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THE ROLE OF ACADEMIC ABILITY IN CHOICE OF MAJOR AND PERSISTENCE IN STEM FIELDS

A Thesis

Submitted to the Faculty

of

Purdue University

by

Anne Marie Lucietto

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

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DEDICATION

This work is dedicated to my family.
This includes
my husband Richard,
my daughter Elisabeth,
my parents Ledo and Elaine,
my aunts, uncles, numerous cousins and friends throughout the world.

They have supported me from the beginning to the end,
through situations that have been thrown in my path,
they have been there and supported me in every way.

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ABSTRACT

Lucietto, Anne M., PhD, Purdue University, August 2014. The Role of Academic Ability in Choice of Major and Persistence in STEM Fields. Major Professor: Matthew W. Ohland.

This study is intended to provide a greater understanding of academic ability and to determine whether it plays a role in the choice of college major. Further, it is also intended to evaluate persistence as it relates to the continuation and modification of choice of major among exceptional students and typical students. The population studied included students from nine public universities in the southeastern United States and spans the timeframe inclusive of 1996 through 2010. These universities are part of a dataset known as Multiple Institutions Database for Investigating Engineering Longitudinal Development (MIDFIELD) project.

A quantitative research program was developed and instituted to answer research questions focused on academic ability and persistence. MIDFIELD data was examined for typical and exceptional students, contrasting demographic data, choice of major at matriculation, choice of major after completion of a FYE program, and the timing and choice of new major if changed. Exceptional students are defined and extracted from the typical student data as the top 3% of students using composite SAT scores. The composite scores were derived as a result of adding the mathematical and verbal scores. These datasets were tabulated, graphed and compared cross tabulation and clustering were also used to examine the data. Cluster analysis provides a better understanding of

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students' change of major and continuation in major areas by grouping data by SAT scores and analyzing the majors most represented in each of the clusters.

The findings indicate that academic ability is not a predictor of persistence. However, exceptional students most often choose STEM majors and tend to stay in STEM fields if chosen at matriculation or following the completion of an FYE program. Therefore, students with higher SAT scores and high school GPAs are more likely to choose majors in STEM subject areas. When exceptional students are examined separately, the data indicates that they are most likely to choose an engineering major. While typical students that graduated with a business degree frequently began their study in a FYE program.

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CHAPTER 1. INTRODUCTION

A great deal of research has been done to further understand the decisions made by students who pursue engineering as a choice of major upon matriculation into an engineering college. The spectrum of research is large. Some researchers narrow the subjects of research, such as Lubinski and Benbow (2006), whose focus is on highly gifted students. Others narrow the areas they research, such as Lichtenstein, Loshbaugh, Claar, Chen, Jackson, and Sheppard (2009) or Lent, Sheu, Singley, Schmidt, Schmidt, and Gloster (2008), whose focus is on the process students use to make a career decision.

Work has been done on how academic ability plays a part in a student's choice of major, however, detail on majors and sub majors, such as engineering and mechanical engineering, and is not readily available. Only recently have students been studied to further understand why they persist in engineering or other STM fields. Those who have studied academic ability generally do not focus on engineering students or others in the STM areas. Lichtenstein, et al. (Lichtenstein, et al., 2009) assert that the decision-making process students use to decide if they will pursue a STEM major is not understood, nor has it been researched at length. This thesis will focus on academic ability and the role it takes in a student's choice of major.

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Recently, some work has been done on persistence and furthering our understanding of how students continue or modify their career decisions. Researchers have asserted that persistence rates for engineering students are no different from those for students studying other areas of STM (Ohland et al., 2008). Matusovich, Streveler, and Miller (2010) assert that while researchers are able to provide characteristics and descriptions of students who persist in a major, there is a general lack of understanding about the decisions they make about their major and persisting in that field of study.

While persistence has been studied, there is a further lack of understanding of how academic ability contributes to the choice of a college major. Ultimately, tying the two together helps in determining if there is a fundamental connection between academic ability and persistence in STEM fields. Research in this area is expected to provide information of particular interest to college recruiters and administrators, providing them with a greater understanding of academic ability and if it can be used to predict or relate to persistence in these fields of study.

The purpose of this research is to provide a greater understanding of the role academic ability plays in a student's choice of major and the persistence he or she exhibits in their academic field of choice. This research is expected to provide a further contrast or likening between students considered exceptional or high achieving and those that are typical of the general population of matriculating students.

Organization

This document consists of five chapters. This chapter is the Introduction, which provides for a general background on the study rationale, the research questions, and other information that will aid in the understanding of this research.

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Chapter 2 is the Literature Review, which provides a synthesis of research as it relates to this study and work in this area. This work provides a view of the subject matter through the lens of STEM, particularly engineering. The summary section provides a synthesis of limitations in present research, substantiating a justification for this unique work.

The third chapter focuses on how the research was performed. The fourth chapter covers not only the findings from the research, but general discussion regarding the findings and reasoning for doing and providing additional analysis. The final chapter of this document is the Conclusion chapter. This final chapter provides insight into the research questions as well as suggestions for future work in this area.

A key construct in this dissertation is Multipotentiality. Multipotentiality affects all exceptional students, because they are faced with an overwhelming number of attractive choices of majors (Achter, Lubinski, & Benbow, 1996). Multipotentiality can be defined as the tendency to perform well in multiple areas or careers. Another foundation for this thesis work is the College Impact Model. The College Impact Model, particularly those concepts contributed by Tinto focus on academic and social integration supporting the concept that student belief and choices are a result of their environment and experiences (Maruyama, 2012).

Therefore, this model will provide a greater input regarding student major choices and the relationship of standardized testing to a choice of major. It also will allow further study in this area by providing a basis in which to continue analysis and understanding of the findings.

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Research Questions

The problem statement made earlier and framework chosen for use in this study are addressed by the following research questions:

Academic Ability

- What is the relationship between standardized test scores and choice of major among exceptional students?
- How is the relationship between standardized test scores and choice of major for the typical student different from the relationship observed for exceptional students?

Persistence

- What academic pathways do students follow as they progress through STEM degree programs?
- How do those decisions affect those students’ choices to continue study in STEM fields?
- How are the pathways and outcomes of exceptional students different from those of the typical student?

The following null hypotheses provide relevance, validity, and testability for this study.

- No relationship exists between standardized test scores and choice of major.
- No differences exist between choices made by exceptional and typical students.
- No differences exist in the academic pathways chosen by exceptional and typical students.

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Delimitations and Limitations of Study

The Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) contains over one million student records and data from 11 universities in the southeastern United States. Because MIDFIELD contains whole population data, all differences are real and no inference is required, although it is still possible to calculate various statistical quantities to describe the data. Other studies, such as the Study of Mathematically Precocious Youth (SMPY) which is a much smaller database containing longitudinal records from approximately 5,000 students who are of the highest scoring students on the SAT. This dataset, by virtue of its selection and the interventions provided to the study population, is by design a highly biased sample of a larger population. Research on the SMPY dataset (Lubinski & Benbow, 2006) aims to describe this special population, but the sample may have other undesirable biases such as a socioeconomic bias.

Differences in an analysis would be expected of data taken from a whole dataset and from a sample dataset, unless the data mined from the whole dataset was targeted at the same demographic as the sample derived data. MIDFIELD includes whole population data, including those with lower performance than those in talent identified datasets. Comparison to datasets that have been derived by defining exceptional students can be done by extracting student data for those students who performed exceptionally well on the SAT in the MIDFIELD dataset.

Keeping innate differences of the population in mind, initially a comparison of mean and standard deviation would provide a good initial comparison of the datasets.

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However, given the number and consistency of participants, I would expect the small sample data taken from studies of high performing to present higher means than the MIDFIELD data. The standard deviation for comparison means should be narrower because the range of the population studied has been restricted. After comparing the results, one may consider calculating an eta squared or Cohen's d to see how much the datasets vary from one another (Pallant, 2010).

Concern regarding exceptional students exists in the comparison of data, particularly because of the different methods used to choose participants while they are in different levels of schooling. This is meaningful, because many typical students are taught to take the SAT, potentially skewing the analysis.

Further limitations exist when comparing results of this analysis to analysis done on data taken from a talent identification participant. Both these datasets and MIDFIELD are considered longitudinal. However, if a comparison of data were to be made, consideration of collection dates to remove social differences and demographics must be made. This will eliminate any differences due to the population in the different studies.

What Can Be Learned from this Research

The research questions and techniques used in this study have not been done previously using MIDFIELD. This work will shed light on the relationships between SAT scores and students' academic choices, such as choice of major at matriculation, and changes that students make as they traverse their academic career. This work will further clarify the impact of First-Year Engineering (FYE) programs and how the pathways and outcomes of exceptional students differ from those of typical students. Due to the unique

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attributes of the MIDFIELD data, such as period of data collection, consistency of data collected, and breadth of participants, correlations and relationships can be established that provide insight into areas that have not yet been explored.

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CHAPTER 2. BACKGROUND

Introduction

The focus of the research studies a narrow facet of academic ability, observes majors chosen by groups of students, and investigates the academic trajectory these students take while in college. Students are broken into two categories typical (the whole population) and exceptional (students with a combined SAT score placing them in the top 3% of students taking the SAT).

The first section of this chapter is a brief summary and analysis of prior research regarding the use of standardized testing, issues regarding when testing occurs, and how socioeconomic factors may play a large role in who is considered and performs as an exceptional student. This chapter goes on to frame the present work by discussing previous research on how academic ability as defined by standardized testing relates to the student’s choice of major, various theories and frameworks that can be used to research career decisions, and how various types of capital affect the choices that students make. Much of the research in this area has been on exceptional students. This work will extend this research to study the general population of students, providing us with an overall understanding of issues related to the academic ability and a student’s choice of major.

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The second section of this chapter focuses on persistence, in particular understanding what researchers have uncovered regarding persistence, discussion of models of persistence, the role of engagement in persistence. This section will provide an overview of available research on persistence, and when available, particularly in engineering and the other STEM fields.

The last section summarizes findings from prior research to provide a rationale for the research questions and hypotheses for this work. The order of discussion is based upon available research; more research has been done with regard to academic ability and standardized test scores than persistence. The literature presented in the first major section of this chapter provides the lens to further explore persistence.

Academic Ability

To understand students and their choice of majors, it is important to understand the role that academic ability plays in their choice of majors. Much of our understanding of academic ability originates in the works by Study of Mathematically Precocious Youth (SMPY) researchers and summarized by Lubinski and Benbow (2006) in their work intended to consolidate findings over a number of years. Through the development of SMPY, a process of participant identification referred to as Talent Identification was developed. Researchers such as Lubinski and Benbow and others who use the Talent Identification Program process have contributed to the information that is available on exceptional students. These researchers believe that providing interventions to exceptional students will provide them with a basis for pursuing STEM majors when they matriculate to college. They examine data after graduation for relationship to the degree

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earned by each of these students, finding that students with certain types of earned degrees had different characteristic SAT scores.

Researchers using the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) dataset have contributed to various conclusions regarding large populations of students. MIDFIELD offers us an opportunity address the same questions in exceptional and typical students who have not received SMPY interventions. Researchers using MIDFIELD data have provided findings that will allow comparisons of exceptional students and typical students with a larger variety of cognitive abilities. To further understand the choices made by students, we will examine academic ability as defined by standardized test scores. This will provide understanding of some of the arguments for and against the use of standardized testing by academia.

Standardized Tests as a Predictor of Academic Achievement

Before applying to college, students are required to take a variety of examinations. Many students fear tests, usually experiencing cognitive fatigue (Ackerman, Kanfer, Shapiro, Newton, & Beier, 2010). The results of those test-taking experiences are often less representative of students’ capabilities than they should be. Some argue that the standardized testing is nothing more than a way to determine socioeconomic status (Sackett, Kuncel, Arneson, Cooper, & Waters, 2009; Sackett et al., 2012).

Use of Standardized Testing.

There is a great deal of discussion and disagreement regarding the use of SAT scores as a predictor of college success (Gregory Park, David Lubinski, & Camilla P Benbow, 2007). Park, Lubinski, and Benbow (2007) argue that when normative assessments are used to evaluate exceptional students, they all receive high scores, so the scores do not differentiate enough to be useful. However, later, when

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students who did not meet the SMPY criteria take the SAT and score well, the SMPY study does not include them in their pool of students and therefore are unable to track student choice and achievement. The SMPY students take the SAT at a much younger age than the general population and this limits the ability to perform a direct comparison. Other researchers argue that students taking the SAT at an earlier age are not prepared for the examination in the same manner as those taking it at the end of high school. The difference in testing environment and timing will need to be a factor considered in the prediction of college success. Clark, Rothstein, and Schanzenbach (2009) assert that students who are not college bound generally do not take the college entrance examinations. However, in recent years some schools require taking the standardized tests as a requirement to graduate from high school, thus affecting the overall scoring based on time and location. The inconsistency of who takes these exams influences the results of the exam, ranking, and interpretation of scores.

Organizations with larger samples, such as the College Board, have published information that confirms the SAT's ability to predict success for higher performing students. They suggest that the SAT should be used with high school GPA to predict college success (Kobrin, Patterson, Barbuti, Mattern, & Shaw, 2008). College success is defined as graduating with a four-year degree. The College Board is administering the examination, therefore there should be a concern regarding bias toward its product.

Issues Regarding Standardized Testing. Opinions regarding standardized assessment vary. Researchers such as Wood and LeBold (1968) assert that standardized testing, such as the SAT, and HS Rank, are good indicators of a student's academic

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ability. Others, such as Brown, Tramayne, Hoxha, Telander, Fan, and Lent (2008), support using standardized testing such as the ACT or SAT to assess general cognitive ability in addition to pre-college performance (either HS class rank or GPA) to assess the academic ability of students. These researchers have either intentionally or unintentionally neglected a discussion of test selection bias and the student's anxiety in the test-taking environment. While using standardized testing to assess academic ability, it is important to discuss those things that may influence the review of such results, particularly those that may result in less favorable views of the student than their actual ability would dictate.

Socioeconomic Factors. It has been recognized that socioeconomic status while in high school affects the ability to predict college success using SAT scores and high school GPA. Zwick and Himelfarb (2011) found that minority students have higher predicted college GPAs than what they actually earn. They state that because minority students are underrepresented in the SAT dataset, when performing a regression analysis to predict future success, their college GPA is over predicted (Zwick & Himelfarb, 2011). It is important to note that often in these situations college success is defined by college GPA.

