efficacy was small to medium and the correlation between sex and engineering exposure was medium to large (Cohen, 1988).

Students who identified themselves as the first generation to attend college were negatively correlated with students who had engineering parents, $r = -0.27$, $p < 0.01$. The results indicate that students who have parents that did not attend college were more likely to also have parents that were not engineers. This result was obvious and expected because engineers are required to have college engineering degrees.

Table 3

Pearson Product Moment Correlations for Measured Variables

Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11
1. Age			--	-0.04	-0.14**	0.07	-0.09	0.06	-0.15**	-0.02	0.09	0.05	0.05
2. Major				--	-0.11*	-0.06	0.04	0.04	-0.06	-0.15**	0.04	0.06	0.09
3. Sex					--	0.07	0.00	-0.02	0.18	0.07	-0.04	-0.21**	-0.39**
4. Residency						--	0.10	0.01	-0.05	0.08	0.09	0.05	-0.08
5. First Gen.							--	-0.27**	0.00	0.11	0.01	0.03	0.04
6. Parents Eng								--	0.03	-0.07	0.09	-0.02	-0.07
7. H.S. GPA									--	0.41**	-0.00	0.04	-0.08
8. 1st Sem GPA										--	-0.07	0.38**	-0.04
9. Ethnicity											--	-0.02	0.02
10. Self-effic.	14.7	6.9										--	0.21**
11. Exposure	75.7	42.6											--

Note: Major = engineering major, Residency = in-state versus out of state residency, First Gen. = first generation to attend college, Parents Eng. = parents were engineers, H.S. GPA = high school grade point average, 1st Sem GPA = anticipated first semester grade point average, Self-effic = engineering self-efficacy score, Exposure = exposure to engineering content score

* $p<0.05$. **$p<0.01$.

The variables of high school GPA and anticipated first semester GPA were found to be positively correlated, $r = 0.41, p < 0.01$. This is considered at medium to large effect (Cohen, 1988). Students with higher GPAs from high school were more likely to have higher anticipated GPAs from their first semester in an engineering program. Anticipated first semester GPA was also found to be positively correlated to engineering self-efficacy scores, $r = 0.38, p < 0.01$. The result suggests students with higher self-efficacy will have higher first semester GPAs in their engineering coursework. While high school GPA was correlated with first semester GPA and first semester GPA was correlated with engineering self-efficacy, a significant correlation was not found between high school GPA and engineering self-efficacy.

The amount of engineering exposure reported by the students was found to be significantly correlated to the variable engineering self-efficacy, $r = 0.21, p < 0.01$. This suggests that students in this sample who have a greater number of engineering experiences also have a higher self-efficacy in their engineering coursework.

Primary Research Questions

Pre-Collegiate Engineering Experiences and People

1. What are the primary influences for students at Colorado State University to study engineering?

Descriptive statistics were used to explore past engineering experiences and individuals who have influenced students to pursue engineering. Likert-type scales with a range of +3 for Strongly Agree to -3 for Strongly Disagree were used to rate the seven engineering experiences and eight categories of individuals identified in the study. The items were ranked by mean score from most influential to least influential and are shown in Table 4. The columns which follow the influences are the mean scores for each influence (M), percentage of frequency responses for each category in the rating scale, and the number of respondents (n).

Table 4

Experiences, Events, and Individuals Influencing Students to Study Engineering

		Percentage of students responding to each item								
		N/A	SA	A	SWA	N	SWD	D	SD	
(Rank) Influences	M		3	2	1	0	-1	-2	-3	n
(1) Something not on the list	1.95	55%	21%	12%	2%	7%	0%	2%	0.3%	149
(2) Engineering hobbies/toys	1.92	4%	36%	34%	16%	7%	2%	2%	0.6%	318
(3) Parent(s)	0.71	0.9%	12%	24%	26%	17%	5%	10%	6%	329
(4) Single-day workshop	0.41	35%	3%	14%	14%	24%	0.9%	6%	4%	215
(5) Pre-engineering class	0.37	27%	9%	11%	17%	15%	6%	11%	5%	241
(6) Extra-curricular programs	0.30	41%	6%	11%	10%	19%	0.9%	7%	5%	196
(7) Work for engineering company	0.17	44%	5%	10%	7%	21%	2%	7%	5%	187
(8) Multi-day program	0.08	43%	4%	8%	8%	22%	2%	10%	4%	191
(9) Other relative	0.03	7%	5%	17%	18%	23%	3%	16%	10%	309
(10) Teacher(s)	-0.12	2%	3%	13%	25%	24%	5%	17%	11%	326
(11) Someone not on the list	-0.18	58%	6%	4%	0.6%	18%	0.9%	8%	5%	140
(12) Siblings	-0.72	6%	2%	7%	11%	32%	5%	21%	16%	313
(13) Friends	-0.78	2%	0.9%	6%	14%	30%	7%	25%	15%	325
(14) School counselor	-0.79	4%	0.3%	6%	14%	30%	6%	23%	17%	320
(15) Co-worker(s)	-0.89	11%	0.9%	3%	9%	32%	5%	23%	16%	295

The data shown in Table 4 suggest something not on the list was the most influential aspect in choosing to study engineering (M = 1.95, n = 149). As shown in the third column, 55% of the respondents either did not answer the question or chose N/A for not applicable. The result suggests a majority of the students did not need an additional influential factor beyond those listed on the questionnaire for the reason they chose engineering. However, for the 45% who did, the additional influence was given as a primary reason for pursuing engineering. The open ended responses following "something not on the list" were qualitatively analyzed for common themes. The themes were summed and ranked in order of most common to least. The list of themes, number of responses, and percentage of respondents are shown in Table 5.

Table 5

Experiences and Events not Listed on the Instrument

(Rank)	Open-Ended Response (Theme)	Number	Percent
(1)	Enjoy math and/or science	25	17.99%
(2)	Family/parents	20	14.39%
(3)	Money	13	9.35%
(4)	Father	10	7.19%
(5)	Teachers	7	5.04%
(6)	Taking things apart/seeing how things work	6	4.32%
(7)	Shadowing/visiting engineers	5	3.60%
(8)	Media- TV, newspapers, magazines, online	5	3.60%
(9)	Interest in motorcycles/cars	5	3.60%
(10)	High school classes	5	3.60%
(11)	Personal interests	4	2.88%
(12)	Other relative	4	2.88%
(13)	Didn't know what else to do	3	2.16%
(14)	Religious/spiritual reasons	2	1.44%
(15)	Puzzles/ problem solving	2	1.44%
(16)	Potential for travel/work with third world countries	2	1.44%
(17)	Hobbies/sports	2	1.44%
(18)	Friends	2	1.44%
(19)	Environmental concerns	2	1.44%
(20)	Challenging	2	1.44%

After something not on the list, engineering toys and hobbies were the second most influential response given by the participants ($M = 1.92$, $n = 318$). Engineering toys and hobbies and something not on the list were the only two responses with an influential mean score greater than 1.00.

Reviewing the ranked influencing factors, engineering experiences were more influential than people. Engineering experiences were ranked in seven out of the eight top spots, with parents as the only exception. People who were influential to study engineering were ranked in the bottom seven spots. With the exception of parents and other relatives, the mean score for the influence of people were below zero on the +3 to -3 scale.

Self-Efficacy of Engineering Students

2. How efficacious are first-year engineering students toward their engineering coursework at Colorado State University?

Self-efficacy has been shown to be a predictor of both persistence and performance in engineering programs (Bandura 1977, 1997; Pajares, 1996). Students were given nine statements regarding their self-efficacy in the context of their engineering coursework. Each statement had seven levels of agreement ranging from Strongly Agree to Strongly Disagree. The statements were scored with a +3 for Strongly Disagree, +2 for Agree, +1 for Somewhat Agree, 0 for Neither Agree nor Disagree, -1 for Somewhat Disagree, -2 for Disagree, and -3 for Strongly Disagree. Table 6 displays the mean score for each statement and the percentage of students who responded to the levels of agreement with the statement. The scores are displayed with the statement having the highest mean on top and in descending order.

Table 6

Means and Percentages for Engineering Self-Efficacy Statements

		Percentage of students responding to each item						
Statement	M	SA	A	SWA	N	SWD	D	SD
I'm confident I can understand the basic concepts in my engineering classes.	2.26	41%	47%	9%	2%	.6%	0%	0%
I expect to do well in my engineering classes.	1.85	19%	55%	20%	5%	.6%	.3%	.3%
I'm certain I can master the skills being taught in my engineering classes.	1.85	19%	55%	20%	5%	1%	.3%	.3%
I'm confident I can do an excellent job on the assignments in my engineering classes.	1.79	18%	53%	23%	5%	.9%	.6%	0%
Considering the difficulty of my engineering courses and teachers, and my skills, I think I will do well in my engineering classes.	1.68	12%	56%	24%	7%	2%	0%	.3%
I'm confident I can do an excellent job on the tests in my engineering classes.	1.36	11%	38%	36%	9%	4%	2%	.6%
I'm confident I can understand the most complex material presented by the instructors in my engineering classes.	1.31	7%	39%	40%	8%	4%	2%	.9%
I'm certain I can understand the most difficult material presented in the readings for my engineering classes.	1.28	9%	36%	40%	8%	4%	2%	.9%
I believe I will receive excellent grades in my engineering classes.	1.23	6%	40%	38%	8%	6%	2%	.9%

Note: SA = Strongly Agree, A = Agree, SWA = Somewhat Agree, N = Neither Agree Nor Disagree, SWD = Somewhat Disagree, D = Disagree, SD = Strongly Disagree

The statement with the highest self-efficacy mean score was "I'm confident I can understand the basic concepts in my engineering classes" (M = 2.26). The statement with the lowest self-efficacy mean score was "I believe I will receive excellent grades in my engineering classes" (M = 1.23). While students, in general, believe they can understand the material and perform well on assignments, they are not as confident in their ability to obtain excellent grades.

The scores from the nine statements were combined into a composite self-efficacy score ranging from -27 to 27. The composite mean self-efficacy score for students in this sample was 14.56 (N = 332). The self-efficacy scores ranged from -19 to 27 and resulted in a standard deviation of 6.75. Thus, ninety-five percent of the students were in the range of 1.33 and 27.79.

Exposure to Engineering Content and Self-Efficacy

3. What is the relationship between exposure to engineering content before entering college and first-year engineering students' engineering self-efficacy?

Data on engineering experiences were collected by having participants place an X next to each type of experience they had during their pre-collegiate years. A summary of the number and percentage of participants selecting each engineering experience is shown in Appendix F. An engineering exposure score was calculated for the participants based on the participants' engineering experiences. The score was calculated by multiplying the number of engineering experiences (e.g., engineering class, field trip, multi-day camp, etc.) by an estimated number of eight-hour days the experience would involve and adding up the scores for each experience. The estimation for each experience was the following:

- Middle school or high school pre-engineering class = 15 days
- Multi-day program focused on engineering = 7 days
- Engineering hobbies or toys = 10 days
- Working in engineering related environments = 20 days
- Extra-curricular engineering school programs = 15 days
- Single-day workshop of fieldtrip that focused on engineering = 1 day

In the preliminary analysis using intercorrelations and as shown in Table 3, the students' engineering exposure score was positively correlated to the composite self-efficacy score, $r = 0.21, p < 0.01$. To further test the predictability of engineering self-efficacy from engineering exposure, a linear regression analysis was performed. The results were statistically significant $F\ (1, 330) = 12.46, p < 0.001$. The resulting equation for the relationship was engineering self-efficacy = 12.28 + 0.03 * (engineering exposure score). The adjusted R^2 value was 0.03, indicating that 3% of the variance in engineering self-efficacy was explained by the exposure to engineering content. This is considered a small effect (Cohen, 1988). While exposure to engineering content before entering college and engineering are positively correlated, increases in engineering exposure only led to small increases of engineering self-efficacy.

Types of Engineering Exposure and Self-Efficacy

4. Are some types of engineering exposure (e.g., class, field trip, summer camp, etc.) associated with higher self-efficacy than others?

From the questionnaire, the 53 types of engineering exposures were combined into the six categories of:

1. Middle school or high school pre-engineering class
2. Multi-day program focused on engineering
3. Engineering hobby or toy
4. Work in an engineering environment
5. Extra-curricular engineering program sponsored by a school
6. Single day workshop or field trip that focused on engineering

The 53 types of engineering exposures within the six categories are shown on the final instrument in Appendix B. Students were given a score for each category that was equal to the count of the number of experiences within that category. The score had a range from 0 to the number of engineering experiences within the category. A simultaneous multiple regression was conducted to determine the best predictors of engineering self-efficacy from the six exposure categories. It was found that the combination of the six categories to predict self-efficacy was statistically significant, F $(6, 325) = 2.63, p = 0.02$. Out of the six categories, middle school or high school pre-engineering class ($\beta = 0.11, p = 0.08$) and engineering hobbies and toys ($\beta = 0.15, p = 0.01$) reached statistical significance at the $\alpha = 0.1$ level.

To further examine individual engineering exposures, participants were sorted into two groups of "did not experience" and "experienced" for the 53 types of engineering exposures. An independent samples t-test was performed for each type of engineering exposure to compare the self-efficacy scores of those who experienced versus those who had not experienced the exposure. Table 7 lists the types of exposure in order from highest mean self-efficacy difference between the two groups to the lowest. Only the differences that resulted in statistical significance at the level of $\alpha \leq 0.05$ are shown.

Table 7

Engineering Experiences and Engineering Self-Efficacy

(Rank) Experience	N	Mean	SD	Mean Difference	t	p
(1) Programming as a Hobby						
Did not Experience	279	14.10	6.85	2.88	2.88	< 0.01
Experienced	53	16.98	5.62			
(2) Electronics as a Hobby						
Did not Experience	251	14.01	6.99	2.25	2.63	< 0.01
Experienced	81	16.26	5.62			
(3) Technology Class						
Did not Experience	201	13.70	7.17	2.18	3.03	< 0.01
Experienced	131	15.88	5.83			
(4) Produce Video Games as a Hobby						
Did not Experience	283	14.22	6.78	2.17	2.08	0.04
Experienced	48	16.40	6.28			
(5) Engineering Class						
Did not Experience	286	14.27	6.84	2.10	1.97	0.05
Experienced	46	16.37	5.85			
(6) Robotics as a Hobby						
Did not Experience	260	14.20	7.00	1.66	2.12	0.04
Experienced	72	15.86	5.54			
(7) Model Rockets as a Hobby						
Did not Experience	152	13.67	7.03	1.64	2.22	0.03
Experienced	180	15.31	6.41			

Out of the 53 types of engineering exposure, seven had statistically significant differences in self-efficacy scores. Of the seven, five were pre-collegiate hobbies. The greatest difference in self-efficacy scores occurred between students who identified programming as a hobby and those who didn't (Mean difference = 2.88, $t = 2.88$, $p < 0.01$). The effect size d is approximately 0.46, which is a medium effect. The next largest difference was between students who did and did not have electronics as a hobby (Mean difference = 2.25, $t = 2.63$, $p < 0.01$, $d = 0.35$). The other hobbies that were significantly different were producing video games (Mean difference = 2.17, $t = 2.08$, $p = 0.04$, $d = 0.33$), robotics (Mean difference = 1.66, $t = 2.12$, $p = 0.04$, $d = 0.26$), and model rockets (Mean difference = 1.64, $t = 2.22$, $p = 0.03$, $d = 0.24$). The two engineering exposures that were not related to hobbies were both pre-engineering classes. In particular, they were technology classes (Mean difference = 2.18, $t = 3.03$, $p < 0.01$, $d = 0.33$) and engineering classes (Mean difference = 2.10, $t = 1.97$, $p < 0.05$, $d = 0.33$). No engineering exposures from multi-day engineering programs, working in engineering environments, school related extra-curricular engineering programs, or single-day workshops/fieldtrips that focused on engineering resulted in significant differences in self-efficacy scores between those who experienced the exposure and those who did not.

The results from analyzing individual engineering exposures agree with the results from analyzing the six categories of engineering exposure. All seven individual engineering exposures that had statistically significant differences in self-efficacy scores for those who participated versus those who didn't are found within the two categories of middle school or high school pre-engineering class and engineering hobbies and toys which predict self-efficacy.

The types of engineering exposure that resulted in significant differences of engineering self-efficacy were hobbies and formal classes with curriculum designed to meet standards. In particular, the hobbies of programming, electronics, producing video games, robotics, and model rockets had statistically significant differences between students who had the hobby and the students who did not. The formal classes that resulted in statistical significant differences were technology and engineering classes.

Primary influences for Major and Self-Efficacy

5. What effect do the primary influences for major and career decisions have on a first-year engineering students' engineering self-efficacy?

Students rated the influence of seven engineering experiences and eight categories of individuals for studying engineering. The degree in which these 15 factors were influential was compared to the self-efficacy of the students. Simultaneous multiple regression was conducted to investigate the best predictors of engineering self-efficacy from the students' primary influences. The combination of variables to predict engineering self-efficacy from influencing factors stemming from pre-engineering classes, multi-day programs, engineering hobbies or toys, working in an engineering environment, extra-curricular engineering programs, single-day workshops, parents, siblings, other relatives, friends, teachers, school counselors, and co-workers was not statistically significant, $F(15, 45) = 1.47$, $p = 0.16$. These results indicate that the reasons students in this sample chose to pursue engineering at Colorado State University did not predict the engineering students' self-efficacy.

Demographical Differences of Self-Efficacy

6. Are there differences among first-year engineering students' engineering self-efficacy related to demographics (e.g., age, sex, residency, ethnicity, engineering program)?

Comparison groups were created from the demographic information on age, engineering major, sex, residency, first-generation status, engineering parents, and ethnicity. Independent samples t-test analyses were used to compare the dichotomous variables sex, residency, first-generation status, and engineering parents to the variable of engineering self-efficacy. One-way independent samples ANOVA analyses were performed to find differences of engineering self-efficacy within the variables age, engineering major, and ethnicity. No statistically significant differences were found within the groups of age, engineering major, residency, first-generation status, engineering parents, or ethnicity.

An independent samples t-test between the sexes resulted in statistical significant differences of engineering self-efficacy. Table 8 shows that males were significantly higher than females on engineering self-efficacy, ($p = 0.003$).

Table 8

Summary of t-Test Results between the Sexes and Self-Efficacy

Variable	n	M	SD	t	df	p	*d*
Self-efficacy							
Males	269	15.07	6.93	2.95	329	0.003	0.45
Females	62	12.29	5.42				

The difference between the means is 2.78 points on a 54-point scale (-27 to 27). The effect size d is approximately 0.45, which is a medium effect (Cohen, 1988). Therefore, there was a statistically significant difference between the self-efficacy in engineering between males and females. The difference was considered to be of medium size.

Secondary Research Questions

The results from analyzing the primary research questions led to further questions about the data. Secondary research questions were generated to gain more information about the primary research questions.

Differences Between the Sexes and Exposure to Engineering

Table 3 shows a negative correlation between the sexes and exposure to engineering $r = -0.39, p < 0.01$. With males identified with a 1 and females a 2, the negative correlation indicates less engineering exposure with females than males. A secondary research question was developed to describe the differences in more detail.

An independent samples t-test was used to examine the differences between the sexes with engineering exposure. Table 9 shows that males had a significantly greater number of engineering exposure hours than females, ($p < 0.001$). The effect size d is approximately 1.06, which is considered to be very large.

Table 9

Summary of t-Test Results between the Sexes and Engineering Exposure

Variable	M	SD	t	df	p
Eng. Exposure					
Males (N=269)	82.95	41.23	7.05	329	< 0.001
Females (N = 62)	43.45	32.59			

To explore the types of exposures that are different between the sexes, the exposures were divided into two groups, informal and formal. Informal experiences were experiences that took place in the home or workplace. In particular, informal experiences included exposure to engineering through toys, hobbies, field work, office work, and farm work. Formal experiences were defined to have educational structure and supported by the schooling system. These experiences included pre-engineering classes, multi-day engineering programs, extra-curricular engineering programs, and single-day workshops or fieldtrips that focused on engineering. Two independent samples t-tests were used to evaluate the differences between the sexes and informal and formal engineering experiences. Table 10 shows males were exposed to significantly more engineering content by both informal experiences ($p < 0.001$) and formal experiences ($p = 0.008$).