Other research on the predictive validity of the SAT, similar to what has been done by Scott-Clayton (2012), asserts that SAT-M (Scholastic Aptitude Test-Mathematics) is predictive of college success, while SAT-V (Scholastic Aptitude Test – Verbal) does not have as strong a correlation. That study was done using community college data from the New York City Community College system, an extremely large community college system with 42,000 students in the testing population from an urban

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environment. Sackett et al. (2009) find that academic and cognitive testing have predictive power even when controlling for socioeconomic status.

Use of SAT to Assess Academic Ability. A great deal of discourse regarding the assessment of academic ability exists. Little and de la Barra (2009) refer to work done by Wood and LeBold (1968), which asserts the use of the Differential Aptitude Test (DAT), High School Rank, and the Scholastic Aptitude Tests for verbal and math (SAT-V and SAT-M) as the most valid in predicting grades in engineering graphics, chemistry and math. The SAT is commonly used to predict academic achievement. Prediction of grades will be discussed later as we explore persistence in-depth. However, it is important to understand academic ability and the role it plays in the pursuance and persistence of STEM majors.

Choice of Major

Research by Kolitch and Brody (1992) indicates that there is a relationship between students identified as exceptional and their choice of a major in college. Lubinski and Benbow (2006) graphically describe and deduce that there is a definitive relationship between choice of college major and factors such as SAT scores (Shea, Lubinski, & Benbow, 2001). The information supplied by these researchers and others working in this area support the assertion that there is a significant relationship between students who are identified as exceptional and their choice of major in college (Lubinski & Benbow, 2006; Malgwi, 2005; Shea, et al., 2001). This will be covered later in this document. We can relate that to not only the gifted students, but also those who perform well as they begin their college career.

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Multipotentiality and College Impact Model

There are many theories that are used to research the career development and decision process. However, two such theoretical frameworks have been used to further our understanding of what majors are chosen and the process by which they are chosen and changed. They are multipotentiality and the College Impact Model. Multipotentiality was chosen because of the relationship of multipotentiality to exceptionality, which often is related to high socioeconomic status. The College Impact Model has a number of facets, the one that is most important to this discussion is the relationship of environment and various kinds of capital to student emotions and resulting choices. Both Multipotentiality and the College Impact Model are summarized here with a description of how they may be useful research regarding the student's career choice.

Multipotentiality. A large number of researchers using a large variety of theories and concepts have modeled the career development process. Since this research is examining the differences between typical and exceptional students it is appropriate to explore and view our findings through the lens of multipotentiality.

Achter, et al. (1996) asserts that multipotentiality affects all exceptional students, because they are faced with an overwhelming number of attractive choices of majors. Fredrickson (1979) states that a multipotential person is defined as "any individual who, when provided with appropriate environments, can select and develop any number of competencies to a high level" (p. 268). Multipotentiality is defined as people who exhibit tendencies to perform well in multiple areas or careers.

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Kerr and Erb (1991) assert that students who are academically talented often are frustrated by the ability to make multiple choices. Ultimately, they delay decisions regarding college majors and often change majors more than the norm. This issue of indecision makes studies focused on exceptional students' choices of majors unreliable, particularly initially, as they may change their career goal multiple times during their undergraduate years. This supports Lubinski and Benbow's (2006) use of data from the variable "Conferred Bachelor's Degree at Age 23." This graph was chosen because it was the only exhibit in the published work by Lubinski and Benbow (2006) that had variables found in the MIDFIELD dataset, so that comparisons could be made.

Kerr and Colangelo (1988), on the other hand, found that students narrow their career/major choices very quickly because the academic path they will consider has been limited. Holland (1959) asserts, "The person directs himself toward the major occupational class for which his development has impelled him…" (p. 38). It is said that there is a linear relationship between ability and those things that one is exposed to and the choice of a college major (Kerr & Colangelo, 1988).

While this research does not have the same qualitative variables as those determined and analyzed by other researchers we do see numerical relationships that indicate the presence of multipotentiality. It is through this lens we further understand the choice of general engineering as a choice of major and a level distribution of choice of major following the completion of an FYE (First-Year Engineering) program. Simply, students are unsure of what they wish to choose as a major, due to general confusion over the availability of many major choices, while students matriculating into an FYE program are provided more information that aides in the choice of major after a period of learning

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about those that are available at their university. This leads us into our discussion of the influence of capital.

Influence of Capital. As stated earlier, students make choices based upon those things they know and those things in which they have shown ability. Therefore, when students focus on the types of capital that impact pre-college students and their choice of majors, particularly on other people and culture, their choice of major or life work is impacted. The other forms of capital, such as financial capital, human capital, natural capital, intellectual capital, and so on, are not discussed, since they are not relevant to the work described in this thesis.

Dewey (1899) was the first to mention social capital, but did not define it. Others have tried to define capital and the result was a compilation as noted in work by Strutz, Cawthorne, Ferguson, Carnes, and Ohland (2011). They define the types of capital as social, cultural, human, economic, symbolic, and experience capital. In this document we will discuss how cultural capital and experience capital influence exceptional students as they make decisions regarding their future careers.

Cultural Capital. Bourdieu (1993) defined cultural capital as the experiences one has that contribute to one’s knowledge and skills as gained through education and rearing. This was the result of his work, in which he attempted to explain the impact of different social classes as related to academic success (Bourdieu, 1986).

As we examine culture, we need to consider many things, such as understanding the people who we are studying -- how they live, their beliefs, and the way they teach their children. It goes even further, encompassing the influence of religion, neighborhoods, and of the socioeconomic environment in which the students live. Rather

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than developing a treatise on this topic, we will focus on the effect of culture and other people on students and how they influence their choices of college major, particularly focusing on socioeconomic factors and the effect of friends.

Socioeconomic Factors. Earlier in this document, we stated that students were more likely to choose a major or career in a field or subject with which they were familiar and have exhibited some skill. Likening that to a statement made by Tramonte and Willms (2010) that higher socioeconomic status families understand college, it can be concluded that students in these groups find schooling less intimidating than students of low-SES families. These families have the skills and knowledge to assist their children, such as providing them with the guidance and encouragement needed in the selection of a college major. We also know that those that know the college application and choices are less intimidated than those that do not. Families from lower socioeconomic status, often due to a lack of skills and knowledge regarding the educational process, rely on others, such as teachers and counselors, to do that for them (Fakas, 1996, 2003; Tramonte & Willms, 2010). Often students from underrepresented ethnic backgrounds are thought to be of a lower socioeconomic status. This is often not the case as there are a disproportional number of students that come from families that may be underrepresented from an ethnic standpoint, but not a socioeconomic background. These students have the benefit of a knowledgeable social network; they score higher on the standardized tests and move through college applications and choices with ease. (Ready & Wright, 2010; MacPhee, Farro, & Canetto, 2013)

Dumais and Ward (2010) have found that cultural capital affects the application process and other facets of college enrollment, including choice of major, particularly in

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first generation students. As more underrepresented students matriculate into engineering and other STEM programs, universities need to understand the barriers that are presented by parents and others living with the student who have no experience in the college application process, or sometimes the relevance of a college education for many careers. These researchers also assert that cultural capital varies at different junctures in students' lives; particularly at times students should be taking standardized tests, visiting universities, and submitting applications. One of the most influential factors affecting pre-college students, particularly at these critical points in a student's life, is their friends (Alvarado & López Turley, 2012). Studies have shown high correlation between exposure to engineering through a friend, family member, or high school activity such as playing a large role in choosing engineering, although these studies have not focused on exceptional students (Strutz, 2012). Friends play a large part in the influence of lower socioeconomic students' choice of major, in particular engineering.

Effect of Friends. The college choice model presented by Hossler and Gallagher (1987) focuses on the student's independent decision-making process. This process falls into three successive phases: disposition, search, and choice. Disposition is the phase in which the students decide if they are going to college, usually affected by activities, courses and interactions with others that they find interesting. The other two phases are searching for a place to go, sometimes including narrowing down their choice of major and then deciding where to go to college after the offer(s) are received. College-bound friends are important throughout all three of the stages in the college choice model. With fewer college bound friends in the disadvantaged minority group, these students are least likely to complete college or in some cases attend (Alvarado & López Turley, 2012).

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Experience Capital. As defined by Strutz et al. (2011), experience capital is accumulated through our life and professional experiences. Some of the experiences that contribute to experience capital are informal learning experiences. Specifically younger students only have life experiences, thus this discussion will focus on those things in life, such as family, friends, classmates, etc., which affect their choice of college majors.

Earlier we discussed the impact of knowledge and skills on the choice of a college major and ultimately a career. Students will choose from those things with which they are familiar. The SMPY (Vanderbilt University, 2013b) program is not only a Talent Identification program, but one that implements interventions to keep the students who are identified interested in the subjects in which they excel. It provides the necessary knowledge and skill sets to open doors to opportunity for exceptional students who may be subject to educational ceilings imposed by standard curriculum. The work that is being done by Lubinski and Benbow, particularly in their document published in 2006, helps us justify the talent identification process, as well as the development of interventions for exceptional students. Most of these interventions are part of an informal learning environment.

Informal Learning. Melber and Abraham (1999) assert that interaction in informal learning settings has a long-lasting impact on those who have learned from them, supporting the concept that informal learning experiences are very important to future choice of majors (Bell, Lewenstein, Shouse, & Feder, 2009). Tang (2013) found that informal learning in most instances forms adolescent attitudes. Things that adolescents learn in their day-to-day activities often promote their interests, but if negative influences occur, guiding the students in a path that interests them as an adolescent becomes a very

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difficult task. Therefore, encouraging students to participate in museum, scouting, and other programs that offer learning experiences outside of the formal environment supports students' quest for knowledge and opens doors that may otherwise not have been open to some students (Lucietto & Cardella, 2013).

After looking at two different types of capital, we can see that there are many different influences on students, regardless of their status of gifted, remedial, or in the norm. The most important thing to consider is that interventions and support need to be individualized for each student. The research done in this document is based upon available quantitative data. Future research should be focused on gathering qualitative data that provides information about social, cultural, and experience capital to support the conclusions made by the findings of this research. Further understanding of student choices and the impact of those choices will be viewed from the context of Tinto's piece of College Impact Models within the context of interpreting the findings of this research.

College Impact Model - Tinto. This last model focuses on Tinto's (Tinto, 1993) model of student departure. This model is based upon Durkheim's theory of student dropout and theory of suicide(Durkheim, 1951). Tinto focus' on longitudinal data where both formal and informal learning in the social and academic are integrated to show how a mismatch in academic ability, student motivation or pacing, and the environment of the university is attributed for student attrition. Further work in this area includes investigation into gender and ethnicity issues (Besterfield-Sacre, Moreno, Shuman, & Atman, 2001), understanding how to increase retention of engineering students (Bernold, Spurlin, & Anson, 2007), attaining parity of genders(Murphy et al., 2007), evaluating the impact of physics and calculus courses in engineering graduates(Tyson, 2011), student

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retention and performance (Vogt, 2008), mixed methods research in engineering education (Borrego, Douglas, & Amelink, 2009), as well as many others.

Tinto, in his model of student departure, focuses on the interaction of universities and individuals with social integration and academic performance and completion(Maruyama, 2012). Studies that use this model examine demographic variables and academic skills as predictors of college graduation (Ishitani, 2003). This research shows that standardized test scores and high school GPA predict student success in the first year. Linking socioeconomic standing of the family to these factors also predicts persistence in the first year. (Maruyama, 2012). Ishitani & DesJardins (Ishitani & DesJardins, 2002)state that these factors become less important in the later years of college, while others such as Hurtado and Carter (Hurtado & Carter, 1997), and Pascarella & Terenzini (Pascarella, Terenzini, & Feldman, 1991) find that motivation, and student faculty interaction play a greater part in student graduation rates. While Adelman (Adelman, 2006)found that there are strong ties to social, ethnic/racial background on academic success of these students.

Another issue that Tinto alludes to and followers of his model have investigated is college readiness. They question the relationship of students in their experiences and knowledge as a preparation for college. Research in this area usually results in different views of readiness and methods to evaluate a student's preparedness for success in college. (Maruyama, 2012)

This study reviews the choice of majors made by students. The choice is interpreted as a reflection of where students believe they belong. In particular studies such as those done by Min et al. (Min, Zhang, Long, Anderson, & Ohland, 2011) used

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survival analysis on MIDFIELD data to predict degree completion and persistence of STEM majors. Min et al's (2011) study does not provide a method of determining the rationale for student choice of major or change in major, rather how to view factors such as dropout rates or retention on a longitudinal basis.

This research uses MIDFIELD, the same database as Min et al (2011). We are concerned with students' choice of major and whether they persist or don't persist in STEM fields. It is basic research done with the intent to promote further studies in this area using qualitative analysis to further the understanding and findings from the initial analysis; therefore, we are using the theory or concepts of multipotentiality to provide a better understanding regarding indecision in the matriculating and current student. The use of Tinto's concepts in retention helps us understand the exploration done using the STEM datasets in comparison of academic ability, and majors of those that drop and those that continue.

Academic Ability in Choice of Major

When considering the exceptional student, a great deal is known about their choice of major. However, when considering the typical student, no one has focused on the choice of major for the entire cross section of students. Studies have not been done that provide insight into the decisions made by a student while going through a course of study. Of particular interest are the changes and decisions that are made along the way. Perry and Perry Jr. (Perry Jr, 1999; 1970) assert that students' methods of career decision making are not always logical. While there are some studies that study student decision making, few have been done on engineering students (George, Neale, Van Horne, & Malcolm, 2001; Kelly, Butz, Carroll, Adamson, & Bloom, 2004). Adelman's (1998)

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findings support the need for determining and defining students' modes of traversing the academic pathway. Based upon those findings and current work done on persistence (Adams et al., 2011; Brown, et al., 2008; Eris et al., 2010; Ohland, et al., 2008), further exploration on the topic follows.

Persistence

Persistence rates in engineering are not that different from other majors (Ohland, et al., 2008). Not all researchers agree with this assessment, however they do agree that understanding why students stay in or leave a particular major, and how they made the decision to do so, is very important in the understanding of students and those things that have an influence on them. Those researchers who do agree with Ohland, et al., (2008) such as Seymour and Hewitt (Seymour & Hewitt, 1997), assert persistence rates are similar for the majors studied. However, Seymour and Hewitt (1997) assert that there is no difference between students who persist and don't persist in a given field of study.

The work that has been done in this area has shown that there are different effects on the decision-making and pursuance of ones goals. The focus of that research was on finding methods in which to retain students as engineering undergraduates (Felder et al., 1998; Knight, Carlson, & Sullivan, 2007). Research in this area shows that factors affecting the choice of major often affect persistence in an academic pathway. At the end of the persistence discussion, persistence and choice of college major as they relate to socioeconomic factors and multipotentiality will be explored.

Little research has been done from the student perspective on how students do or do not persist (Matusovich, et al., 2010). Research done using the Social Cognitive Career Theory have resulted in the following conclusions: general cognitive ability and

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high school GPA correlate closely, while academic self-efficacy belief and academic goals correlate, with academic goals and overall performance, and academic goals to persistence following closely behind (Brown, et al., 2008). These predictors illustrate the fact that academic ability and persistence should be studied together to further understand influences on a student's decision-making as it relates to college choices and study in STEM fields.

Ohland, et al. (2008) found that engineering students persisted in engineering at the same rate as students in other fields. They also found that the MIDFIELD dataset provides compelling evidence that retention is not an issue with respect to the assertion made by Duderstadt (2007) and Fortenberry, Sullivan, Jordan, and Knight (2007) regarding the dearth of engineers being prepared in the United States. While this is the case, consideration of multipotentiality, as noted earlier in this document, is an important piece of understanding student's decision-making process and its effect on their career goals. The earlier discussion focused on exceptional students and the multitude of choices they have due to their cognitive ability. What we don't have sufficient research on is how this affects the typical student other than what is presented in studies done by those using the MIDFIELD dataset (Lord et al., 2009; Ohland, et al., 2008).

Research on persistence indicates that the current method of using standardized college admission testing, such as the SAT or ACT should be reconsidered. Findings show that non-cognitive factors have a great deal to do with college success, particularly attitudes and beliefs of one's ability, as well as those attitudes that are formed during a student's freshman year, and other factors such as ethnicity, attitudes related to math and

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science, as well as academic preparation (Burtner, 2005; Engberg, 2013; Levin & Wyckoff, 1991).

Until this point, there has been a great deal of emphasis placed on the use of high school GPA and standardized test scores to predict the ability of pre-college applicants. Those who are concerned with college success suggest a variety of selection methods, including factoring high school GPA into the admissions review, and including other methods of attitude assessment.

High School GPA/SAT Scores. Research presented by Abdel-Salam, Kauffmann, and Williamson (2005) indicates that the relationship between SAT scores and college GPA is weak, while there is a closer relationship between high school GPA and college GPA. Some researchers believe that the HS GPA along with SAT or other standardized testing is indicative of a student’s success in college (Atkinson, 2005; Kobrin, et al., 2008; Wood & LeBold, 1968). Others, such as Mattern and Patterson (2013), found while using regression analysis that the use of GPA and SAT scores to predict college success was not accurate. They found that grades were over predicted for some groups and under predicted for others. Often it is assumed that these differences are attributed to socioeconomic factors (Zwick & Himelfarb, 2011).

Further research into the topic of persistence has provided a basis for developing two generalized models supporting our career pathway inquiry. In particular, they can be used to further understand student’s decision-making process while choosing and changing majors. Some of these students stay in engineering and others leave; these are trajectories that should be understood, particularly for counselors and advisors.

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Models of Persistence

Three basic models of career pathway relate to this conversation. The first is that exceptional students formulate and decide what career path they will take at an earlier time and do not change their major. The second is that other exceptional students exhibit the traits of multipotentiality by changing majors or picking up additional majors as they pursue their career goals at the university. Often students that fall into the second model pathway are considered “explorers,” while they really are having difficulty choosing from a plethora of choice of majors. The third model is that of students who do not persist in engineering, but move on to other majors or leave college at any point prior to completing a degree. It should be noted that none of these choice of majors are positive or negative; rather they are a choice made by a student and a point of analysis for this study.

Students Who Do Not Change Majors. There are a few reasons that students do not change majors. Some of the reasons include the fact that the student has been driven toward a specific career goal for a long time, the student has developed resilience (Bédard, Lison, Dalle, Côté, & Boutin, 2012) and has pursued the chosen major with a vengeance, and those that are change adverse. Students in the first group have a goal and pursue it. They have nurtured this area of interest for many years and have not found a compelling reason to change majors.

While administration and faculty do not necessarily have a reason to focus on these students, they should be encouraged to do so; this interaction will help students stay in their major. This is primarily attributed to the students becoming more engaged and

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motivated in their major, reducing the compulsion to change majors. (Ricco and Ohland, 2012)

Students Who Change Majors or Add Areas of Study. Students who change majors within the field of engineering or add areas of study to their engineering studies is a concern to engineering educators, and perhaps less of a concern to engineering education researchers. However, multiple changes to a major can set a student back in terms of meeting the requirements of the final major they choose. Many universities have provided for this possibility by creating a multidisciplinary engineering experience in the first year of engineering. (Adams, et al., 2011; Orr et al., 2012; Stebleton, Jensen, & Peter, 2010)

Students changing focus within engineering are usually experiencing and dealing with multipotentiality. (Achter, Lubinski, & Benbow, 1996) These students will change majors multiple times; sometimes they leave STEM fields and other times they change majors within engineering. Some will add other areas of study, in STEM fields and sometimes outside of STEM fields.

Students Who Leave STEM Majors or Leave College. Moving outside of a STEM field is often regarded as a negative. It is not. Rather one must consider an exceptional student moving out of STEM as a positive for that field. (Lubinski & Benbow, 2006) In other situations, anyone moving from a STEM field on into a non-STEM area takes the knowledge they gained and the appreciation for the field they left with them, effectively sharing the good of engineering or STEM fields with others. Malgwi, How, and Burnaby (Malgwi, Howe, & Burnab, 2005) concluded that students are more likely to change

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majors due to the positive aspects of the new major, rather than the negative aspects of the old major.

Furthering our knowledge in these areas will provide information to university advisors and administrators about what a student is likely to do and then enable them to be prepared to advise or counsel students in ways that provide positive support regarding their career goals. Robertson, et al. (Robertson, Smeets, Lubinski, & Benbow, 2010) assert that reliable observation requires the use of a large longitudinal type dataset, because it allows the researchers to observe reliable data due to the size and nature of a whole dataset.

Relationship of Academic Ability in Choice of Major and Persistence in STEM Fields. Consideration of those things that influence the decision leading to a choice of major were outlined in the previous section on academic ability. In this section we will consider how a variety of things impact a student's choice of major and then their persistence. While others have pursued research in areas focused on student attitude and perception, it is important to relate those findings to what we are exploring in this work. Clearly those researchers have found that freshman engineering students' attitude and initial perceptions impact decisions regarding retention, and that race/ethnicity and gender also influence student persistence. (Besterfield-Sacre, Moreno, Shuman, Atman, 2001; Seymour and Hewitt, 2000; Besterfield-Sacre, Atman, Shuman, 1997) These same things should be considered in the discussion of persistence, in particular how socioeconomic status and multipotentiality affect student's decisions regarding their academic paths.

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Multipotentiality

Earlier it was noted that multipotentiality affects all exceptional students (Achter, et al., 1996). The exceptional student is able to develop his or her competencies to a high level (Frederickson, 1979). Therefore, we find that multipotentiality is an attribute of people who perform well in multiple areas. This can be translated to choice of major and potentially indecisiveness of one's ultimate career choice.

Frederickson (1979) defines multipotentiality as any individual exhibiting these traits, while others such as Achter, et al., (1996) clearly assert that exceptional students are all impacted by the ability to perform well in multiple areas. Most research in this area has found that students who are considered exceptional are most often those who exhibit multiple talents that result in multiple challenges (Rysiew, Shore, & Leeb, 1999). While to some this may appear to be good to have multiple choices, students often become frustrated (Kerr & Erb, 1991), and when provided an intervention or assistance in decision making remain focused and unstressed by the decisions they face (Kerr & Colangelo, 1988; Rysiew, et al., 1999).

Multipotentiality affects students in all decision making regardless of if it is the choice of a major, or if they should persist in the course of study they have chosen. If what Achter (1996) asserts is true regarding exceptional students, and that students are confronted with a plethora of choices (Rysiew, et al., 1999), intervention is necessary to encourage persistence of exceptional students.

Socio Economics

A great deal of research has been done regarding the effect of socio economics on students and the educational realm. Earlier discussions that included the impact of socio

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economics included family involvement in a student's education and career trajectory, available resources in the schools, and the impact of cultural and experiential capital. Recent studies by Reardon (2011) and the U.S. Department of Education (Hemphill & Vannerman, 2011; Vanneman, Hamilton, Baldwin Anderson, & Rahman, 2009), assert that the achievement gap between rich and poor, often relating to different races, is becoming more of an issue in education. Through a macro-economic analysis done by Reardon (2011) it is evident that the income achievement gap has been increasing in scope for at least the last fifty years.

This increase is seen in a few ways, one being a larger gap in students from opposing ends of the family income distribution. The gap is evident when a student begins school and does not significantly change in the duration of a student's academic experience (Reardon, 2011). Other studies show that the disparity also may be attributed to higher income families' investment in the student's cognitive development (Faul, 2008), such as out of classroom experiences (Miller, 2012; Votaw, 2008), and family activities (Hwang & Vrongistinos, 2010).

Reardon (2011) also observed that the educational level of the parents and academic achievement of their children is stable over the same fifty years that students have been observed. He also states that the relationship between family income and achievement has become more evident. Other researchers agree, using studies proving that supplements to poor families, increased spending in lower socioeconomic areas, and use of charter schools results an increase in the children's academic performance (Folbre, 2014) Many researchers have stated that family socioeconomic status, beginning in 1966

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with the Coleman Report (Coleman, 1966), affect a student's academic achievement, alluding to the fact that a student's persistence may relate to socioeconomic status.

Summary

Recently researchers have determined that students are affected by the socioeconomic status of their family. Multiple factors influence their degree of academic success, including level of parental education, and cultural and experiential capital. Students who are categorized as exceptional are also affected by multipotentiality, often causing them a great deal of angst when confronted with decisions of life-altering consequence, such as the choice of a college major.

Researchers have studied the use of the SAT and other standardized assessment tools as measures of a student's academic ability. However, they have not established a direct relationship with a student's choice of major. Researchers such as Shea, Lubinski, and Benbow (2001) have found there are relationships between the SAT verbal and math scores, and choice of major with exceptional students. However, the findings are limited to descriptive statistical methods on limited data populations. The nature and ability to predict a choice of major based on current research is limited. Thus, the availability of a long-term, broad-based, longitudinal database provides the researcher with a great deal of data to use in the development of either findings that confirm or reject the concept of major prediction based upon SAT scores. If the research confirms the ability to predict, in some manner, the choice of college major, this study will lay a foundation for further work in this area.

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While investigating the pre-college decision making of choice of major and how it relates to SAT scores, further investigation is necessary to understand the students' persistence in that decision of field of study. While the two areas appear to be unrelated, the process of choosing and deciding to stay or change majors through an academic career are closely related. Prior to college, students are influenced by cultural and experiential capital. It is the same as they begin and continue to traverse their academic path. Many early college programs focus on experiential learning to provide an environment that aids in the students' accumulated experiences, resulting in the persistence of students (Adams, et al., 2011; Dumais & Ward, 2010; Orr, et al., 2012).

As noted earlier, Matusovich, Streveler, and Miller (2010) stated that little research has been done to understand the reasons why students do or don't persist in engineering. The same is true for other STEM fields. Performing a parallel study using the same or similar extraction criteria on MIDFIELD data, and then descriptive and inferential statistics techniques to evaluate the relationships, provides researchers with a basis to continue examination in the areas of persistence and choice of major as it relates to academic ability.

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CHAPTER 3. METHODS

Introduction

Data for this study was obtained from the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD). The following section describes the procedures that were used in the development of this research. To answer the research questions, the independent variable, dependent variables, and the population studied will vary from one study to another.

Research Methods

This study utilizes quantitative descriptive analysis for this study, in particular use of SPSS (v.21) to study the effect of demographic variables and develop comparisons of data for a clearer understanding of student choices in major and course of study. MIDFIELD includes whole population data from the participating universities, so inferential statistics, which are used to estimate the behavior of a population based on a sample, are not used—all measured differences are real. It remains critical to consider the effect size of measured differences; while differences are all statistically significant, many have no practical significance.

Datasets Used in this Work

The population used in this study was taken from the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) data set.

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It began as Southeastern University and College Coalition for Engineering Education (SUCCEED) Longitudinal Database in 1996 with the collective contributions of data going back to 1997 from the following universities: Clemson University, Florida A&M, University, Florida State University, Georgia Institute of Technology, North Carolina A&T State University, North Carolina State University, University of Florida, University of North Carolina at Charlotte, and Virginia Polytechnic Institute and State University (Ohland, et al., 2004). In 2002, the name was changed to MIDFIELD, and in 2004, the scope of the data increased with technological advances in data storage. In 2010, Purdue University and University of Colorado in Boulder joined the partnership. The existing data comprise 1,014,984 unique college students in the database (Long, 2014).

The MIDFIELD data includes data from degree-seeking undergraduate students at eleven public universities, mostly from the southeastern United States. These universities provide a great deal of information on engineering students, which makes MIDFIELD data overrepresented by engineering majors. These universities represent 1/9 of the engineering graduates nationwide. African-American students are overrepresented due to the population in this part of the country, primarily due to the fact that the universities contributing data are historically black colleges and universities. For example, 1/5 of all African-American students earning a BS in engineering graduate from the universities contributing to the MIDFIELD data. (Ohland et al., 2008)

The MIDFIELD dataset was chosen, because of its size and comprehensive scope. We anticipated comparing analysis done on MIDFIELD data to results from other studies. In particular we found that the Study of Mathematically Precocious Youth (SMPY) established by Julian C. Stanley in the fall of 1971 at Johns Hopkins University

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was most likely a good comparison. The purpose of Stanley's work was to complete a 50-year study that provided further understanding of how students who are identified as precocious or gifted in math develop over their lifetimes. The study dealt with students who were highly gifted in mathematics and focused on developing interventions to help them continue their learning beyond normative curriculum (Stanley, 2005). While the title of the study implies that only the students who performed well in mathematics are included in the study, the SMPY researchers later studied a population of students who showed high performance in verbal and general skills testing; previously they had used only mathematics scores. The researchers chose to maintain the title; therefore it continues to reference mathematically precocious students (Vanderbilt University, 2013b). Benbow (2013) took the dataset and developed more cohorts as she moved from Johns Hopkins University to the University of Iowa where she began working with Lubinski (2013). They both moved on to Vanderbilt University, co-directing SMPY, where the study currently resides (Vanderbilt University, 2013b).