Table 10

Summary of t-Test Results between the Sexes and Informal and Formal Engineering Exposure

Variable	M	SD	t	df	p
Informal Engineering Exposure					
Males (N = 269)	51.60	25.67	8.66	329	< 0.001
Females (N = 62)	21.61	19.00			
Formal Engineering Exposure					
Males (N = 269)	31.35	25.49	2.68	329	0.008
Females (N = 62)	21.84	24.14			

The difference between the informal means is 29.99 and has an effect size of 1.33, or a very large effect size. The difference between the formal means is 9.51 and has an effect size of 0.38, or a medium effect size. While both types of engineering exposure are significantly different, the engineering exposure gap for formal engineering exposure is less than informal engineering.

Differences Between the Sexes, Anticipated GPAs, and Engineering Self-Efficacy

Table 3 shows a positive correlation between anticipated GPA and engineering self-efficacy, $r = 0.38, p < 0.01$ and a negative correlation between sex and engineering self-efficacy, $r = -0.21, p < 0.01$. A 4 x 2 between groups ANOVA was used to further investigate the effect of anticipated GPA and engineering self-efficacy by sex. Table 11 illustrates males have a higher engineering self-efficacy score in each of the four anticipated GPA groups.

Table 11

ANOVA Summary Table of Sex and Anticipated GPA on Engineering Self-Efficacy

Groups	N	Mean	Std. Deviation
3.50-4.00 anticipated GPA			
Male	41	19.68	3.94
Female	16	13.94	4.91
Totals (Within Experimental Group)	57		
3.00-3.49 anticipated GPA			
Male	113	16.45	5.57
Female	22	13.23	5.20
Totals (Within Experimental Group)	135		
2.50-2.99 anticipated GPA			
Male	75	13.67	6.19
Female	18	10.72	6.04
Totals (Within Experimental Group)	93		
2.00-2.49 anticipated GPA			
Male	24	9.92	7.29
Female	4	8.75	4.27
Totals (Within Experimental Group)	28		

Table 12 shows that there is not a significant interaction between anticipated GPA and sex on engineering self-efficacy ($p = 0.55$). There were, however, significant main effects on sex and self-efficacy, $F\ (1, 320) = 4.25, p = 0.04$ and anticipated GPA and self-efficacy, $F\ (5, 320) = 10.07, p < 0.01$. Estimated effect sizes, η, were 0.11 for sex and 0.37 for anticipated GPA. These are considered small and large effects respectively (Cohen, 1988).

Table 12

Summary of ANOVA Results for the Sexes, Anticipated GPA, and Self-Efficacy

Source	Sum of Squares	df	Mean Square	F	Sig.
Sex	150.85	1	150.85	4.25	0.04
First semester GPA	1784.93	5	356.99	10.07	< 0.01
Sex x First semester GPA	108.53	4	27.13	0.77	0.55
Error	11350.24	320	35.47		

Summary of Results

With the exception of parents, students in this sample were more influenced to study engineering by engineering experiences than individuals. Enjoying math and science and engineering hobbies and toys were the top two experiences that influenced their decision to pursue engineering. As the research suggests, parents and other relatives were the top individuals influencing their decision.

Exposure to engineering content during the pre-collegiate years was shown to have a positive effect on the students' engineering self-efficacy. Students with more contact hours showed a higher self-efficacy in their engineering coursework. In particular students who had the hobbies of programming, electronics, producing video games, robotics, and model rockets showed higher self-efficacy scores than the students who did not. In addition, students who experienced formal coursework in the form of a technology class or a pre-engineering class had higher self-efficacy scores in engineering than those who did not.

A difference in engineering self-efficacy was found between male and female engineering students. Males were shown to have higher engineering self-efficacy than females at every level of academic achievement. Further investigation showed a significant difference between the sexes in pre-collegiate engineering exposure as well. When the exposure is broken down into formal versus informal experiences, a larger gap exists between the sexes in informal exposure.

CHAPTER 5: DISCUSSION

Overview of the Problem

Recent trends in decreasing engineering enrollment, high attrition rates at engineering schools, and large growth in technology have resulted in concerns of an upcoming shortage of engineers (Noeth, Cruce, & Harmston, 2003; Besterfield-Sacre, Atman, & Shuman, 1997; Shuman et al, 1999; Zhang et al, 2004). The literature suggests that engineers are critical to the United States' economic success and national security (Committee on Science, Engineering, and Public Policy, 2007; Popper & Wagner, 2002; National Science Board, 2003; Committee on Science, 2007). Responding to the concerns, research regarding engineering students' success and persistence and K-12 pre-engineering outreach programs has gained attention and funding. Two common goals among K-12 pre-engineering programs and engineering outreach programs are to motivate students to pursue engineering in college and provide knowledge and skills to help the students succeed once they get there. Little research has been done on the effectiveness of the K-12 pre-engineering programs and engineering outreach programs in meeting their long-term goals.

The purpose of this study was twofold: first, to explore relationships between exposure to engineering content through pre-collegiate engineering experiences and engineering self-efficacy during the first-year of studying engineering, and second, explore factors that motivate students to pursue engineering as a career. Specifically, formal pre-engineering outreach programs and informal engineering experiences were evaluated based on engineering self-efficacy differences for those who participated versus those who did not. The ability of these programs and experiences to influence students to pursue engineering as a career was also evaluated.

Major Findings

Influences to Study Engineering

First-year engineering students were asked about their influences to study engineering. They rated the level to which their pre-collegiate engineering experiences and individuals influenced their decision to study engineering. A mean score of the ability to influence students to study engineering was generated for each engineering experience and individual. The experiences and individuals were ranked from highest mean score to lowest. It was found that engineering experiences were more influential than individuals. In particular, the top influences were the enjoyment of math and science and engineering hobbies. The influence from engineering hobbies concurs with research done by Kleif and Faulkner (2002). They concluded that the decision to pursue engineering often develops from tinkering with technology during childhood. The only category of individuals in the top eight influential reasons students choose to study engineering was parents, with the third highest mean score. Peers, siblings, other relatives, teachers, school counselors, and co-workers ranked below all the engineering experiences.

The findings contradict Seymour and Hewitt (1997), who explored the reasons students chose to study a discipline. The researchers found the number one reason given by science, mathematics, and engineering majors was "Active Influence of Others" (18%). Open-ended follow-up questions revealed the primary group described by the participants within the "Others" was family. Other studies have also found family influences to be the primary reason for career choice (Lent, et al., 2002; Bank, Slavings, & Biddle, 1990; Koch, 2006). One possible reason for the different findings in the current study from previous research is through the direct comparison of people to experiences. The previous studies noted here did not analyze the ability of particular experiences compared to individuals (family, friends, teachers, etc.) in influencing career choice.

Another possible reason for categories of individuals ranking below experiences is the nature of influence. The influences of parents, peers, teachers, and others are indirect and take place over the lifetime of the students. Therefore, students may not consider the influences as directly relating to the study of engineering. The engineering experiences, on the other hand, have a direct connection to the students' studies and allow students to see the association between past experiences and their decision to study engineering.

Relationship between Engineering Exposure and Engineering Self-Efficacy

This study created an engineering exposure score based on the number of experiences and type of experiences of the students. The score was weighted based on an approximate number of eight-hour days the experience would encompass. The engineering exposure score was compared to an engineering self-efficacy score. The self-efficacy score was calculated by summing the level of agreement for nine Likert-style questions regarding the students' confidence in their engineering coursework.

The results suggest that more exposure to engineering content during the K-12 years leads to a higher self-efficacy in engineering. This is an assumption of many pre-collegiate outreach programs. However, this study provides some insight into the types of exposure that are most related to higher self-efficacy in future engineering students.

For preparing students, this study found that the most effective formal programs are semester-long classes at the high-school or middle-school level. In particular, technology education classes and pre-engineering classes had the largest difference in self-efficacy scores between students who had experienced the class and those who did not. Higher self-efficacy scores lead to better performance and persistence in engineering (Bandura 1977, 1997; Pajares, 1996). Therefore, participation in technology and pre-engineering classes should lead to lower attrition levels in engineering schools and increased performance.

In regard to informal experiences and self-efficacy, hobbies and toys were shown to have a positive impact on engineering self-efficacy. In particular, the hobbies of programming, electronics, producing video games, robotics, and model rockets all had statistically significant higher self-efficacy scores for students who experienced them. Some common attributes among these hobbies include:

- Self-motivation
- Use of problem-solving strategies
- Hands-on application of complex subject matter
- Use of computer applications (with the exception of model rockets)

While some formal programs showed large differences in mean self-efficacy scores, they did not achieve statistical significance. This is due to the small number of students reporting to have been exposed to those programs or experiences. The nature of the statistical analysis allows for an inverse relationship between the sample size and the size of the coefficient needed for statistical significance (Morgan, Gliner, & Harmon, 2006). A large sample size can easily lead to trivial statistical significant results and a small sample size may not provide statistical significance where important results exist. In this study, the University of Colorado's Success Institute (Mean Difference = 4.0, N = 7, $p = 0.13$), Middle School MESA Day (Mean Difference = 3.1, N = 7, $p = 0.23$), and the Science Olympiad (Mean Difference = 2.3, N = 25, $p = 0.10$) showed substantial mean differences, but did not have statistical significance. In other words, the results are not at least 95% sure that there is a difference in self-efficacy between those who participated in the programs and those who did not. However, due to the high self-efficacy of the students who experienced these programs, further studies with larger sample sizes should be used to determine the programs' ability to raise self-efficacy.

Relationship between Engineering Self-Efficacy and Performance

Students were asked for their anticipated GPA at the end of the semester. The GPAs were compared to the self-efficacy scores computed from the nine questions about their perceived abilities in engineering. Anticipated first semester GPA scores were found to be positively correlated to engineering self-efficacy scores. The result suggests students with higher self-efficacy will have higher first semester GPAs in their engineering coursework.