Earlier work by Benbow and Stanley (1983), while at Johns Hopkins University, states that searches for mathematically precocious students began in 1972. Six searches took place with the intent of developing a cohort of students who were highly performing. In these searches, middle school students took the Scholastic Aptitude Test (SAT) and were chosen if they scored in the top 3% of those taking the test.

A table has been developed to highlight and contrast the attributes of both the SMPY and MIDFIELD datasets. This can be seen in the next section in Table 3.1.

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Available Data

MIDFIELD includes a record of what courses students took, when, and the grades they earned. It also includes cumulative credits, GPA and major each term, degrees awarded, demographic data (race/ethnicity, gender, age at matriculation, etc.), pre-college variables (high school GPA, SAT/ACT scores, etc.), and a table of institutional data that sometimes provide useful context.

It is not possible to replicate the SMPY study using MIDFIELD, because not all the SMPY data are available in MIDFIELD. In particular, the SMPY researchers utilized a spatial ability test; this data is not available for the students represented in the MIDFIELD database. Therefore, this study was done in a more independent fashion than originally anticipated. Other differences exist; further discussion on this issue is in the next section.

Because of the different purposes, these datasets are constructed differently. MIDFIELD can be used for generalization, whereas SMPY is intended for specific data related to highly gifted students. Where data cannot be matched between the two datasets, no comparisons can be made, and this is a limitation. The MIDFIELD population is a whole population for a few different universities, whereas the SMPY population is a high-performing sample of a larger population. When doing any comparison, therefore, I would expect the SMPY results to reflect higher performance from the highly gifted population than that derived from the MIDFIELD population. Because MIDFIELD is large and contains whole population data, a population of exceptional students can be identified within the larger dataset.

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Table 3.1 - Attributes of MIDFIELD and SMPY Datasets

	MIDFIELD	SMPY
Inception	Data from 1987; Collecting began in SUCCEED in 1996 (Purdue University, 2010b)	Data from 1972; Program began 1971 (Lubinski & Benbow, 2006)
Number of Individual Participants	1,014,948 (Long, 2014)	5000 (Vanderbilt University, 2013a)
Purpose of Research	Academic choices and outcomes. (M. W. Ohland, Zhang, Thorndyke, & Anderson, 2004)	Identifying highly gifted students and providing opportunities for them to learn and excel. (Stanley, 2005)
Age Participants are Identified	College Student	12 yrs. to Graduate Student
Method Used to Identify Participants	College Records	SAT tests, Grade Level Achievement Test Graduate Student Performance, and DAT results (Vanderbilt University, 2013a)
Organization of Data	Completely Searchable Dataset	Five Different Cohorts (Vanderbilt University, 2013a)
Demographic/Area Where Data was Gathered	Predominantly College Data from the Southeast with other Colleges adding data later in the study. (Long, 2014)	Data from students in the Greater Baltimore Area, Mid-Atlantic States, Mid-Western States, and Nationally distributed. (Lubinski & Benbow, 2006)

Note: Data taken from online resources (Purdue University, 2014a, 2014b; Vanderbilt University, 2013).

Data that are Used in this Study

Considering the differences in the datasets and available information about both, results from MIDFIELD will be compared to published graphs and conclusions from the SMPY study. Analysis and further probing for this study will originate from MIDFIELD

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data. Table 2 displays the MIDFIELD data that is used in this study in the context of the overall MIDFIELD database structure.

Table 3.2 - MIDFIELD Data

	Description of the Data	Number of Data Variables	Generalization of Variables
Student File	Demographics	33	Standard Demographics; High School Information; Matriculation Information; SAT Test Results; Transfer Status and Information
Term File	Information on All Enrolled Terms	15	COOP Information; Grade Information/Term; Class Status; Living Arrangements; Registration Status
Course File	Information on All Courses by Term	13	Courses Taken; Credits and GPA/P/F; Course Delivery; Course Catalog Information; Rank of Instructor
Graduation File	Record of Graduation One Record Per Bachelor's Student	5	Degree Granted; Graduation Information; Student Identifier

Note: Data taken from Online Resources (Purdue University, 2014a) and Email (Long, 2013)

Population and Data Definitions for Each Study

To answer the research questions posed in this study, each question was addressed and an answer presented. Incorporation of descriptive or inferential statistics will be done in each section as appropriate.

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Standardized Test Scores and Choice of Major – Exceptional Students

The MIDFIELD dataset is a whole dataset and includes students from all academic levels. Therefore, data from all students will be obtained for this portion of research from MIDFIELD for only exceptional students. Exceptional students will be defined as those performing in the top 3% of students taking the SAT. SAT scores and college major choice upon matriculation will be used. Due to the SAT score distribution the exceptional student data set was based upon combined SAT scores of 1420 or greater.

Standardized Test Scores and Choice of Major – Typical Student

The “typical” student dataset includes all students represented in the MIDFIELD data, including the exceptional students. This definition has the advantage that the findings for “typical” correspond to the entire student body, yet keeping the exceptional students in this group should not be of consequence due to the size of the exceptional student dataset of 3% of the general population. Not all students have reported SAT scores, therefore when analyzing student data for demographics the entire dataset is used, while analyzing for SAT related data for defining exceptional students, only students with reported SAT scores were utilized, thus those student datasets are smaller than the reported general population. The population of each study is noted in the tables found in the findings chapter.

Academic Pathways – Exceptional Students

This relationship requires a comparison of data from matriculation to graduation. The information that was chosen and used in these comparisons are the first major, the major chosen at the first change of major, and the major at graduation. When extracting the data for

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students completing an FYE program, the variable used has data for choice of major after completion of the FYE program, which is usually after one year in the program.

Academic Pathways – Typical Students

This relationship is reviewed in the same manner as the exceptional students. This information is similar in that the first major, the major chosen at the first change of major, and the major at graduation. Extraction of data for students completing an FYE program is done in the same way as described in the previous paragraph.

Treatment of Data

Similar studies have been done with a great deal of descriptive statistics. The following section describes the quantitative methods that will provide a fundamental understanding of student's performance and decision-making available in the MIDFIELD data.

Quantitative Data Treatment – Descriptive Statistics

This study uses descriptive statistics to provide a basis for this research, and supporting decisions to do further investigation using other techniques. Shea, Lubinski, and Benbow (2001) as well as others in similar research groups rely heavily on descriptive techniques.

Demographic Data. Demographic data was collected and displayed with the intent of further understanding the typical and exceptional populations. Each of these populations is discussed in detail in the following sections.

Typical Students. For this study tables are created representing the typical student who initially matriculates into the colleges contributing to MIDFIELD. The data is

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presented for the entire student group as well as those who matriculated only into engineering, STM (Science, Technology, and Mathematics), and a comparison of STEM majors. This demographic data includes student population in each grouping, high school GPAs (30% of the universities do not report this data), ethnic groups, gender, SAT scores, average age and the number of students transferring into the majors in that category.

Exceptional Students. Further development of demographic data is done in the same manner as used for typical student data. The dataset represents the top 3% of students in the MIDFIELD dataset. Demographic data for this much smaller population is provided in the findings section.

Racial and Gender Comparison of Typical and Exceptional Students. When the demographic data was developed, the findings indicated that a comparison of racial data in the typical and exceptional student groups should be made. The comparison of data between typical and exceptional students was made using the all student databases, engineering at matriculation, and STM at matriculation student groups. This provides the ability to compare and contrast the gender and racial makeup of the datasets.

Choice of Major. The first two research questions focus on choice of major, the following sections elaborate on the data sorting and review that was done to further understand the data and to provide an insight into the material being studied.

Majors Chosen by Typical and Exceptional Students at Matriculation. A comparison of majors chosen at matriculation was done on the typical student data. Groupings were done to see if a relationship or disparity became more evident between major groups. This table includes data from all students, engineering majors, STM

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majors, non-STEM majors, and STEM majors to see if the sub categories of engineering or STM affect the overall findings. The same comparison was done using the exceptional student database.

Majors Chosen by Typical Students Matriculating into FYE Programs. An additional table was developed to view the majors chosen by students matriculating into FYE programs from the typical student group. A similar table was created to view the majors chosen by exceptional students matriculating into FYE programs.

Quantitative Data Treatment - Cluster Analysis, Pathways, and Cross Tabulations. Further analysis may be done using a few inferential statistical techniques. One is cluster analysis. Another is cross tabulation, or simple statistical calculations to attain a better understanding of the massive data available in the MIDFIELD dataset. Multiple ways of understanding student pathways were explored as well—an analysis of first major change and a comparison of leavers and stayers.

Cluster Analysis. Cluster analysis is classified as part of multivariate statistics and is a form of data exploration (Berkhin, 2006). It is used to group a set of data or cluster them into categories, which is a particularly useful tool for exploring the contents of a dataset such as MIDFIELD. The variable is of central importance in this kind of statistical analysis (Berkhin, 2006; Hair & Black, 2000). When using this technique, the variables are carefully chosen, and data are obtained from the whole dataset. Cluster analysis is an iterative process, and allows for intermediate examination of data. It is used to discover relationships within data when there are no other explanations of how the data are related. (Blashfield, 1980)

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In the case of this research, we will pay particular interest to the consolidation of clusters when comparing exceptional and typical students. Cluster analysis allows us to explore the available data, particularly learning if there are any trends in choice of major by SAT score. This analysis technique can take us further into an exploration of differences by college or program, providing leading researchers results in areas that have not yet been explored, such as programs that are more successful in attracting students than others, and furthering the understanding of the factors that attract students.

Typical Student Data – Clusters Identified. The k-means cluster analysis method was used to find the optimal number of clusters and iterations. With this initial analysis it was found that ten clusters was the ideal number of clusters to present points that were unique and provided significantly different points. MIDFIELD is large enough to permit the identification of a very large number of clusters, but larger numbers of clusters made the analysis more complex without improving our understanding of the data beyond what was achieved using ten clusters. Clusters of exceptional students were identified in a manner similar to that of the typical data clusters. The populations of the clusters are much smaller than in the case of the typical students.

Majors Associated with Clusters of Typical Students and of Exceptional Students. Once the clusters were identified, separate development of databases for each cluster was done with an analysis of which majors were chosen at matriculation by the students represented in that cluster. The table separates data for the first majors chosen by the non-FYE program student, the major chosen after completion of an FYE program, and by universities without FYE programs with provisions for students to initially matriculate as general engineering majors, declaring specific majors at a later time. The method utilized

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to study clusters of typical students was also used to study clusters of exceptional students to develop the table showing the choices made by these students relating to the SAT scores they earned.

Cross Tabulation. The process of cross tabulating data also is referred to as frequency tables. With cross tabulation, a table is used to represent each variable via row, column, and data, with more than two variables by layer. The result of this analysis technique is a summary of participants with similar combinations of variables. Since our data is categorical, such as college major, we are able to use this technique. Once this data is processed by a statistical package, correlations become evident (Pallant, 2010).

The technique is used to find similarities and combinations of data that would not otherwise be known. Learning more about students who choose mechanical or civil engineering as a major will aid administrators in the recruitment of such students. Further examination of conferred degree will confirm the validity of such findings and provide a foundation for further research in these areas.

Further Examination. Depending upon what is found with descriptive statistics, cluster analysis, and cross tabulation, further examination using mean, median, standard deviation, computing correlations and so on may be used to place the findings in context. These are common techniques and allow a better understanding of how one major relates to another, how exceptional students relate to typical students, and if there is a significant similarity to liken one variable to another in some way.

Summary of Average First Semester of Change in Major. After evaluating the data in the MIDFIELD database and the results of the cluster analysis further investigation into the timing of a change in major became necessary to our understanding

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of this research. Therefore this table was developed using the typical student data, exceptional student data, and STEM majors that dropped or continued.

Majors Chosen By Typical and Exceptional Students in First Major Change. The information in this table provided a concise view of when different student groups changed major. It became evident that there was some difference in typical students pursuing a majors through a FYE program, and those typical students that did not attend a university with an FYE program. This table was constructed to help in the understanding of student choices as they progress through the earliest stages of their studies. A similar examination of exceptional students was done to compare the exceptional student data to the typical student data.

Data for Dropped and Continuing Students in STEM. The preceding data provided the impetus to further investigate SAT scores, GPA and the first major grouping chosen by students that dropped or continued. This table provides the same data for typical students and exceptional students for comparison.

Students Migrating into STEM Programs. This table provides the number of students, both typical and exceptional, that migrate into STEM programs from non-STEM programs.

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CHAPTER 4. RESULTS

General Observations

This chapter addresses the results of the data extraction and factual observations made with regard to the various descriptive analyses that were done to explore the data. There are two major sections in this chapter. The first section shows the data that relates the choice of major to SAT scores. The second section further explores this data to determine the persistence of the students in the majors that they chose at matriculation or after completing an FYE program.

Exploring the Choice of Major and the Relationship to SAT Scores

To address the research questions posed earlier in this document it is necessary to explore a student's choice of major and examine the results of various descriptive analyses. This section of this chapter evaluates general demographic and other data in order to further our understanding of the MIDFIELD typical students and those that are in the top 3% SAT scorers, referred to as exceptional. At the end of this subsection, observations regarding the contrast or similarities are noted.

Typical Data – All Students, ENG (Engineering), and STM. The data extracted from the MIDFIELD dataset for the purpose of this research was all inclusive. Table 4.1 is for students for whom SAT scores were reported. This table includes all students as well as those that chose a major in ENG, and STM. A comparison of the typical data with

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all students, those that upon matriculation chose a major in the following four categories can be seen in Table 4.1.