The literature implies students with higher engineering self-efficacy will outperform students with lower engineering self-efficacy (Bandura 1977, 1997; Pajares and Miller, 1994; Pajares, 1996). Results from this study confirm previous research. Performance was based on the students' anticipated grade point averages at the end of their first semester in an engineering program. As the survey was done during the final two weeks of the semester, students should have an accurate assessment of their grades and associated GPAs.

To verify their ability to predict their GPAs, actual student GPAs were compared to the anticipated student GPAs from the survey. It was found that the average anticipated GPA (2.94) was slightly higher than the actual GPA (2.55). One possible explanation of the difference between anticipated GPA and actual GPA is the use of a range of GPAs on the survey instead of students writing an exact GPA value. When students need to choose from a range of scores and they are on the border, they would likely guess the higher range.

Differences between the Sexes and Engineering Exposure and Engineering Self-Efficacy

Prior research has shown college women have a lower perception of their capabilities to succeed in engineering then those of men (Hackett, 1985; Pajares & Miller, 1994). Results from this study agree with the previous research. While women with higher anticipated GPAs had higher self-efficacy than those with lower anticipated GPAs, their self-efficacy scores were lower than their male counterparts at every anticipated GPA interval level. When the differences between actual GPAs and anticipated GPAs are broken down by sex, it was found that males over-reported by 0.43

points and females over-reported by 0.25 points. This results in actual male GPAs being lower than anticipated. Therefore, the differences between the sexes and self-efficacy in each GPA interval level are greater than the results reported in Table 10. With prior research linking persistence and success in engineering to self-efficacy (Multon, Brown, & Lent, 1991; Bandura 1977, 1997; Pajares, 1996), women are at a disadvantage when they begin an engineering program.

Results from the current study suggest exposure to engineering content during the K-12 years will lead to higher engineering self-efficacy and females are less exposed both informally and formally. For that reason, the self-efficacy gap between males and females could be decreased through increased exposure to engineering for females. It is more difficult to increase engineering exposure through informal methods than formal methods. Informal exposure to engineering results from family influences and personal interests. To increase informal engineering exposure, marketing methods of toys and hobbies as well as methods to educate the parents about the benefits of engineering exposure would need to be used. An easier method to increase engineering exposure for females is through formal means. Outreach programs targeted at the female population would be beneficial in decreasing the gap in exposure between males and females. Existing female programs, such as Girl Scouts, could be used as a method to promote engineering to young females.

Recommendations for Practice

K-12 engineering outreach programs should continue to be a vehicle for recruiting students to study engineering and providing the skills necessary to succeed. This study helped confirm assumptions that exposure to engineering content during the K-12 years leads to increased interest in studying engineering and increased abilities to perform in an engineering setting. Some outreach programs are more concerned with promoting engineering and technological knowledge to the public than developing engineering students. While these programs are important for society, they are not the focus of this study and the recommendations do not apply.

Engineering experiences should increase promotion for females. As research suggests and this study confirmed, females are less likely to be exposed to engineering content than males. While the engineering content exposure gap between the sexes is greater with informal exposures than formal exposures, females are receiving less than males in both forms. Engineering outreach programs should target and encourage females to participate. While work has been done in this area, the gap between the sexes still exists and areas for more exposure should be explored. Some examples include female only engineering summer camps, engineering emphasis in Girl Scouts, and high school extra-curricular programs focusing on female enrolment.

Pre-engineering programs should use the same principles as students experience with their personal hobbies. The results from this study suggest that personal hobbies are effective in recruiting students to pursue engineering and in increasing the self-efficacy during the study of engineering in college. The principles common with hobbies include hands-on experiences, self-motivated learning, real-life application, and problem-based projects. The same principles should be utilized by outreach programs when delivering content or in the general pedagogy of the program. For example, outreach programs using computer programming, electronics, and robotics with student-based exploration would provide learning opportunities that are similar to what the students experience with their hobbies.

Outreach programs that are focused on preparing students to study engineering in college should be academically rigorous. This study determined those students who participated in technology classes and pre-engineering classes were more likely to have a higher engineering self-efficacy than those students who did not. By their nature of being within a graded curriculum, technology and pre-engineering classes are more rigorous than most outreach programs. They are more likely to use mathematical and engineering analysis to solve problems and design solutions. College engineering programs require high levels of mathematical and engineering analysis to solve problems. Therefore, in order for outreach programs to be effective in preparing students to study engineering, they should have grade appropriate levels of academic rigor. For example, a high school summer camp should incorporate algebra and trigonometry usage as part of the experience. Hands-on experiences without an analytical component give students a false sense of collegiate engineering programs.

Suggestions for Further Research

Further research is needed to determine how effective hobbies and toys are in influencing students to study engineering and building self-efficacy in engineering. In particular, research is needed to determine why some hobbies and toys are more effective in influencing and preparing students to study engineering than others. This study found programming, electronics, producing video games, robotics, and model rockets to be a common factor among students with high self-efficacy. Research is needed to explore direct relationships of self-efficacy and exposure to these hobbies.

The self-efficacy was examined for differences among demographic groups. It was not found that self-efficacy statistically varied among the different ethnic groups. However, due to the nature of statistical analysis, larger differences are needed for smaller sample sizes to achieve statistical significance. Although not statistically significant, large differences in self-efficacy among some ethic groups exist. In particular, participants who identified themselves as Other (N = 11) or African American/Black (N < 5) had much lower self-efficacy scores. Further research is needed to determine the differences in self-efficacy based of ethnicity. Table 13 displays the number of participants in each group, mean self-efficacy scale, and standard deviation.

Table 13

Self-Efficacy by Ethnicity

Ethnicity	N	Mean	Std. Deviation
African American/Black (non-Hispanic)	< 5	10.0	8.5
American Indian/Alaskan native	< 5	16.3	4.2
Asian American/Asian	6	13.8	3.8
Hispanic/Latino	15	15.2	5.6
Native Hawaiian/Pacific Islander	< 5	18.0	5.6
White (non-Hispanic)	269	14.8	6.5
Multi-racial	17	15.1	6.7
Prefer not to respond	7	13.29	9.1
Other	11	8.7	10.9
Total	332	14.6	6.7

Note: Actual number of participants, N, are not shown for cases where N<5 in order to keep participants anonymous.

This study used anticipated GPAs as a measure of success. With only a couple of weeks remaining in the semester when the survey was given, it was assumed that students would be able to accurately predict their GPAs. To check the validity of the assumption, actual mean GPAs were compared to anticipated mean GPAs. Table 14 shows the comparison between actual mean GPAs and anticipated mean GPAs by sex.

Table 14

Actual GPA versus Anticipated GPA by Sex

Sex	Actual GPA	Anticipated GPA	Difference (actual-anticipated)
Male	2.49	2.92	0.43
Female	2.81	3.06	0.25
Total	2.55	2.94	0.39

When comparing actual to anticipated GPAs, Table 14 shows that both males and females over-estimated their scores. However, males over-estimated by a larger margin than females. The males in the sample of this study reported higher self-efficacy scores than the females. The over-reporting by male students may be directly related to their higher self-efficacy. Further research is needed on the effect of anticipated GPA versus actual GPA and relation to self-efficacy.

This study found differences between the sexes in both formal and informal engineering exposure. Males were shown to have significantly more exposure with both types. However, the differences between the sexes were less with formal exposure than informal exposure. Further research is needed on why the differences between the sexes exist and methods to increase female exposure to both formal and informal engineering experiences.

During the process of analyzing the self-efficacy of students in this study, students were asked for level of agreement with nine statements about their engineering coursework. As shown in Table 6, student self-efficacy decreased as the statements moved from basic concepts to complex material. While students believed they could master the basic concepts, they were less confident when the material became more difficult. Further research is needed to determine the effect of academic rigor in K-12 engineering outreach programs and the self-efficacy of students with complex or difficult engineering concepts. A hypothesis is that students who are exposed to complex engineering problems during K-12 instruction and taught problem-solving skills to work through them will have higher self-efficacy for challenges in college engineering coursework.

According to Bandura (1977), efficacy perceptions are gained through four major informational sources:

1. Personal performance and accomplishments – one's patterns of past successes and failures
2. Vicarious learning - comparing oneself to the performance of others
3. Social persuasion - encouragement or discouragement one receives from significant others
4. Physiological states and reactions - pleasant or unpleasant emotional or physical reactions (anxiety, fatigue, happiness, etc.)

While the four sources are commonly accepted as factors involved with self-efficacy development, little is known about the types of pedagogy that fosters high self-efficacy.

In particular, research is needed to explore how the four sources of self-efficacy are manifested in engineering outreach programs.

Conclusions

A shortage of U.S. trained engineers has been predicted in the near future. As global competitiveness increases, the U.S. needs to produce engineers capable of maintaining the nation as a world leader in the areas of science, technology, and engineering. To accomplish this task, programs that develop a source of top engineers need to be created. Consequently, the engineering community has reached out to K-12 education to produce a pipeline of students studying engineering. This study was an attempt to evaluate the effect of K-12 outreach programs to motivate students to study engineering and prepare them for the rigor associated with studying engineering at the collegiate level.

Through a questionnaire, it was determined that outreach programs are effective in recruiting students to study engineering. However, hobbies, toys, and work experiences were also influential. It appears that exposure to engineering content will assist in recruiting students to study engineering. Therefore, if the sole purpose is to recruit more students, focus should be placed on programs that offer the greatest number of students exposure to engineering content. In particular, single-day workshops or fieldtrips to engineering schools and colleges would be an effective method to expose large numbers of high school and middle school students at a relatively low cost.

The second part of this study evaluated the ability of K-12 outreach programs to prepare students to study engineering in college. Engineering self-efficacy was used to measure the preparedness of first-year engineering students. This study revealed that engineering outreach experiences did not result in significant differences in self-efficacy between students who participated in them and those who did not. In other words, students who experienced the outreach programs did not have a higher self-efficacy than those who did not. The only outreach programs that did show significant differences in student self-efficacy were the formal technology and pre-engineering classes. This could be a result of the academic rigor required by these classes or the extended exposure to engineering and technology content a student would experience in a formal educational setting. A two-week summer camp is much less likely to have the academic rigor of a graded class that would appear on a student's transcript. While students who participate in the summer camp would be more likely to pursue engineering than those who didn't, they would not be better prepared for success in engineering. However, the amount of dollar expenditures and effort in these outreach programs is significant. Meanwhile, we have trained technology teachers effectively infusing engineering principles in the formal setting of pre-engineering and technology classrooms. The results from this study indicate that students who have participated in these classes have a higher engineering self-efficacy than those who did not. Therefore, those interested in the K-12 preparation of students to study engineering in order to increase the pipeline of students choosing to pursue engineering in college should focus their interests and energy on formal K-12 technology and pre-engineering programs. Opportunities to engage in these programs are inexpensive and offer the possibility of both recruiting and preparing students for success in a collegiate engineering program. Second, colleges and schools of engineering could benefit from forming lasting partnerships with local teachers of technology and pre-engineering that could yield a natural continuum of students from technology and pre-engineering programs to college level programs in engineering.

In the context of this study, hobbies that require engineering related activities, analysis, and problem solving appear to have greater success in raising student self-efficacy. In particular, students who were involved with computer programming, electronics, and robotics have a better chance of success in an engineering program. This seems logical as many of the same aspects involved with the engineering design process are found in these hobbies (defining a problem, search for solutions, engineering analysis, optimization, etc.). The results of this study suggest that K-12 outreach programs with the goal of preparing students for success in engineering programs should model many of the same aspects of hobbies (hands-on, self-motivated, real-world application, etc.).

Another area for exploration for the engineering community involves methods to identify individuals who have a pre-disposition toward engineering. The hobbies identified as possible sources for increasing self-efficacy in this study are self-selected and require use of computer programming and electronics. If the engineering community is looking for students with a pre-disposition to study engineering, they may want to look at informal activities that are easily accessible. Examples of easily accessible activities include robotics clubs, gaming groups, and other community organizations directly involved with hobbies involving high-levels of engineering principles.

Females are typically underrepresented in engineering programs. While progress has been made to close the gap, there are still significantly more males studying engineering than females. Part of this study involved an analysis of the differences between males and females with regard to their self-efficacy. It was determined that females have lower self-efficacy in engineering than males. When the two groups were compared by achievement level, male self-efficacy proved to be higher than female self-efficacy at every level of achievement. Top achieving male students had higher self-efficacy than top achieving female students and struggling male students had a higher self-efficacy than struggling female students. Therefore, females are at a disadvantage at the beginning of the engineering degree process. This study also examined differences between the sexes in regard to K-12 engineering exposure. It revealed that females had significantly less exposure, both formal and informal, than males. With previous studies showing the positive correlation between exposure and self-efficacy (Multon et al., 1991; Bandura, 1977, 1997; Pajares, 1996) it is clear that increased K-12 engineering exposure for females would help decrease the self-efficacy differences between the sexes.

In reflecting on the results from this study, they seem to indicate that females who were engaged in formal pre-collegiate engineering activities had a higher self-efficacy than those who did not. This positive signal implies that strengthening and expanding pre-engineering and technology programs targeted at female students would be beneficial in closing the self-efficacy gap between the sexes. When examining programs that focus on promoting female participation, a majority are located outside the formal K-12 school environment (girl scouts, summer camps, etc.). However, results from this study indicate that the outreach programs outside the formal school environment are less effective in raising engineering self-efficacy than the formal K-12 school programs involving pre-engineering and technology. Therefore, those concerned with closing the self-efficacy gap between the sexes should focus their efforts and resources on promoting female participation in formal K-12 pre-engineering and technology programs.

This study was a broad examination of K-12 engineering outreach programs. Other influencing factors were compared to outreach programs to determine the ability of outreach programs to recruit and prepare future college engineering students. Future studies should narrow the scope and examine individual K-12 outreach programs. Such studies should also include the level of academic rigor involved with K-12 engineering outreach programs and resulting self-efficacy. As an engineering community, while we need to continue our K-12 efforts in recruiting and preparing students to study engineering in college and closing the self-efficacy gap between the sexes, it is clear we could be more efficient and optimal if we focus on pre-collegiate engineering experiences that promote engineering self-efficacy.

REFERENCES

Agresti, A., & Finlay, B. (1997). *Statistical Methods for the Social Sciences, third edition.* Upper Saddle River, NJ: 1997.

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy.* New York: Oxford University Press.

Astin, A. W. (1971). *Predicting Academic Performance in College.* New York: Free Press.

Astin, A. W., & Astin, H. S. (1992). *Undergraduate science education: The impact of different college environments on the educational pipeline in the sciences.* Los Angeles: University of California, Los Angeles.

Bandura, A. (1977). Self-Efficacy: Toward a unifying theory of behavioral change. *Phychological Review 84(2)* , 191-215.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist 37(2)* , 122-147.

Bandura, A. (1986). *Social Foundations of Thought and Action: A social cognative theory.* Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1997). *Self-Efficacy: The Exercise of Control.* New York: W. H. Freeman.

Bank, B. J., Slavings, R. L., & Biddle, B. J. (1990). Effects of peer, faculty, and parental influences on students' persistence. *Scoiology of Education 63* , 208-225.

Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1997). Characteristics of freshman engineering students: Models for determining student attrition in engineering. *Journal of Engineering Education 86(2)* , 139-149.

Betz, N. E. (2000). Self-efficacy theory as a basis for career assessment. *Journal of Career Assessment 8 (3)* , 205-222.

Borg, R. (1996). Factors determining career choice. *European Education 28(2)* , 6-21.

Boy Scouts of America. (2008). *Merit badge program.* Retrieved October 19, 2008, from Boy Scouts of America National Council: http://www.scouting.org/media/factsheets/02-500.aspx

Brainard, S. G., Laurich-McIntyre, S., & Carlin, L. (1995). Retaining female undergraduate students in engineering and science. *Journal of Women and Minorities in Science and Engineering 2* , 255-267.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education 97(3)* , 369-387.

Burtner, J. (2004). Critical-to-quality factors associated with engineering student persistence: The influence of freshman attitudes. *34th ASEE/IEEE Frontiers in Education Conference.* Savannah, GA: IEEE.

Colorado State University. (2008). *Fact Book 2008-2009.* Retrieved January 18, 2009, from Institutional Research: http://www.ir.colostate.edu/pdf/fbk/0809/fctbk0809.pdf

Cohen, J. (1988). *Statistical Power and Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Committee on Science, Engineering, and Public Policy. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Washington, DC: The National Academies Press.

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Thousand Oaks, CA: SAGE Publications, Inc.

Crotty, M. (1998). *The Foundations of Social Research: Meaning and Perspective in the Research Process.* Thousand Oaks, CA: Sage Publications, Inc.

CU College of Engineering. (n.d.). *Our History.* Retrieved October 19, 2008, from Integrated Teaching and Learning Program: http://itll.colorado.edu/ITLL/index.cfm?fuseaction=OurHistory

DeVellis, R. F. (2003). *Scale Development: Theory and Applications.* Thousand Oaks, CA: Sage Publications, Inc.

Field, A. (2005). *Discovering Statistics Using SPSS: Second edition.* Thousand Oaks, CA: SAGE Publications.

Freeman, R. B. (2005). *Does Globalization of the Scientific/engineering Workforce Threaten U.S. Economic Leadership?* Cambridge, MA: National Bureau of Economic Research.

French, B. F., Immekus, J. C., & Oakes, W. C. (2005). An examination of indicators of engineering students' success and persistence. *Journal of Engineering Education 94(4)* , 419-425.

Garcia, T., & Pintrich, P. R. (1995). *Assessing students' motivation and learning strategies: The Motivated Strategies for Learning Questionnaire.* Retrieved October 22, 2008, from Eric Document Reproductive Service No. Ed 383770: http://www.eric.ed.gov/ERICWebPortal/Home.portal?_nfpb=true&ERICExtSearch_SearchValue_0=no:ed383770&searchtype=basic&ERICExtSearch_SearchType_0=no&page

Size=10&eric_displayNtriever=false&eric_displayStartCount=1&_pageLabel=RecordDetails&objectId=0900019b80

Girl Scouts of the United States of America. (2008). *Science, Technology, Engineering, and Math (STEM)*. Retrieved October 19, 2008, from Girl Scouts: http://www.girlscouts.org/program/program_opportunities/science/

Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math-related majors of college women and men: A path analysis. *Journal of Counseling Psychology 32 (1)*, 47-56

Hartman, H., & Hartman, M. (2006). Leaving engineering: Lessons from Rowan University's College of Engineering. *Journal of Engineering Education 95(1)* , 49-61.

Healy, C. C., O'Shea, D., & Crook, R. H. (1985). Relation of career attitudes to age and career progress during college. *Journal of Counseling Psychology 32(2)* , 239-244.

International Technology Education Association. (2000). *Standards for Technological Literacy: Content for the Study of Technology 3rd ed.* Reston, VA: International Technology Education Association.

Jeffers, A. T., Safferman, A. G., & Safferman, S. I. (2004). Understanding K-12 engineering outreach programs. *Journal of Professional Issues in Engineering Education and Practice 130(2)* , 95-108.

Kleif, T., & Faulkner, W. (2002). Boys and their toys: Men's pleasures in technology. *Wie naturlich ist Geschlecht? Gender und die Konstruktion von Natur und Technik* , 240-255.

Koch, D. C. (2006). Factors that influence students' choice of careers in Construction Management . *Ph.D. dissertation, Purdue University* . Indiana: from Dissertations & Theses: Full Text database. (Publication No. AAT 3263590).

Larson, J. H., Butler, M., Wilson, S., Medora, N., & Allgood, S. (1994). The effects of gender on career decision problems in young adults. *Journal of Counseling & Development 73* , 79-84.

LeBold, W. K., & Ward, S. K. (1988). Engineering Retention:National and International Perspectives. *Proceedings, 1988 ASEE Annual Conference* (pp. 843-851). ASEE.

Lent, R. W., Brown, S. D., Talletrand, R., McPartland, E. B., Davis, T., Chopra, S. B., et al. (2002). Career choice barriers, supports, and coping strategies: College students' experiences. *Journal of Vocational Behavior 60* , 61-72.