Table 4.1 - Demographic Data for Typical Students

Typical Data	All Students	ENG Only	STM Only
Population	1,014,984	174,934	217,873
HS GPA	3.396	3.550	3.451
Ethnic Group			
Asian	4.5%	6.8%	5.6%
African-American	13.1%	10.0%	12.5%
Hispanic	4.4%	3.6%	4.6%
Native American	0.4%	0.4%	0.5%
International	2.5%	4.5%	2.4%
White	73.4%	73.1%	72.8%
Other/Unknown	1.7%	1.6%	1.7%
Gender			
Male	52.6%	80.2%	50.5%
Female	47.4%	19.8%	49.5%
SAT Score			
Math	572	638	577
Verbal	534	565	541
Average Age	19.0	18.6	19.3
Transfer	29.4%	22.2%	31.0%

The comparison of these datasets provides us with a number of observations. The following is a summary discussion regarding the findings.

General Findings. When exploring the dataset for typical students at matriculation, we see that there are more students choosing majors in the STM areas than engineering. Further examination of the dataset also reveals that students with the highest high school grade point averages (GPA) and SAT scores are more likely to choose engineering as their choice of major at matriculation. Based on the general population and examination of a standard data distribution, at this early point in data exploration we

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can surmise that the number of students choosing STM majors upon matriculation fall into the mid-range of student performance in both SAT and high school GPAs. Therefore, there would be more of these students matriculating into STM, whereas the higher performing students are more apt to choose an engineering discipline as their first major. Further examination of the data presented in Table 4.1 will provide a greater insight into these early findings.

Ethnic Observations. During the data exploration, it was found that Asian students chose engineering more often than STM majors, while African-American students choose engineering less often than STM majors. Hispanic students chose STM and engineering in similar percentages. As was expected, international students are most likely to choose engineering over STM majors, and the percentage of white students is significant.

When examining the demographics of students choosing STM or engineering majors upon matriculation, we find that students who are usually associated with lower socioeconomic standing are not included in the dataset. Earlier in this document, we briefly discuss how the lower number of students coming from underrepresented groups is related to socioeconomic status. Thus, students from such backgrounds don’t perform as well going into college, are accepted based upon a predicted success higher than what they actually achieve, ultimately doing the students a disservice in areas of remediation. (Zwick & Himelfarb, 2011)

We see that Asian students score higher on standardized testing, that they choose engineering over other majors more frequently, and often come from homes rooted in a culture of education and study. (Pang, 1990) Further, they often have other family

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members who have pursued engineering. These family members often provide guidance and support in the student's quest to follow these mentors' examples.

Gender Observations. The gender ratio of the overall population of students indicates a slightly higher number of males overall. The population that chose engineering upon matriculation includes significantly more male students than female students. Based upon Table 4.1 we see that a greater number of females choose STM majors than males. The female STM population is meaningfully different from the female engineering population. Since the dearth of women in engineering is well-known, it is no surprise that odds ratios show that typical White, Black, and Asian male students have higher odds of choosing engineering than that of a typical female student in the same racial group. The odds ratio findings are shown in Table 4.2 below.

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Table 4.2 Odds Ratios on Typical Students First Major in STM and ENG

White Students		STM	ENG	Odds of ENG
	Male	81574	104503	0.56
	Female	76288	22985	0.23
	Totals	157862	127488	
Black Students		STM	ENG	Odds of ENG
	Male	11386	11219	0.49
	Female	15933	6068	0.28
	Totals	27319	17287	
Asian Students		STM	ENG	Odds of ENG
	Male	2400	5670	0.70
	Female	6402	9508	0.60
	Totals	8802	15178	
Hispanic Students		STM	ENG	Odds of ENG
	Male	4750	5024	0.51
	Female	1322	5254	0.80
	Totals	6072	10278	

For the typical students, the odds ratio for being a White female is 23%/56%, which is 0.41. Therefore a White female enrolled in STEM is 41% as likely to have chosen engineering as a White male in STEM. Conversely, a White male in STEM is 2.5 times more likely to choose engineering than a White female in STEM (1/41%). Similar statements can be made for Black students using the data in Table 4.2. The odds ratio for being a Black female is 28%/49%, which is 0.57, so a Black male in STEM is 1.75 times more likely to choose engineering than a Black female in STEM (1/57%).

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Review of the Asian and Hispanic student data shows a very different result—the odds ratio for being an Asian female is 60%/70%, which is 0.86, so an Asian male in STEM is only 1.16 times more likely to choose engineering than an Asian female in STEM (1/86%). Among Hispanic students, the results are surprisingly different—the odds ratio for being a Hispanic female is 80%/51%, which is 156%--a Hispanic female enrolled in STEM is 1.56 times as likely to have chosen engineering as a Hispanic male in STEM! Of those who enroll in STEM majors in the MIDFIELD institutions, Hispanic females are much more likely to choose engineering disciplines than women of other racial/ethnic groups. This deserves further study.

The STM population is meaningfully different from that of the engineering population in terms of gender proportion, yet the STM population is not meaningfully different from the general population—the ratio of male to female for STM majors approximates the general population.

Exceptional Data – All Students, ENG, and STM. Students scoring in the stop 3% of a combined SAT score were extracted from the typical MIDFIELD data, for those students that had SAT scores reported. For the duration of this discussion the students in this group are referred to as exceptional students (Benbow & Stanley, 1983; Lubinski & Benbow, 2006). Table 4.3 displays the general observations of the exceptional student analysis.

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Table 4.3 - Demographic Data for Exceptional Students

Exceptional Data	All Students	ENG Only	STM Only
Population	19,028	8,948	5,218
HS GPA	3.843	3.866	3.851
Ethnic Group			
Asian	8.0%	9.0%	8.5%
African-American	1.2%	1.1%	1.3%
Hispanic	2.2%	1.9%	2.1%
Native American	0.2%	0.2%	0.2%
International	1.4%	2.3%	1.1%
White	84.9%	83.9%	84.6%
Other/Unknown	2.1%	1.6%	2.3%
Gender			
Male	73.2%	83.2%	70.2%
Female	26.8%	16.8%	29.8%
SAT Score			
Math	748	754	748
Verbal	721	717	724
Average Age	18	17.9	18.1
Transfer	8.1%	6.0%	9.4%

Following a review of the general and ethnic exceptional student data, the following has become apparent.

General Findings

This dataset shows that the High School GPAs for students in the exceptional group are noticeably higher than those in the typical student dataset. This provides some substantiation that students with higher SAT scores generally have higher GPAs than the typical student. (Abdel-Salam, Kaufftnann, & Williamson, 2005) This data also shows that the number of students in this group choose engineering as their major at matriculation slightly more than majors in STM, which is also true for males separately, but not for females.

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Based upon the data in this table, we find that exceptional students most often choose STEM majors upon matriculation or completion of a FYE program. This is far from the case with the typical student population.

Ethnic Observations. More Asian students by percentage are represented in the exceptional students than the data exploration general population, which may be attributed to the values and practices of many Asian households as well as family member mentors that drive these students to success (Moore, 2012; Pang, 1990).

Although African-American students are overrepresented in the MIDFIELD population compared to a national sample, the representation of African-American students among the exceptional students is less than the typical student group. Earlier arguments suggest that culture, family member involvement, and drive to success may contribute to the success of the student. If this is the case, further examination regarding the African-American students should be considered. Most likely this is related to the racial biases that have become evident in the administration of the SAT. This bias keeps the highest scoring African-American students from having scores as high as the highest performing white students. Further examination of the cultural norms regarding education would enhance those things that are already known about socioeconomic biases, including the impact on SAT scores. That examination needs to review the environmental norms of these students which would include a better understanding of family or community members who are mentoring these students into STEM majors and the encouragement of these students to achieve high levels of academic success. Researchers such as Byars-Winston, Estrada, et al. (2010) find that students achieve goals and become involved in those things that interest them based upon their own expectations. Surely,

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some of these students are exposed to factors that influence their outcome expectations, and those are the ones we see in this exceptional group. We must ask what happens to those that do not have the exposure or opportunity to form outcome expectations that include STEM majors in their choice of college major, when they choose college as an option.

Race/Ethnicity and Gender. Considering the findings thus far we found a meaningful difference in Black and White student populations as determined using odds ratios. The odds ratio findings are shown in Table 4.4.

Table 4.4 - Odds Ratios on Exceptional Students First Major in STM and ENG

White Students	STM	ENG	Odds of ENG
Male	3076	6267	67%
Female	1337	1240	48%
Totals	4413	7507	

Black Students	STM	ENG	Odds of ENG
Male	39	76	66%
Female	28	25	47%
Totals	67	101	

Asian Students	STM	ENG	Odds of ENG
Male	327	647	66%
Female	117	156	57%
Totals	444	803	

Hispanic Students	STM	ENG	Odds of ENG
Male	81	141	64%
Female	28	28	50%
Totals	109	169	

For the exceptional students, the odds ratio for being a White female is 48%/67%, or 0.72. White males in STEM are 1.3 times more likely to choose engineering than a White female in STEM (1/72%). The odds ratio for being a Black female is 47%/66%,

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which is 0.71, so a Black male in STEM is 1.4 times more likely to choose engineering than a Black female in STEM (1/71%). As with the typical student population, exceptional Asian males in STEM is 1.16 times more likely to choose engineering than an Asian female in STEM (1/86%). Exceptional Hispanic students do not show the markedly different behavior that the typical Hispanic students do—the odds ratio for being a Hispanic female is 50/64%, which is 78%, so Hispanic males in STEM are 1.3 times more likely to choose engineering than Hispanic females in STEM (1/78%).

Following that analysis further tabulation to investigate the differences in race and gender for both the typical and exceptional groups is shown in Table 4.5.

Table 4.5 - Racial and Gender Contrasts of Typical and Exceptional Students

Typical Student Population

	African-American		White		
	Male (%)	Female (%)	Male (%)	Female (%)	Total
All	49,939 (5.0)	63,236 (7.0)	377,984 (40.0)	320,675(34.0)	940,206
ENG	11,386 (7.0)	6,068 (3.0)	104,503 (59.9)	22,985 (13.2)	174,397
STM	11,219 (5.2)	15,933 (7.3)	81,574 (37.6)	76,288 (35.2)	217,044

Exceptional Student Population

	African-American		White		
	Male (%)	Female (%)	Male (%)	Female (%)	Total
All	141 (0.7)	90 (0.5)	11789 (62.0)	4357 (22.9)	19,027
ENG	76 (0.9)	25 (0.3)	6267 (70.0)	1240 (14.0)	8,948
STM	39 (0.8)	28 (0.5)	3076 (59.0)	1337 (25.6)	5,218

The students represented in the typical and exceptional student population show a few different things. The first is that there are more female black students in the general population than male black students. Although nationally there are more women than men among all college students, we find that this is the case amongst the typical white students, as they are represented closer to a general population demographic. However,

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when we examine the exceptional student population as a whole we see that white students far outnumber the black students regardless of gender differences as do white males in contrast with white females. But reviewing the population of black engineering students, women are about one-third, and among white engineering students' women are about one-fifth.

Male students, regardless of whether they are black or white, outnumber female students in their choice of engineering at matriculation. As was expected, this data shows that white students far outnumber black students in their choice of engineering as their major at matriculation, supporting our stance of socioeconomic biases on the SAT and other standardized tests.

Interestingly we see that female black students outnumber male black students in their choice of STM majors at matriculation. Further supporting what we already know as true, white males outnumber female students in all categories when choosing STEM fields at matriculation.

The exceptional database was developed using SAT scores, choosing students performing in the top 3% of that standardized test. The results are meaningful and support the assertions that socioeconomic factors play a large part in student performance on the SAT. Table 4.5 shows us that the number of black students is much lower than that of white students regardless of gender.

Other Findings. The overall average age at matriculation is approximately 18.0 years old. The number of white students in this dataset is rather large at an average of approximately 85%.

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Choice of Major

While potential research questions have been revealed in the section of General Observations, this research further investigates these datasets for information regarding particular student’s choice of major upon matriculation, or in cases of universities with First Year Engineering (FYE) programs choice of major upon completion of their first year. The data from FYE will be shown in separate tables. First, the datasets with typical students are evaluated followed by the datasets with exceptional students.

Matriculation Patterns of Students

The following Table 4.6 shows the majors chosen upon matriculation as a percentage of students from the following groups of students: all students, all students at FYE universities, exceptional students at FYE universities, all students at non-FYE universities, and exceptional students at non-FYE universities. To further clarify, FYE universities are Clemson University, Purdue University, and Virginia Polytechnic Institute and State University. These groups of students are also compared within matriculation groups of engineering majors in Table 4.7 and STM majors in Table 4.8.

The data for FYE university columns and non-FYE university columns in Tables 4.6, 4.7, and 4.8 were derived differently. FYE universities matriculate engineering students as FYE, data was taken from the variable for these students in the major chosen after FYE. While those in the non-FYE university data uses the matriculation data provided by that university. Therefore a direct comparison of FYE and non-FYE columns should not be done. However, a comparison between typical and exceptional students may take place within any of the FYE or non-FYE institutional data.

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Table 4.6 - Majors Chosen by Students at Matriculation

Major group	All Students (%)	All Students at FYE Universities (%)	Exceptional Students at FYE Universities (%)	All Students at Non-FYE Universities (%)	Exceptional Students at Non-FYE Universities (%)
	N=1014984	N = 305107	N=5021	N = 635099	N = 14006
Arts/Humanities	22.3	12.4	6.7	18.9	14.2
Agriculture	2.7	6.0	1.5	1.4	0.3
Business	12.4	9.8	4.9	15.0	4.3
Engineering	17.2	23.1	50.3	16.4	45.8
History	0.9	0.6	0.2	1.2	0.7
Multi/Interdisciplinary	0.3	0.1	0.1	0.4	0.7
Other Non-STEM	12.6	12.6	4.9	13.4	2.5
Science/Math	19.6	18.4	26.0	22.3	27.9
Social Sciences	8.3	6.6	3.0	10.0	3.4
Technical	2.1	4.6	1.5	1.1	0.1
Undecided	1.7	5.7	0.9		0.0

Note: Populations in various columns may not add up to total populations. Raw data was used to determine major groups in the "All Student" population, while other columns used data from cleaned files.