Levin, J., & Wyckoff, J. (1990). *Identification of student characteristics that predict persistence and success in an engineering college at the end of the sophomore year: Informing the* *practice of academic advising.* Division of Undergraduate Studies Report No. 1990.1: University Park, Pennsylvania State University.

Mendez, G., Buskirk, T. D., Lohr, S., & Haag, S. (2008). Factors associated with persistence in science and engineering majors: An exploratory study using classification trees and random forests. *Journal of Engineering Education 97(1)* , 57-70.

Morgan, G. A., Gliner, J. A., & Harmon, R. J. (2006). *Understanding and Evaluating Research in Applied and Clinical Settings.* Mahwah, NJ: Lawrence Erlbaum Associates.

Morgan, G. A., Leech, N. L., Gloeckner, G. W., & Barrett, K. C. (2007). *SPSS for Introductory Statistics: Use and Interpretation Third edition.* Mahwah, NJ: Lawrence Erlbaum Associates.

Morrison, C., Griffin, K., & Marcotullio, P. (1995, December). Retention of minority students in engineering. *NACME Research Letter 5(2)* , pp. 1-20.

Moskal, B. M., Skokan, C., Kosbar, L., Dean, A., Westland, C., Barker, H., et al. (2007). K-12 outreach: Identifying the broader impacts of four outreach projects. *Journal of Engineering Education 96(3)* , 173-189.

MSPnet. (2008). *Project profile: "Rocky Mountain Middle School Math Science Partnership".* Retrieved October 19, 2008, from MSP Projects: http://hub.mspnet.org/index.cfm/showcase_project/project_id-4800

Multon, K., Brown, S., & Lent, R. (1991). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology 38(1)* , 30-38.

National 4-H Council. (2008). *Science, engineering, & technology.* Retrieved October 19, 2008, from National 4-H Council: http://www.fourhcouncil.edu/scienceengineeringtechnology.aspx

National Research Council. (2003). *National Science Education Standards.* Washington, DC: National Acadamy Press.

National Science Board. (2003). *The science and engineering workforce realizing America's potential.* Retrieved September 21, 2008, from http://www.nsf.gov/nsb/documents/2003/nsb0369/nsb0369.pdf

Noeth, R. J., Cruce, T., & Harmston, M. T. (2003). *Maintaining a Strong Engineering Workforce: ACT policy report.* Iowa City, IA: ACT.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research 66(4)* , 543-578.

Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concept beleifs in mathematical problem solving: A path analysis. *Journal of Educational Psychology 86(2)*, 193-203.

Pintrich, P. K., Smith, D. A., Garcia, T., & McKeachie, W. J. (1991). *A Manual for the use of the Motivated Strategies for Learning Questionnaire.* Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (MSLQ). *Educational and Psychological Measurement 53*, 801-813.

Poole, S. J., deGrazia, J. L., & Sullivan, J. F. (1999). Assessing K-12 pre-engineering outreach programs. *29th ASEE/IEEE Frontiers in Education Conference.* San Juan, PR: IEEE.

Popper, S. W., & Wagner, C. S. (2002). *New Foundations for Growth: The U.S. Innovative System Today and Tomorrow.* Santa Monica, CA: Rand.

Reagor, J. D., & Rehm, M. L. (1995). Perspectives on work from rural parents with different levels of education. *Journal of Vocational and Technical Education 12(1)*, Retrieved October 12th, 2008 from http://scholar.lib.vt.edu/ejournals/JVTE/v12n1/Reagor.html.

Reyer, J. A. (2007). Influence of high school students' perceptions on their preperation for engineering. *37th ASEE/IEEE Frontiers in Education Conference.* Milwaukee, WI: IEEE.

Reys, M. A., Anderson-Rowland, M. R., & McCartney, M. A. (1999). Student success: What factors influence persistence? *29th ASEE/IEEE Frontiers in Education Conference* (pp. 21-25). San Juan, PR: IEEE.

Sandler, M. E. (2000). Career-decision making self-efficacy, perceived stress, and an integrated model of student persistence: A structural model of finances, attitudes, behavior, and career development. *Research in Higher Education 41 (5)*, 537-580.

Santiago, A. M., & Einarson, M. K. (1998). Background characteristics as predictors of academic self-confidence and academic self-efficacy among graduate science and engineering students. *Research in Higher Education 39(2)*, 163-198.

Sax, L. J. (1994). Retaining tomorrow's scientists: Exploring the factors that keep male and female college students interested in science careers. *Journal of Women and Minorities in Science and Engineering 1(1)*, 45-61.

Schunk, D. (1989). Self-efficacy and cognitive skill learning. In C. Ames, & R. Ames, *Research on Motivation in Education: Vol 3. Goals and Cognitions* (pp. 13-44). San Diego, CA: Academic Press.

Selingo, J. (2007). Powering up the pipeline: Schools hope their innovative K-12 programs will propel more students into college engineering courses-and careers. *Prism 16(8)* , Retrieved October 12th, 2008 from http://www.prism-magazine.org/apr07/feature_K-12.cfm.

Seymour, E., & Hewitt, N. M. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, CO: Westview Press.

Seymour, E., & Hewitt, N. (1994). *Talking About Leaving. Factors Contributing to High Attrition Rates Among Science, Mathematics, and Engineering Undergraduate Majors: Final report to the Alfred P. Sloan Foundation on an ethnographic inquiry at seven institutions.* Boulder, CO: Westview Press.

Shuman, L. J., Delaney, D., Wolfe, H., Scalise, A., & Besterfield-Sacre, M. (1999). *Engineering attrition: Student characteristics and educational initiatives.* Retrieved July 11, 2008, from ASEE conference: Session 1430: http://www.me.pitt.edu/~ec2000/grant_papers/Shuman+ASEE-99.PDF

Splete, H., & Freeman-George, A. (1985). Family influences on the career development of young adults. *Journal of Career Development 12*(1) , 55-64.

Staff, C. C. (2007). *Colorado State University College of Engineering.* Retrieved July 26, 2008, from Undergraduate Recruiting: http://www.engr.colostate.edu/dean/admin/strategic_plan.shtml

Streveler, R. A., Moskal, B. M., Miller, R. L., & Pavelich, M. J. (2001). Center for engineering education: Colorado School of Mines. *Journal of Engineering Education 90(3)* , 383-387.

VanderStoep, S. W., & Pintrich, P. R. (2003). *Learning to learn: The skill and will of college success.* Upper Saddle River, NJ: Prentice Hall.

Williams, A. B. (2003). The qualitative impact of using LEGO MINDSTORMS robots to teach computer engineering. *IEEE Transactions on Education 46(1)* , 206.

Young, R. A. (1994). Helping adolescents with career development: The active role of parents. *Career Development Quarterly 42(3)* , 195-204.

Zhang, G., Anderson, T., Ohland, M., Carter, R., & Thorndyke, B. (2004). Identifying factors influencing engineering student graduation and retention: A longitudinal and cross-institutional study. *Journal of Engineering Education 93 (4)* , 313-320.

APPENDIX A. PILOT INSTRUMENT

Thank you for completing this survey. The data from this survey will help in the development of middle school and high school pre-engineering programs. Your participation in this study is voluntary and your identity will be confidential. Participation in this survey will not affect your grade in this class. You may withdraw your consent and stop participating at any time while completing the survey. Turing in the survey will serve as your voluntary participation in this study.

About me:

Answer the following questions by circling the letter next to the response that best describes who you are.

1. What is your age?
   a. 17 years or under
   b. 18
   c. 19
   d. 20
   e. 21-24
   f. 25 years or older
2. What is your sex?
   a. Male
   b. Female

3. Are you a resident of Colorado?
   a. Yes
   b. No

4. Are you a first-generation college student?
   a. Yes
   b. No

5. What was your high school GPA range?
   a. 4.00 or greater
   b. 3.50-3.99
   c. 3.00-3.49
   d. 2.50-2.99
   e. 2.00-2.49
   f. 1.99 or less
   g. I don't know

6. What is your anticipated GPA from your first semester in an engineering program?
   a. 3.50-4.00
   b. 3.00-3.49
   c. 2.50-2.99
   d. 2.00-2.49
   e. 1.99 or less
   f. I don't know

7. What is your engineering major?
   a. Biomedical
   b. Chemical and Biological
   c. Civil
   d. Computer
   e. Electrical
   f. Engineering science
   g. Environmental
   h. Mechanical
   i. Undeclared/undecided
   j. Other ____________________

8. What is your ethnicity (circle all that apply)
   a. African American/Black (non-Hispanic)
   b. American Indian/Alaskan Native
   c. Asian American/Asian
   d. Hispanic/Latino
   e. Native Hawaiian/Pacific Islander
   f. White (non-Hispanic)
   g. Multi-racial (more than one race/ethnicity)
   h. I prefer not to respond
   i. Other: ____________________

9. Why did you choose to study engineering?

My engineering experiences and events

Please place an X next to each experience you have had or event you attended.

Middle school or high school pre-engineering classes

____Engineering class
____Drafting class
____Programming class
___Technology class
___Other: ________________________.
___Other: ________________________.

Working for engineering or construction company

___Summer job
___Full-time job
___Field work
___Office work
___Other: ________________________.
___Other: ________________________.

Multi-day program focused on engineering

____EWeek
____Girl Scouts/Boy Scouts
____iD Tech camp
____ASM Materials camp
____Mines- Engineering Design camp
___Mines-Prep. for engineering program
____ DU-Making of an engineer/scientist
____CU-High school honors institute
____CU-Success Institute
____PEER summer camp
____Other: ________________________.
____Other: ________________________.

Extra-curricular engineering program at your school

____FIRST robotics
____JETS
____Future City
___TechXplore
____BEST robotics
____ThinkQuest
____LEGO Engineering
____INSPIRE!
____Botball
____Odyssey of the Mind
____WestPoint Bridge Competition
____Other: ________________________.
____Other: ________________________.

Personal hobbies or toys

____Building/assembly (LEGOS, Connex)
____Model rockets/airplanes
____Robotics
____Radio-controlled toys
____Video games
____Programming
____Electronics kits
____Microscopes
____Other: ________________________.
____Other: ________________________.

Single day workshops or field trips that focused on engineering

____CSU High School days
____School of Mines visit
____CU Discover Engineering Day
____Middle School MESA day
____Other: ________________________.
____Other: ________________________.

Please respond to the following statements by circling the letters for the level of agreement that is true for you. Circle "N/A" if you did not have that experience. If needed, see the previous page for examples of each experience.

N/A = Not Applicable, SA = Strongly Agree, A = Agree, SWA = Somewhat Agree, N = Neither Agree Nor Disagree, SWD = Somewhat Disagree, D = Disagree, SD = Strongly Disagree

My middle school or high school pre-engineering class(es) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My multi-day program(s) that focused on engineering completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My work for an engineering or construction company completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My extra-curricular engineering program(s) at school completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My personal hobbies and/or toys completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My single day workshop(s) or field trip(s) that focused on engineering completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
Something not on this list completely influenced my decision to study engineering. (please list ____________________)	N/A	SA	A	SWA	N	SWD	D	SD

Please respond to the following statements by circling the letters for the level of agreement that is true for you. Circle "N/A" if you do not have contact with the individual.

N/A = Not Applicable, SA = Strongly Agree, A = Agree, SWA = Somewhat Agree, N = Neither Agree Nor Disagree, SWD = Somewhat Disagree, D = Disagree, SD = Strongly Disagree

My parent(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My sibling(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My other relative(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My friend(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My teacher(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My school counselor completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My co-worker(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
Someone not on this list completely influenced my decision to study engineering. (please list ____________________)	N/A	SA	A	SWA	N	SWD	D	SD

<u>My engineering Self-confidence</u>

Please respond to the following statements by circling the letters for the level of agreement that is true for you.

SA = Strongly Agree, A = Agree, SWA = Somewhat Agree, N = Neither Agree Nor Disagree, SWD = Somewhat Disagree, D = Disagree, SD = Strongly Disagree

I believe I will receive excellent grades in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm certain I can understand the most difficult material presented in the readings for my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm confident I can understand the basic concepts in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm confident I can understand the most complex material presented by the instructors in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm confident I can do an excellent job on the assignments and tests in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I expect to do well in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm certain I can master the skills being taught in my engineering classes.	SA	A	SWA	N	SWD	D	SD
Considering the difficulty of my engineering courses, the teachers, and my skills, I think I will do well in my engineering classes.	SA	A	SWA	N	SWD	D	SD

You're done. Thank you for participating in this survey!!!

APPENDIX B. FINAL INSTRUMENT

Written on board: "Questions/comments, contact: Todd Fantz 303-601-3090"

Recruitment text (verbal):

Hello. My name is Todd Fantz and I'm a doctoral student in the School of Education. I am asking for your participation in my dissertation research study of your pre-collegiate experiences, your influences to study engineering, and your self-confidence in the subject of engineering.

You are being asked to participate in this study because you are in your first year of studying engineering at Colorado State University.

The purpose of the study is to determine what exposure to engineering have you had before coming here, why you chose to study engineering, and if there is any relationship between your exposure to engineering, reasons you chose to study engineering, and your self-confidence in studying engineering.

You will be asked to complete a 5 to 10 minute survey asking you about your engineering experiences, reasons why you chose to study engineering, and your engineering self-confidence. Your participation is voluntary and your identity will be kept anonymous. You may stop participating at any time during the survey.

When you are finished, please place your survey in the boxes by the doors.

Thank you for completing this survey. The data from this survey will help in the development of middle school and high school pre-engineering programs. Your participation in this study is voluntary and your identity will be anonymous. Participation in this survey will not affect your grade in this class. You may withdraw your consent and stop participating at any time while completing the survey. Turning in the survey will serve as your voluntary participation in this study.

PRINCIPAL INVESTIGATOR:	Michael De Miranda, Ph.D. School of Education, 105H 970-491-5805
CO-INVESTIGATOR:	Todd D. Fantz Research and Development Center 303-601-3090
BENEFITS FOR PARTICIPATING:	None known
RISKS OF PARTICIPATION:	None known

About me:

Answer the following questions by circling the letter next to the response that best describes who you are.

1. What is your age?
   a. 17 years or under
   b. 18
   c. 19
   d. 20
   e. 21-24
   f. 25 years or older

2. What is your engineering major?
   a. Biomedical
   b. Chemical and Biological
   c. Civil
   d. Computer
   e. Electrical
   f. Engineering science
   g. Environmental
   h. Mechanical
   i. Undeclared/undecided
   j. Other ____________________

3. What is your sex?
   a. Male
   b. Female

4. Are you a resident of Colorado?
   a. Yes
   b. No

5. Are you a first-generation college student (neither parent graduated from college)?
   a. Yes
   b. No

6. Were either (or both) of your parents an engineer
   a. Yes
   b. No

7. What was your high school GPA range?
    a. 4.00 or greater
    b. 3.50-3.99
    c. 3.00-3.49
    d. 2.50-2.99
    e. 2.00-2.49
    f. 1.99 or less
    g. I don't know

8. What is your anticipated overall GPA from your first semester in an engineering program?
    a. 3.50-4.00
    b. 3.00-3.49
    c. 2.50-2.99
    d. 2.00-2.49
    e. 1.99 or less
    f. I don't know

9. What is your ethnicity (circle all that apply)
    a. African American/Black (non-Hispanic)
    b. American Indian/Alaskan Native
    c. Asian American/Asian
    d. Hispanic/Latino
    e. Native Hawaiian/Pacific Islander
    f. White (non-Hispanic)
    g. Multi-racial (more than one race/ethnicity)
    h. I prefer not to respond
    i. Other: ____________________

<u>My engineering Self-confidence</u>

Please respond to the following statements by circling the letters for the level of agreement that is true for you.

SA = Strongly Agree, A = Agree, SWA = Somewhat Agree, N = Neither Agree Nor Disagree, SWD = Somewhat Disagree, D = Disagree, SD = Strongly Disagree

I believe I will receive excellent grades in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm certain I can understand the most difficult material presented in the readings for my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm confident I can understand the basic concepts in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm confident I can understand the most complex material presented by the instructors in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm confident I can do an excellent job on the assignments in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm confident I can do an excellent job on the tests in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I expect to do well in my engineering classes.	SA	A	SWA	N	SWD	D	SD
I'm certain I can master the skills being taught in my engineering classes.	SA	A	SWA	N	SWD	D	SD
Considering the difficulty of my engineering courses and teachers, and my skills, I think I will do well in my engineering classes.	SA	A	SWA	N	SWD	D	SD

My engineering experiences and events

Please place an X next to each experience you have had or event you attended when you were in middle and/or high school.

Middle school or high school pre-engineering classes

- ____Engineering class
- ____Drafting class
- ____Programming class
- ___Technology education class
- ___Shop class
- ___Other: _______________________.

Working in engineering related environments

- ___Field work
- ___Office work
- ___Farm work
- ___Other: _______________________.

Multi-day program focused on engineering

- ____EWeek
- ____Boy Scouts/Girl Scouts
- ____iD Tech camp
- ____ASM Materials camp
- ____Mines- Engineering Design camp
- ___Mines-Prep. for engineering program
- ____ DU-Making of an engineer/scientist
- ____CU-High school honors institute
- ____CU-Success Institute
- ____PEER summer camp
- _____Other: _______________________.

Extra-curricular engineering program at your school

- ____FIRST robotics
- ____JETS
- ____Future City
- ___TechXplore
- ____BEST robotics
- ____ThinkQuest
- ____LEGO Engineering
- ____INSPIRE!
- ____Botball
- ____Odyssey of the Mind
- ____WestPoint Bridge Competition
- ____Science Olympiad
- ____Other: _______________________.

Engineering hobbies or toys you enjoyed

- ____Building toys (LEGOS, Connex)
- ____Building projects (cars, houses)
- ____Model rockets/airplanes
- ____Robotics
- ____Radio-controlled toys
- ____Produce video games
- ____Programming
- ____Electronics kits
- ____Microscopes
- ____Firearms
- ____Other: _______________________.

Single day workshops or field trips that focused on engineering

- ____CSU High School days
- ____CSU College Engineering/Career Day
- ____School of Mines visit
- ____CU Integrated Teaching and Learning
- ____CU Discover Engineering Day
- ____Middle School MESA day
- ____Air & Space Museum
- ____Other: _______________________.

My engineering influences

Please respond to the following statements by circling the letters for the level of agreement that is true for you. Circle "N/A" if you did not have that experience. If needed, see the previous page for examples of each experience.

N/A = Not Applicable, SA = Strongly Agree, A = Agree, SWA = Somewhat Agree, N = Neither Agree Nor Disagree, SWD = Somewhat Disagree, D = Disagree, SD = Strongly Disagree

My middle school or high school pre-engineering class(es) influenced my decision to study engineering.	N/A	SA A SWA N SWD D SD
My multi-day program(s) that focused on engineering influenced my decision to study engineering.	N/A	SA A SWA N SWD D SD
My work for an engineering or construction company influenced my decision to study engineering.	N/A	SA A SWA N SWD D SD
My extra-curricular engineering program(s) at school influenced my decision to study engineering.	N/A	SA A SWA N SWD D SD
My personal hobbies and/or toys influenced my decision to study engineering.	N/A	SA A SWA N SWD D SD
My single day workshop(s) or field trip(s) that focused on engineering influenced my decision to study engineering.	N/A	SA A SWA N SWD D SD
Something not on this list influenced my decision to study engineering. (please list ________________) (________________________)	N/A	SA A SWA N SWD D SD

My personal influences

Please respond to the following statements by circling the letters for the level of agreement that is true for you. Circle "N/A" if you did not have contact with the individual.

N/A = Not Applicable, SA = Strongly Agree, A = Agree, SWA = Somewhat Agree, N = Neither Agree Nor Disagree, SWD = Somewhat Disagree, D = Disagree, SD = Strongly Disagree

My parent(s) influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My sibling(s) influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My other relative(s) influenced my decision to study engineering. (please list ______________)	N/A	SA	A	SWA	N	SWD	D	SD
My friend(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My teacher(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My school counselor completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
My co-worker(s) completely influenced my decision to study engineering.	N/A	SA	A	SWA	N	SWD	D	SD
Someone not on this list completely influenced my decision to study engineering. (please list ________________)	N/A	SA	A	SWA	N	SWD	D	SD

In your own words, why did you choose to study engineering?