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Upon examination of the data in Table 4.4, we see that exceptional students are less likely to matriculate into an agricultural engineering major than typical students. We should note that universities providing data to the MIDFIELD dataset are land grant universities and therefore have agricultural programs. It is also noted that the number of typical students choosing business majors is significant, particularly when compared with the number of exceptional students choosing a majors in this area. Further examination of this table shows that the number of exceptional students choosing an engineering major regardless of university is three times more likely than typical students making the same choice. MIDFIELD data is from universities that are engineering focused, therefore this is worthy of note. STM majors are more likely to be chosen by exceptional students than typical students and exceptional students are less likely to pursue majors in the social sciences than typical students.

Since many large engineering schools use the FYE model, MIDFIELD data shows that nearly 40% of the students choose and universities of higher learning that have a FYE (FYE) program. It should be noted that this is different than a national sample, where no more than 60 out of 408 universities with engineering programs use the FYE model. The national sample indicates that 22.5% of typical students enter FYE programs (Chen, Orr, Brawner, Ohland, 2014).

Further examination of available data in MIDFIELD is noted in Table 4.7. This table focuses on majors chosen by students declaring engineering as their major of choice. In the case of a non-FYE university, students may choose a specific discipline, or general engineering which is undeclared at those universities. Students at the FYE universities declared engineering and matriculated into a FYE program at that university.

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Table 4.7 - Majors Chosen by Engineering Students at Matriculation

	All Engineering Matriculants (%)	All Engineering Matriculants at FYE Universities Choosing a Specific Engineering Major (%)	Exceptional Engineering Matriculants at FYE Universities Choosing a Specific Engineering Major (%)	Engineering Matriculants at Non-FYE Universities (%)	Exceptional Engineering Matriculants at Non-FYE Universities (%)
ENG Major	N=174934	N = 70504	N = 2527	N = 103893	N = 6421
Architectural	0.9			1.5	0.2
Aerospace	5.3	5.0	8.3	8.8	12.9
Ag/Biological	1.0	1.9	2.9	1.6	1.5
Chemical	5.8	6.2	8.2	9.5	12.3
Computer	5.5	5.7	12.9	9.0	13.6
Civil	6.0	9.3	5.7	9.7	3.6
General	7.5			12.7	17.0
Electrical	10.1	9.6	11.6	16.2	14.1
Environmental	0.8	0.1		1.4	0.5
Other	2.2	0.1	0.3	3.7	2.3
Science & Mechanics	0.7	0.8	1.1	1.1	1.2
FYE	38.8				
Industrial/Systems	3.0	5.3	3.80	4.8	4.0
Mechanical	9.2	14.5	15.70	14.9	12.0
Materials	0.7	2.5	2.90	1.0	2.0
Nuclear	0.6	0.5	1.30	1.1	1.6
Textile	0.7			1.1	1.0

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Table 4.7 shows students matriculating into engineering programs. We should make note of the following that 9.6% of the typical students choose to matriculate into electrical engineering following completion of an FYE program and that 16.2% the typical students matriculate into electrical engineering at a non-FYE institution. The data also shows that materials engineering attracts 2.5 % of the typical students completing a FYE program, and only 1.0% of these students choose the same at a non-FYE institution. Regardless of typical or exceptional student classification, electrical and mechanical engineering are the most frequently chosen major upon matriculation or completion of an FYE program. The data collected in MIDFIELD includes the tech bubble and subsequent burst, which may explain this finding.

When comparing typical students and exceptional students at FYE universities, we see that fewer exceptional students choose civil engineering than typical students. Students at non-FYE universities show some differences between typical and exceptional students, but not the same percentage shifts as noted in the FYE universities.

The distribution of majors after an FYE program is known to be different than those at a non-FYE university. This table shows that exceptional students are 33% more likely than typical students to choose chemical engineering, which supports work done by Zhang, Thorndyke, Carter, Anderson, and Ohland (2003) and Brawner, Lord, and Ohland (2011). We also find that exceptional students are slightly less likely to choose industrial and systems engineering than typical students. This may be due to the fact that a higher percentage of exceptional students are male and industrial/systems engineering attracts women more than other engineering majors.

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Exceptional students are 50% more likely than typical students to choose general engineering at the non-FYE universities. Choosing general engineering leaves student's choice of major open, allowing them to further investigate the different engineering disciplines available to them. Supporting our earlier discussion regarding multipotentiality where students have difficulty making decisions because of the options and opportunities available to them.

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Table 4.8 - Majors Chosen By STM Students at Matriculation

	All STM Matriculants (%)	All STM Matriculants at FYE Universities (%)	Exceptional STM Matriculants at FYE Universities (%)	All STM Matriculants at Non-FYE Universities (%)	Exceptional STM Matriculants at Non-FYE Universities (%)
Specific STM major	N=217,873	N = 68505	N = 1306	N = 149368	N = 3912
Agricultural	6.0	7.6	4.1	5.3	1.8
Architecture	8.5	6.7	9.9	9.4	6.2
Chemistry	4.4	3.9	4.2	4.7	7.2
Computer Science	14.0	13.3	29.9	14.3	32.8
Environmental	1.1	1.2	0.3	1.0	0.8
Geosciences	1.8	1.5	0.8	1.9	1.1
Life/Bio Sciences	28.9	25.4	22.1	30.6	22.2
Mathematics	3.8	4.3	7.4	3.6	8.8
Med Tech	0.3	0.1		0.3	
Physics/Astronomy	5.1	4.0	10.9	5.7	13.5
Psychological Sciences	16.6	11.5	4.8	19.0	5.1
Technical Sciences	0.2	0.5	0.7		
Computer Technology	1.5	4.6	2.0	0.1	
General Technology	1.1	3.4	0.9		
Engineering Tech	5.5	8.3	0.6	4.3	0.3
Transportation/Moving	1.2	3.8	1.5		

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When reviewing the data in Table 4.8 for STM major matriculation we see a larger number of exceptional students choosing computer science than any other major. In the case of exceptional students in both FYE and non-FYE universities, 28.9% of students choose computer science over other majors. As noted previously, the data in the MIDFIELD dataset includes the dot com bubble. While we cannot be sure given this research, future research might include how much persuasion or pre matriculation interest was generated in computer science with the exceptional student.

Exceptional students choose mathematical sciences twice as often as typical students regardless of university. This is also true for students choosing majors in the areas of physics and astronomy. Conversely, psychological sciences are chosen twice as often by typical students than exceptional.

Comparison of Findings

Students in both the typical and exceptional groups display some trends that are alike, but also dissimilar trends. The typical students often choose liberal arts and business as their first major. The disparity in choice between STEM fields only becomes apparent when the data is filtered by STM and ENG only data. The STM only data shows that students most often choose computer science, life/biological sciences, and psychological science in larger numbers than any other major in that grouping of variables. We find that the ENG only data shows that some majors are chosen at matriculation more often than others. Those majors are mechanical and electrical engineering. This is most likely because the less available majors are not offered at all universities contributing to the MIDFIELD database, while the foundational majors such

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as mechanical and electrical engineering are typically offered at all universities with engineering programs. In the typical student database, this forty percent choosing a university that has an FYE program in the ENG only dataset represents only 8.5% of the students. Supporting the separation of data for an in-depth examination of students choosing engineering majors upon matriculation.

Exceptional students are found in all majors, but are overrepresented in engineering and computer science. Those who perform well on standardized tests generally seek out or are encouraged to pursue these fields. When examining the STM data we found that the exceptional students more often choose computer science, and physics and astronomy majors at matriculation, with liberal arts representing majors in fine arts and humanities. Further examination shows that their choice of major is not evenly distributed. There appears to be a second tier of majors chosen by these students; the majors include architecture and chemistry. Other majors have few, if any, students choosing them at matriculation.

When considering the choice of major, further questions arise regarding the academic pathways that students take with regard to their choice of STEM major at matriculation and the characteristics of these students as they choose to continue to study or not. Further investigation of academic pathways and continued study of STEM fields of students that choose STEM majors at matriculations follows in the next section.

Cluster Analysis

Cluster analysis was chosen as a method of evaluating the data for trends in the choice of major and SAT scores. We were able to input SAT_M and SAT_V as 2D coordinates and run the cluster analysis on the data for both typical and exceptional

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students. After the clusters were determined, the coordinates for the center of each coordinate was used to define separate files for each cluster, providing us with information that correlates the choice of major by students scoring different scores on the SAT.

Typical - Top Clusters and Matriculation/FYE Majors. Cluster analysis was run on the data for typical students using SAT_M and SAT_V available data. To optimize the information derived using this method, three trials were run. All the trials allowed up to one hundred iterations, while each trial had a specific number of clusters identified. The number of clusters that were used for the trials were ten, twenty-five, and fifty. Based upon the results of these analyses the number of clusters in the analysis and resulting cluster populations, the results for ten clusters shows a better distribution of population (and results that are simpler and easier to interpret) than the twenty-five or fifty cluster analysis. Table 4.9 below lists the clusters, using the numbers generated in SPSS, this data includes the centroid of the cluster.

Table 4.9 - Typical Student Data – Clusters Identified

Cluster	Population	SAT_M	SAT_V
1	98,064	625	568
2	37,225	389	375
3	103,821	534	510
4	65,940	533	598
5	66,202	506	414
6	49,395	725	676
7	60,704	623	664
8	63,629	619	458
9	40,137	728	534
10	19,007	420	505

The centroids listed in Table 4.9 have been graphed and can be found in Figure 4.1. Due to the clustering procedure, Figure 4.1 shows that the data is evenly distributed and therefore clearly represents the data.

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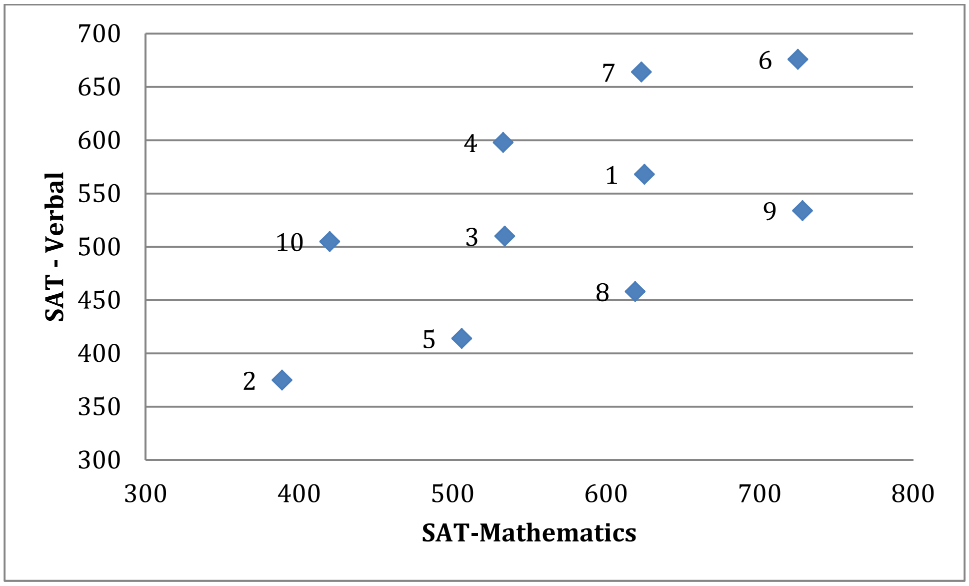

Figure 4.1 - Typical Student Data – Cluster Graph

Using this information, extracting data within the range of the SAT data, and considering majors that represent a large portion of the population for the following information was assembled: first majors chosen, and majors chosen at those universities using the undecided or "general" engineering designation (EGE). Most resulting categories are small; therefore, those that appear in this table represent those major choices most highly represented in each cluster. For the most part, this includes those majors that represent more than 10% of the majors chosen in a given cluster. The choice of major for the typical student using the cluster data shown in Table 4.9 and Figure 4.1 are provided in Table 4.10.

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Table 4.10 - Choice of Major by Typical Student Group by Cluster

Cluster	First Majors Chosen	EGN Majors Chosen
1	Business Liberal Arts FYE Life/Bio Sciences	Mechanical Civil Industrial
2	Liberal Arts Business Education	
3	Liberal Arts Business	Mechanical
4	Liberal Arts Business	Business
5	Liberal Arts Business	
6	FYE	Mechanical
7	Liberal Arts Life/Bio Sciences	Mechanical
8	Business FYE Liberal Arts	Mechanical Electrical
9	FYE Business	Mechanical
10	Liberal Arts Business Education	

Typical students are shown in this cluster analysis, with distinct information on the relationship of SAT scores and choices made by the typical student. For instance, we see that cluster number 2 is comprised by students that have comparatively low SAT scores. These students initially choose liberal arts, business, and education, in the unlikely event that they were admitted to an FYE program, they pursued Civil and Mechanical engineering. These engineering students are rare as students with low SAT_M scores are usually not admitted to engineering programs. Students choosing mechanical engineering are found throughout Table 8; therefore a similar observation cannot be made for these students. Further analysis was done of students falling into the exceptional student group for comparison.

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Exceptional Data – Top Clusters and Matriculation/FYE Majors. Cluster analysis was also run on the exceptional data using SAT_M and SAT_V available data. Similar methods were used analyzing ten, twenty-five, and fifty clusters with up to one hundred iterations. The results of the analysis were similar to the typical student analysis indicating that ten clusters provided a better distribution of population. Table 9 below, lists the clusters, using the numbers generated in SPSS, this data includes the centroid of the cluster.

Table 4.11 - Exceptional Student Data – Clusters Identified

Cluster	Population	SAT_M	SAT_V
1	1283	787	785
2	1349	718	790
3	2419	712	727
4	2852	740	698
5	3119	783	671
6	2367	788	721
7	1544	797	637
8	1557	685	756
9	1532	745	749
10	805	654	790

The centroids listed in Table 4.11 have been graphed and can be found in Figure 4.2. Due to the clustering procedure, Figure 4.2 shows that the data is evenly distributed and therefore clearly represents the data. Due to the criteria used to choose student data that is exceptional the graph has no data below a certain point, the axes were adjusted to accommodate the data used in this graph.

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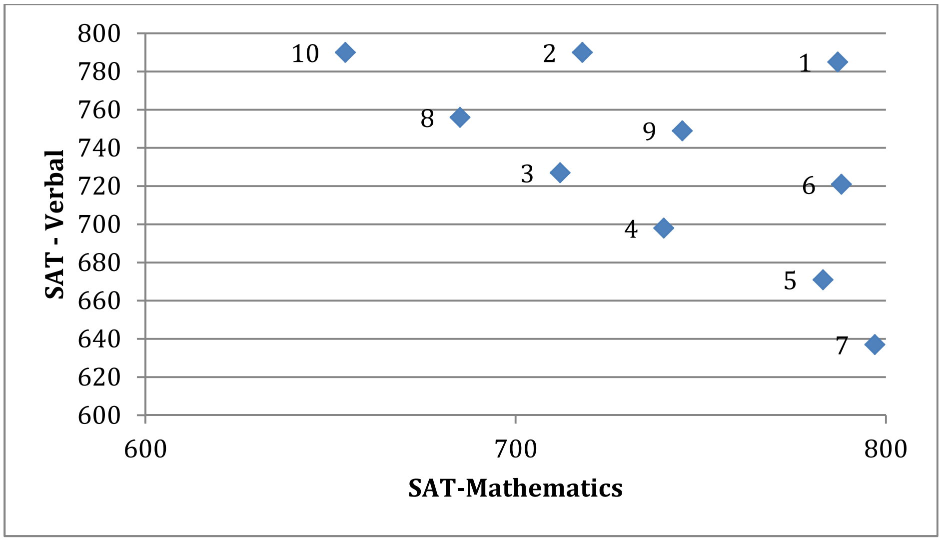

Figure 4.2 - Exceptional Student Data – Cluster Graph

Using this information, extracting data within the range of the SAT data, and considering majors that represent a large portion of the population for the following information was assembled, first majors' chosen, and majors chosen at those universities using the general engineering designation. Most resulting categories are small; therefore, those that appear in this table represent those major choices most highly represented in each luster. For the most part, this includes those majors that represent more than 10% of the majors chosen in a given cluster. The choice of major for the exceptional student using the cluster data shown in Table 4.11 and Figure 4.2 are provided in Table 4.12.

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Table 4.12 - Choice of Major by Exceptional Student Group

Cluster Number	First Majors Chosen	EGN Majors Chosen
1	Computer Science FYE	Electrical
2	Computer Science FYE Liberal Arts Life/Bio Sciences	
3	FYE Liberal Arts Computer Science	Mechanical
4	FYE Computer Science	Mechanical
5	FYE Computer Science	
6	FYE Computer Science	Mechanical Electrical
7	FYE Business Computer Science	Mechanical Electrical
8	Liberal Arts FYE	Mechanical
9	FYE Computer Science	Electrical Mechanical
10	Liberal Arts FYE	

As the data was reviewed to develop Table 4.12, it was noted that students who matriculated into an FYE program most often were not observed to choose a particular major, but rather choose majors throughout the spectrum of majors offered by their university.

Comparison of Typical and Exceptional Students. Obvious differences between the typical and exceptional data are the size of the cluster populations. A typical cluster has well over 25,000 students, while exceptional clusters are more likely to have 1000

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students. Based upon previous comparisons of data the exceptional dataset more often represents students in engineering or other STEM fields. Therefore, the findings that the typical clusters with higher student representation are most often choosing business or liberal arts majors is of no surprise. It should also be noted that the clusters of data in the exceptional datasets most often represent computer science or other basic engineering majors such as mechanical or electrical engineering.

This leads us to the discussion of where these students end up after a few years. What majors do they graduate with and the resulting changes in their course of study that was a result of unknown factors.

Exploring Persistence in STEM Majors

The data format in the MIDFIELD dataset limits this investigation into the pathways that students have taken as they traverse their course of study. Therefore, after examination of possible methods of evaluation it was determined that cross-tabulation would provide early information on the relationship of majors chosen at matriculation or completion of FYE and actual degrees awarded. The method chosen to evaluate the path is cross tabulation.

Cross Tabulation – Change of Major

Both the typical data and exceptional data for STEM students at matriculation or following FYE were examined using cross tabulation. The results of those findings can be found in each of the following sections.

Typical Data Cross Tabulation. Prior to completing the cross tabulation of the typical student dataset, a review of the high school GPA data was made. It was found that

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approximately 30% of the students were from Georgia Tech. Georgia Tech did not report High School GPAs. That did not affect this part of the data as the cross tabulation evaluates major at matriculation vs. graduating major, and major following FYE vs. graduating major. The data for these variables is present for all of the dataset.

The total number of students evaluated in this dataset is 260,470. Many of the graduating majors are not represented in great numbers. Therefore, the data that presents during the cross tabulation will be referred to in terms of percent, otherwise the findings may seem more or less relevant based upon relative numbers.

STEM Matriculation Students Graduating with Non-STEM Majors. Of the STEM majors students graduating as business majors most often declared engineering upon matriculation. However, 51% of the STM students matriculating into computer science, life and biological science, and psychology graduated with degrees in business. Students matriculating as life and biological science and psychology majors comprise approximately 40% of the communication and journalism graduates.

Further observations of the resulting cross tabulation analysis show that students graduating with an education major most often matriculated as an FYE, life and biological sciences, or psychology major. Family and consumer science majors at graduation matriculated in FYE, life and biological sciences, and psychology 77% of the time. Students graduating with a degree in health professions most often matriculated as life and biological science majors. Interdisciplinary majors upon graduation most often matriculated as life and biological sciences majors. Very small numbers of students originally matriculated as STEM majors graduate in law, liberal arts or library science.

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The results of the cross-tabulation show us that natural resources and conservation graduates are most likely to matriculate as life and biological sciences, and FYE, while philosophy and religion graduates most often matriculate as psychology, life, and biological science majors. Those that are graduates of parks and recreation programs most likely began in that major with an equal number of students from other majors at matriculation changing majors throughout their studies.

Students graduating with degrees in social sciences most often changed from first majors in life and biological sciences, and psychology, while students graduating with degrees in the visual and performing arts most often began their studies in architecture, FYE, life and biological science, and psychology.

The type of data provided by MIDFIELD does not lend itself to understanding why students change to these different majors, but does provide a basis to continue work in furthering our understanding of why students make the changes they do. In an attempt to evaluate the persistence of STEM students in STEM majors, the following describes the findings in the same datasets with students in this category.

STEM Matriculation Students Graduating with STEM Majors. Students matriculating in STM and engineering generally graduate from majors in STM and engineering. While there are some that do not, most do, therefore we are discussing the aggregate of the data as the findings of STEM reinforced STM and engineering.

Based upon the analysis, it is important to stress the distinction of choosing a major at matriculation versus choosing a major after FYE. To determine if there are multiple changes in a student's academic pathway by analyzing graduating majors in MIDFIELD, would require a different type of analysis. The results of those analyses

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would provide information what majors were chosen, rather than enhance this analysis. Our focus provides insight on choice of major and the major at graduation Therefore, we are compelled to evaluate student's choice of major at matriculation or after FYE, the first change in major and comparing it to graduation data of these same students.

81% of the students graduating in agricultural studies chose that major at matriculation. The majority of students changing majors into this field came from life and biological sciences. Of the students choosing architectural engineering upon matriculation, they comprise 64% of these students graduating in that major. Students choosing architecture as a major at matriculation or after FYE persisted in this major nearly 90% of the time. 90% of the aerospace engineering graduates either matriculated as or followed an FYE program with that choice of major.

Students choosing chemistry upon matriculation comprise 53% of the graduates in this major, with students changing majors from life and biological sciences, and physics and astronomy in equal amounts. Students choosing computer engineering at matriculation comprise 34% of the graduates while 39% of the graduates were a result of an FYE program. Students choosing computer science at matriculation comprised 69% of the graduates in that major. Students choosing computer science after FYE comprise only 7.5% of the graduates with others transferring into the program from computer engineering, general engineering, and electrical engineering.

Nearly half of civil engineering graduates chose this major after completion of an FYE program. 25% of the graduating students in civil engineering matriculated with this major. The balance of the students graduating are from other STEM majors in particular aerospace engineering, architecture, and mechanical engineering. Nearly two-thirds of the

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electrical engineering graduates matriculated or chose the major after completion of an FYE program. Students graduating with a degree in environmental engineering persisted while others transferred in from general engineering and other engineering fields.

Students graduating with a degree in engineering science and mechanics most often chose the major after completing an FYE program; few transferred in from other programs. Students choosing geosciences, or physics and astronomy after completion of an FYE program most frequently graduated with a degree in geosciences. Others transferred in very small percentages from other STEM majors.

Industrial and system engineering was most often chosen by students after completion of an FYE program. 21% of the graduates of such a program chose it as their major at matriculation. Others transferred in from general engineering and smaller percentages transferred from other majors in the STEM fields.

Throughout this discussion, particularly the section on non-STEM graduates' we see that students that matriculate as life and biological science majors frequently transferred to other fields. However, when examining the cross tabulation for graduates in life and biological sciences we find that 81% of the students that matriculated in this major persisted, with others coming in after FYE programs, and majors in agriculture, chemistry, and physics and astronomy. Slightly over half of the students that graduated with a degree in math, matriculated in that major and approximately 12% of those graduating in math chose that major upon completion of an FYE program.

Mechanical engineering graduates most often matriculated into mechanical engineering, general engineering, aerospace engineering, or chose this major after an

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FYE program. Only 10% of the graduates in this major began in a field other than those listed.

Students graduating from a medical technology program most often came from a life and biological sciences program with few transferring in from another major. The nuclear engineering programs most often obtained their graduates from an FYE program or at matriculation; few students transferred into this program. Most graduates in physics and astronomy matriculated in that major with a few coming in from life and biological sciences, or after an FYE program. Graduates of the STEM psychology program most often matriculated into the program with approximately 13% of these graduates coming from the life and biological sciences major.

Computer technology graduates most often matriculated in their field, however there were some that came from computer science and the FYE programs. Students graduating in general technology most often matriculated as such or came in after an FYE program. Those students choosing to study engineering technology at matriculation or after an FYE program consist of 86% of the graduates of that program. Nearly 97% of the technology transportation and moving services majors matriculated or chose this as their major after an FYE program. Students majoring in engineering textile programs make up over half of the graduates in that major, with others transferring in from general engineering.

Summary of Findings in Typical Data. The data provides an insight into student choices during their course of study. Students who start in STEM fields do not always stay in STEM. However, the data shows that most students choosing a STEM major at matriculation or following the completion of a FYE program are persistent in their

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chosen field. It is evident that many of the students choosing engineering as a major at matriculation or following an FYE program stay with engineering.

The typical student data includes data from students identified as exceptional students. To further understand the differences or similarities of students that perform at a higher academic level, cross tabulations of data for that student group were done to provide a contrast to the typical student data.

Exceptional Data Cross Tabulation**.** The total number of exceptional students evaluated in this dataset is 14,140. This section, like the last, has majors that are not represented in great numbers. Therefore, the data that is presented in this section will also be referred to in terms of percent. Some majors will not be included in the discussion due to the very low number of graduates from that program. For example, Area Ethnic Cultural and Gender Studies had two graduates in this group; therefore we will not discuss this major in this section.

STEM Matriculation Students Graduating with Non-STEM Majors**.** Graduates whose first major was computer science make up the largest number of graduates from a non-engineering major. The balance came from computer engineering, general engineering, and a fairly even distribution of other STEM majors. Otherwise non-STEM final majors are not significant enough in number to discuss.

Students Matriculating Into FYE Programs and Graduating with Non-STEM Majors**.** Exceptional students who completed FYE programs and graduated from non-STEM majors are most likely to graduate from a variety of programs. These graduates can be found in a variety of programs such as business, English language and literature, interdisciplinary, and social sciences.

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Students Completing FYE Programs and Graduating with STEM Majors. Most of the students represented in the exceptional student dataset chose majors in STEM fields after completion of an FYE program. The majors with the largest representation in this group of students include chemical engineering, electrical engineering, and mechanical engineering. The balance of these students graduated from other programs in fairly evenly distributed numbers.

Summary of Findings in Exceptional Data. Based upon the cross tabulation tables we see that exceptional students are more likely to choose a STEM major and persist. Many of the majors that the exceptional student chose if they changed majors were also STEM majors. However, a small percentage of these students left STEM majors to pursue non-STEM majors.

Further comparison of data from this group and the group of typical students follows.

Comparison of Typical and Exceptional Data. Since typical students switch more than exceptional students, provided information on which majors students tended to leave and which majors they gravitated towards. This is particularly true with regard to the movement out of STEM fields by the typical student. It was also noted that the typical student more often than the exceptional student moved into a non-STEM field after completing an FYE program. Some fields received relatively low numbers of students that matriculated as STEM majors such as law, liberal arts, or library science.

It was also noted that typical students matriculating in a STEM major generally persist in STEM, however a large number of these students will move on to a non-STEM field, relative to the number of students graduating in that field. Overall, the number of

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exceptional students matriculating into a STEM field and graduating in a non-STEM major is not significant. Exceptional students generally matriculate or choose a STEM major after an FYE program and persist.

These findings generate more questions regarding the choices made by the typical and exceptional students. This leads us to review other factors that contribute to a change of major that can be found in the MIDFIELD dataset.

Other Factors Contributing to Change of Major

In this last section of this chapter, further investigation is made into the data in these same datasets, which are a subset of the MIDFIELD dataset. We know that students change majors, however, we have not investigated when they change major, nor have we checked which major is chosen at that time. Following that investigation we also will look at final majors by STEM students in both the typical and exceptional datasets. Finally, an examination of students that dropped and those that transferred in will complete the investigation for this body of research.

When STEM Students Change Major**.** A basic frequency analysis of typical and exceptional student data was completed, as well as an analysis using the typical STEM student, sorting using the first major for both students that dropped out and those that did not. Table 4.13 lists the average term when a student in each of these groups changes majors.

Table 4.13 - Summary of Average First Term of Change in Major

	Typical Student Overall	Exceptional Student Overall	STEM Majors Did Not Drop	STEM Majors Dropped
Mean	5.5	5.8	6.2	4.0
Median	4	4	5	3

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Comparing the mean time the typical student changes majors to the exceptional students' timing, we see that the exceptional student takes slightly longer to change majors than the typical student. Previously, we also noted that the exceptional student is less likely to change majors than the typical, proving that it takes a longer time for the exceptional student to make such a change.

While changing majors is an important factor to consider. This provides us with a better idea of the changes students are making with regard to STEM majors. Table 11 shows that students dropped STEM majors much sooner than students making a change of major within STEM majors. This leads us to question of what majors were chosen by students when they made their first major change.