You're done. Thank you for participating in this survey!!!

APPENDIX C. PERMISSION TO USE MSLQ

To: "Todd Fantz" <todd.fantz@colostate.edu>
From: Marie Bien <mabien@umich.edu>
Subject: Re: Motivated Strategies for Learning Questionnaire (MSLQ)
Cc:
Bcc:
Attachments:

Dear Ms. Bien,

I am completing a doctoral dissertation at Colorado State University. I would like permission to duplicate the following for research use:

Title: A manual for the use of the motivated strategies for learning questionnaire (MSLQ)

Copyright: The Regents of the University of Michigan, 1991

Authors: Pintrich, P; Smith, D. A. F.; Garcia T.; and McKeachie, W.J.

Material to be duplicated: Self- efficacy subscale (items 5, 6, 12, 15, 20, 21, 29, and 31 from the questionnaire)

Use: To be included in my dissertation entitled "Pre-collegiate factors influencing the self-efficacy of first-year college engineering students"

The authors will be cited for their work on the MSLQ. Your electronic signature or e-mail reply signifies permission is granted.

Sincerely,

Todd D. Fantz
Doctoral Candidate

PERMISSION GRANTED
Marie Bien [Marie Bien]
OTHER CONDITIONS, IF ANY:

--
Todd D. Fantz
Graduate Research Assistant
Research and Development Center

APPENDIX D. COLORADO STATE UNIVERSITY IRB REQUEST FOR EXEMPTION

Colorado State University

Institutional Review Board

REQUEST FOR EXEMPTION

for the Use of Human Subjects in Research

Research involving surveys, interviews, the use of existing data, taste and food quality evaluation and standard educational research generally fall within the exempt category. Projects that are considered exempt must be less than minimal risk to the participants.

An IRB Administrator or IRB member must review the application and determine that the project is exempt from expedite or full review. Once a protocol has been determined to be exempt, the protocol will not be monitored by the IRB on an ongoing basis. If the research qualifies for exemption, a notification will be forwarded to the PI. Please keep the notification for documentation that the project is considered exempt and does not need continuing review by the IRB. The PI must notify the IRB Administrator if any proposed changes to the research will be made. At that time, an IRB Administrator or IRB member will determine whether the status of the research has changed. Any complaints that may have been received during the course of the research must also be reported.

A determination that research is exempt does not absolve the investigators from ensuring that the welfare of human subjects participating in research activities is protected, and that methods used and information provided to gain subject consent are appropriate to the activity.

Data collection may not begin until the PI has been notified that the project has been determined to be exempt.

Click to access the six exempt categories. Below are exceptions that are NOT considered exempt.

Exceptions:

Exemptions will not be granted for the following circumstances:

☐ Research involving prisoners. All prisoner research is reviewed by the full IRB.

☐ Research that includes both exempt and non-exempt activities cannot be determined to be exempt and should be submitted for expedite or full review.

☐ Research involving coercion, undue influence, deception, risks or discomforts greater than encountered in daily life.

☐ Research conducted outside of the United States.

Colorado State University

Institutional Review Board (IRB)

REQUEST FOR EXEMPTION

APPLICATION INSTRUCTIONS: Complete the 2 parts below, submit to address at the end of this form.

GENRAL INFORMATION

Title of Project: PRE-COLLEGIATE FACTORS INFLUENCING THE SELF-EFFICACY OF FIRST YEAR COLLEGE ENGINEERING STUDENTS

Principal Investigator (PI): Michael De Miranda **email:** mdemira@cahs.colostate.edu

Department: School of Education

Campus mail code: Education 105H **phone:** 970-491-5805

Co- Principal Investigator (Co-PI): Todd Fantz **email:** todd.fantz@colostate.edu

Department: School of Education

Campus mail code: type campus mail code here**phone:** 303-601-3090

Source of funding: Non-funded research

If externally funded, include PASS number if known: enter pass number here

Please provide a copy of the grant proposal, if applicable.

Indicate the anticipated start and ending date for this project.

Start: 12/1/2008 **End:** 7/3/2009

Rank of PI: ☒ Faculty ☐ PhD student ☐ Masters Student ☐ Undergraduate ☐ Other: describe 'other' here

PART II: PROJECT DESCRIPTION

1. **Provide a lay summary for all study activities.**
This study will examine pre-collegiate exposure to engineering content and influences toward the study of engineering of first-year engineering students at Colorado State University. The amount and type of engineering exposure will be compared to the engineeing self-confidence of the participants. The level of influence of the experiences and individuals who influenced the participants to study engineering will also be compared to the self-confidence of the participants.

2. **Describe the participant population, including age range and inclusion/exclusion criteria.**
Participant population includes all students in the first year of an engeering program at Colorado State University

3. **Describe how potential participants will be approached about the research and how informed consent will be obtained. Alternatively, provide an explanation of why informed consent or documented informed consent will not be obtained. Please attach a copy of the consent document, if applicable.**
A brief introduction of the project and request for participation will occur in four entry-level engineering courses. Students will be asked to be surveyed during the last 10 minutes of class time. Documented informed consent will not be obtained to ensure anonymity. A cover sheet will state, "Turing in the survey will serve as your voluntary participation in this study."

4. **Describe how identifying information will be recorded and associated with the data, i.e., codes. Alternatively, provide details on how study data will be collected and stored anonymously (i.e., without a code or identifiers linking the data to the participants' identity.)**
There will be no identifying information linking participants to surveys. All researchers involved will leave the room after the instrument is disseminated. A collection box near the exit will be used to ensure anonymity.

5. **Describe all study procedures, including topics that will be discussed in interviews and/or surveys. Please attach the interview questions or survey questions, if applicable.**
   The survey contains demographic questions of age, sex, residency, first-generation college student, high school GPA, engineering program, and ethnicity. The next two sections are a checklist of experiences and events related to engineering and the influence those experiences had to the participants interest to study engineering. The next section is concerned with individuals who influenced the participants (parents, friends, teachers, etc.) to study engineering and to what extent were they influential. The final section asks participants to state their level of confidence with engineering at CSU by using a 7-point Likert scale to measure agreement with 10 statements. See attached for the survey instrument.

6. **Which exemption category does your study fall in? (see next page of this document for description of categories)**
   category 2

As the principal investigator, I assure the IRB that all procedures performed under this project will be conducted exactly as outlined in this form and that any modification to this protocol will be submitted to the IRB in the form of an amendment for its approval prior to implementation.

Principal Investigator:

Michael De Miranda______________________________________ enter date here

(typed/printed name) (signature) (date)

WHEN COMPLETE:

Email electronic version from PI's email address to: Janell.Barker@Research.Colostate.edu

Sent email will serve as electronic signature from PI.

OR

Deliver signed original copy to:

IRB Administrator, RICRO, 321 General Services Building, campus delivery 2011

Thank you! We will soon contact you regarding the status of this application.

APPENDIX E. COLORADO STATE UNIVERSITY IRB APPROVAL LETTER

Colorado State University

Research Integrity & Compliance Review Office
Office of Vice President for Research
Fort Collins, CO 80523-2011
(970) 491-1553
FAX (970) 491-2293

DATE: December 1, 2008

TO: Michael DeMiranda, Education, 1588
Todd Fantz, Education, 1588

FROM: Janell Barker, IRB Administrator
Research Integrity & Compliance Review Office

TITLE: Pre-Collegiate Factors Influencing the Self-Efficacy of First Year College Engineering Students

IRB ID: 028-08H **Review Date:** December 1, 2008

The Institutional Review Board (IRB) Administrator has reviewed this project and has declared the study exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b)(2). The IRB determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as proposed in the Exempt application**, including obtaining and documenting (signed) informed consent if stated in your application or if required by the IRB.
- **Any modification of this research should be submitted to the IRB through an email to the IRB Administrator, prior to implementing any changes**, to determine if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB proposal will need to be submitted and approved before proceeding with data collection.
- **Please notify the IRB if any problems or complaints of the research occur.**

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB may make the determination of exemption**, even if you conduct a similar study in the future.

APPENDIX F. SUMMARY OF ENGINEERING EXPERIENCES

Middle school or high school pre-engineering classes	N	%	Working in engineering related environments	N	%
Engineering class	46	13.9	Field work	50	15.1
Drafting class	85	25.6	Office work	24	7.2
Programming class	58	17.5	Farm work	40	12.0
Technology education class	131	39.5	Other:	27	8.1
Shop class	149	44.9			
Other	16	4.8			
Multi-day program focused on engineering			**Extra-curricular engineering program**		
EWeek	6	1.8	FIRST robotics	11	3.3
Boy Scouts/Girl Scouts	50	15.1	JETS	3	0.9
iD Tech camp	1	0.3	Future City	4	1.2
ASM Materials camp	0	0	TechXplore	1	0.3
Mines- Engineering Design camp	3	0.9	BEST robotics	0	0
Mines-Prep. for engineering program	2	0.6	ThinkQuest	0	0
DU-Making of an engineer/scientist	0	0	LEGO Engineering	9	2.7
CU-High school honors institute	8	2.4	INSPIRE!	0	0
CU-Success Institute	7	2.1	Botball	0	0
PEER summer camp	3	0.9	Odyssey of the Mind		
Other:	9	2.7	WestPoint Bridge Competition	14	4.2
			Science Olympiad	25	7.5
			Other:	18	5.4
Engineering hobbies or toys			**Single day workshops or fieldtrips**		
Building toys (LEGOS, Connex)	263	79.2	CSU High School days	20	6.0
Building projects (cars, houses)	181	54.5	CSU College Engineering/Career Day	82	24.7
Model rockets/airplanes	180	54.2	School of Mines visit	43	13.0
Robotics	72	21.7	CU Integrated Teaching and Learning	0	0
Radio-controlled toys	163	49.1	CU Discover Engineering Day	15	4.5
Produce video games	48	14.5	Middle School MESA day	7	2.1
Programming	53	16.0	Air & Space Museum	54	16.3
Electronics kits	81	24.4	Other:	5	1.5
Microscopes	67	20.2			
Firearms	127	38.3			
Other:	12	3.6			