Majors Chosen by STEM Students in First Major Change**.** Further examination of the data that shows the majors that were chosen at the first change of major summarized in the following Table 4.14. Those majors that are listed in this table are those that are significant with regard to the other majors that appear in the list. They are ordered from most to least popular.

Table 4.14 - Majors Chosen By Typical Students in First Major Change

Typical Students	Typical FYE Students	Typical Non FYE Students
Business	Business	Business
Social Sciences	Undeclared	Social Sciences
Liberal Arts	Health Professions	Life/Biological Sciences
Health Professions	Agriculture	Liberal Arts
Life/Biological Sciences	Education	Comm & Journalism
Education	Family & Consumer Sci	Psychology
Communication & Journalism	Life/Biological Sciences	Education
Psychological Science		
Visual & Performing Arts		

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Table 4.14 provides an insight into what typical students choose, in order of their significance, as their first major change following matriculation. It should be noted that typical students at non-FYE universities generally do not change into STEM fields, with the exception of life/biological sciences, and psychological sciences. The typical students at FYE universities often follow varying paths with their first major change. Based upon findings provided earlier in this chapter the major most often found transferring into other majors is life and biological sciences. This provides us with the understanding that the student body that originally chooses, and later chooses life and biological sciences may likely transfer to other majors and ultimately out of STEM majors. To further our understanding of how students behave Table 4.15 presents our findings of the first major change by exceptional students. These majors are also ordered from most to least popular.

Table 4.15 - Majors Chosen By Exceptional Students in First Major Change

Exceptional Students	Exceptional FYE Students	Exceptional Non-FYE Students
Mechanical Engineering	Mechanical Engineering	Computer Science
Business	Health Professions	Mechanical Engineering
Computer Science		Business
		Social Sciences

Table 4.15 indicates a higher level of students changing major into engineering fields. It is important to note that typical students generally do not transfer into engineering majors, as recognized by the majors noted in Table 4.14.

When reviewing the majors chosen most often at the first major change by exceptional students we find the most typical of engineering disciplines: electrical, mechanical, and chemical, as well as computer science. Others choose to move into business or social sciences. When reviewing findings with regard to students in FYE programs we did note that the first change of major was into another engineering major, while the data shows some movement into majors outside of engineering the number of

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those students relative to the whole is not noteworthy. Finally, the student attending a non-FYE university often chooses majors outside of STEM majors in their first change of major. These majors include business and social sciences, while changes within STEM majors are most often to computer sciences, life/biological sciences and mechanical engineering.

Overall, these findings show us that typical students choose majors in non-STEM majors when they change majors. Exceptional students often move to an evenly distributed choice of technical and non-technical majors. Students who change their major and did not drop out of their college usually chose technical programs. Those that dropped out usually were in programs such as FYE, life and biological sciences, and psychology science. This suggested further investigation to determine the final major for students that chose STEM fields upon matriculation or completion of an FYE program.

Final Major by STEM Students**.** A review of the dataset with data from students that chose STEM majors upon matriculation or completion of an FYE program was done. It was completed for both typical and exceptional students, and compared below.

Typical Final Major**.** Due to the size of this dataset, only the majors that represented over 5000 students will be included, using a percentage based upon the number of graduates in these majors. General observations show that students matriculating into a STEM field most often graduated from programs noted in Table 14 below. This table is based upon a total of 100%, using those items that were significant in number to include in this table.

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Table 4.16 - Typical Students Matriculating into STEM Majors – Major Awarded

Major	Percentage (%)
Life/Biological Sciences	14
Mechanical Engineering	12
Psychological Sciences	12
Electrical Engineering	11
Computer Science	10
Civil Engineering	9
Business	9
Industrial/Systems Engineering	6
Chemical Engineering	6
Architecture	5
Computer Engineering	5
Agricultural	4

The only field that represents those students that left STEM majors is business. Further investigation would be needed to understand the reasons these students moved into business after choosing a STEM major at matriculation.

Exceptional Final Major. While this dataset is much smaller than that used to analyze typical student data, the majors that represent over 500 students will be included, using a percentage based upon the number of graduates in these majors. General observations show that students matriculating into a STEM field most often graduated from programs noted in Table 15 below. The total percentage is based upon the sum of the top majors chosen.

Table 4.17 - Exceptional Students Matriculating into STEM Majors – Major Awarded

Major	Percentage(%)
Computer Science	32
Mechanical Engineering	25
Electrical Engineering	24
Computer Engineering	19

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The data in Table 4.17 confirms that the majority of exceptional students that chose STEM majors upon matriculation did not leave STEM fields, but persisted.

Comparison of Final major for Typical and Exceptional STEM Students. This data shows us that typical students are more likely to leave STEM majors and move into business majors, while exceptional students are more likely to move around STEM majors and persist. That is a very broad generalization given the dataset with which we are working.

Because of the limitations of the data, further examination of these datasets with regard to students dropping and transferring in may give more insight into the path STEM students take with their academic career. Further consideration of drop outs must include the possibility of transferring out and completing degrees at another institution.

STEM Students that Dropped or Continued. The same datasets used for the previous analysis were used to analyze the median SAT scores for both typical and exceptional student groups that did and did not drop out of college. The following Table 16 includes SAT Scores, HS GPA (when available), and the sub-category of students matriculating or following an FYE programs.

Table 4.18 – Data for Dropped and Continuing Students in STEM

	SAT-M	SAT-V	High School GPA	First Major Group - ENG	First Major Group – S&M	First Major Group - TECH
Typical Dropped	567	534	3.36	44.8	51.8	3.4
Typical Continuing	580	530	3.41	50.4	44.7	4.9
Exceptional Dropped	750	720	3.81	62.0	37.6	0.4
Exceptional Continuing	760	720	3.84	66.0	33.4	0.6

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This table shows that the difference between students that dropped out of college and those choosing to continue, regardless of them being typical or exceptional is not determined by SAT scores or HS GPA. However, looking at the major groups, in particular students choosing engineering as a first major, we find that they are much more likely to drop out of college than those pursuing a technical major. There is one exception to this finding and it is students in the typical group drop out less often than those choosing a science or mathematics based major upon matriculation.

Since this data didn’t provide a great deal of insight into student’s choices, further investigation into students transferring into STEM fields is investigated in this last section of the chapter.

Students that Transferred into STEM Programs**.** Further investigation regarding students choosing to transfer into STEM programs from non-STEM programs as well as other universities yielded the information presented in Table 17.

Table 4.19 - Students Transferring into STEM Programs

	Transfer Students
Typical Students	13%
Exceptional Students	7.1%

The data in Table 15 shows that more students represented in the typical student database transferred into STEM majors, while fewer exceptional students transferred into STEM majors. Previously we saw that exceptional students most often choose a STEM field upon matriculation or completion of a FYE program. This may contribute to the lower number of exceptional students transferring into a STEM program, because they are already working in a STEM program.

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Summary of Findings

While analyzing the data in the MIDFIELD dataset, many things have become evident. Some may have been obvious via inference; other things directly refute findings in other smaller datasets. While we are not certain why the differences exist, we may be able to compare demographics of the study population. The MIDFIELD database with two exceptions represents many of the universities in the southeastern portion of the United States. This should be considered when reviewing and evaluating the data presented in this dataset.

General Observations

Typical students, at matriculation, most often choose majors in STM rather than engineering. We also found a direct relationship of SAT Scores and choice of major area. Students choosing engineering majors tend to have higher SAT scores and high school GPAs. When viewing these variables, those performing in the mid-range of both SAT scores and high school GPAs were most likely to choose STM majors.

Exceptional student data showed a direct relationship between SAT scores and high school GPAs, increasing proportionally. It was also determined that students in this sub category choose STM and engineering majors in almost the same rate, whereas this is not the case with the typical student.

Ethnic Observations. Asian students were more likely to choose engineering than other STEM majors in both the typical and exceptional student datasets. Conversely, African-American students chose STM majors at matriculation much more frequently than engineering majors. When comparing the percentage of African-American students

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to other students in both the typical and exceptional student populations, there are far fewer students in the exceptional student group than in the typical student population.

When comparing Hispanic student populations in both the typical and exceptional student data we found that they chose STM and engineering majors in similar percentages. Students classified as international choose engineering over STM students in both the typical and exceptional student datasets. Generally, Asian students score higher on SAT Scores and have higher high school GPAs than other ethnic groups.

Gender Observations. The gender split in the typical students becomes more divergent from the general population figures as STM and engineering majors are evaluated. When examining the data for exceptional students, the majority of students in that group are male. This becomes more pronounced as STM and engineering majors were analyzed, finding that the most extreme scenario is engineering students in the exceptional student group, with the white male population at nearly 84%.

Choice of Major

At Matriculation. Typical students generally choose a large variety of majors; however those that are chosen most often are business or liberal arts majors. Students choosing a STEM major at matriculation generally chose FYE or life and biological sciences. Typical students that do choose a STEM field, and do not have FYE programs available, were most likely to choose general engineering, electrical engineering, or mechanical engineering as their major of choice at matriculation. Exceptional students usually choose computer science, FYE programs or other engineering fields upon matriculation.

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After FYE Program Completion. Typical students that complete an FYE program often choose the foundational engineering programs such as chemical, civil, electrical, industrial, and mechanical engineering. Exceptional students chose majors that were fairly evenly distributed throughout the list of available majors.

Cluster Analysis. The cluster analysis of both the typical and exceptional database supported the findings in the earlier section. We were able to see that the majority of students in the typical student population chose business or liberal arts majors at matriculation, supporting what was already found. The results of the analysis also showed that students not performing in the higher levels of the SAT chose majors other than STEM at matriculation.

The exceptional student data provided substantiation that the first major chosen by this group is most often FYE, life and biological sciences, computer sciences and general engineering. All of these generally demand higher academic performance for acceptance into the various programs.

Based upon the clusters found in the exceptional student data, we found students that performed well in both the SAT_M and SAT_V, but not at the top of the SAT_M scores were most often in non-engineering majors. Is this an artifact of admissions policies? How should we encourage academic counselors to suggest engineering to students that perform well on the SAT_V and not quite as high on the SAT_M?

Persistence

Cross tabulation of matriculation/FYE choice of major data and graduating major was done to analyze the data for both typical and exceptional students. This was intended to evaluate the data for persistence or general continuation of study within STEM majors.

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Typical students that graduated with a degree in business frequently began their study in an FYE program, others began in agriculture and life and biological science, while 40% of the communication and journalism majors began in STM fields of life and biological science and psychology science.

Overall the findings indicate that students beginning in more specialized STEM majors tend to persist. The majors with less specialization in the first year or two did not have this level of persistence that was evidenced in the analysis. Good examples of persistence are students choosing architecture, aerospace engineering, and chemical engineering. It is also evident that students entering and completing FYE programs were most likely to continue in engineering majors.

Exceptional students are most likely to choose a STEM major and persist. While we are unable to determine the reasons why students make the choices they do regarding career trajectory from the MIDFIELD data, further study in this area is suggested for future work.

First Major Change. When examining the findings from the section on the first major change, we find that the exceptional student persists in STEM fields, while typical students choose fields that are not generally related to STEM. Further examination of the analysis indicates that exceptional students generally stay with STEM majors, with the exception of business. When STEM majors are engaged in their major, they do not drop out of the university programs. However, the findings indicate that students in FYE, life and biological science, and psychology science most often drop. After examining all of the data in the preceding sections of this chapter we find that students in life and biological science and psychology science transfer at least once. This may indicate that

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they are more likely to quit. We neglect to include FYE as these students tend to be the higher performing students, and therefore we cannot make an inference on these students or their choices.

Final majors. We find that typical students that matriculate into a STEM field will graduate from a variety of programs in and outside of STEM majors. Exceptional students tend to persist in STEM majors.

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CHAPTER 5. CONCLUSION

The questions posed in this research were a result of an in-depth examination of Shea, Lubinski and Benbow's (2001) research on students identified as exceptional. Later work by Lubinski and Benbow (2006, p. 325) modified a graph constructed by the original researchers entitled College Major (Age 23) that provided a correlation of conferred degree related to SAT scores. The dataset used by Shea, Lubinski, and Benbow and others in the Study of Mathematically Precocious Youth (SMPY) consists of data from students identified in middle school and provided intervention in STEM subjects, culminating in research of the majors students pursued and ultimately their conferred degree.

While we do not have a sample group of this type, we do have MIDFIELD data. MIDFIELD data is collected from various universities, with no contact with the subjects – so the behaviors of the exceptional students in MIDFIELD are free of the interventions associated with the SMPY. The MIDFIELD data is a longitudinal research database that contains academic data from over a million students. This data was collected from the standard student records of participating universities, so it does not include special testing such as spatial ability that the SMPY researchers were able to include in their research.

This research is based upon the intersection of SAT scores and how they relate to college major at matriculation, and major upon graduation. A direct comparison to SMPY

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results is difficult as the SMPY researchers included the spatial data and we do not have data on that attribute, yet it is still possible to explore the typical SAT verbal and math scores that characterize different disciplines. This is shown in the findings chapter where cluster analysis is used to determine how majors related to SAT scores.

Focusing on the research questions and a review of the findings, an in-depth discussion regarding the answer for each question are presented in this chapter. The first two questions are related to academic ability and the last three are based on student persistence.

Previous literature addressed smaller groups of students, using a variety of statistics to prove or disprove various hypotheses. MIDFIELD data is whole population data, and with simple summaries and comparisons we are able to use these findings to advance research in this area. Each of the following sections addresses findings, conclusions, and recommendations for future work.

Academic Ability

The first question asks, “What is the relationship between standardized test scores and choice of major among exceptional students?” To answer this question, we must review the findings in the sections that address choice of major at matriculation and after completion of an FYE program as they relate to SAT scores. The students classified as exceptional scored in the top 3% of the students in the dataset; combined SAT Verbal and SAT Mathematics were used for this selection.

Academic Ability and Choice of Major**.** The MIDFIELD data demonstrated that higher SAT Scores were associated with higher high school GPAs. It was also noted that students in the exceptional group were more likely to choose an engineering field as a

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choice of major at matriculation or completion of an FYE program, but it was difficult to predict what major they would choose. When compared to STM majors as a choice at matriculation, exceptional students are more likely to choose engineering majors. Exceptional students are also more likely to choose STEM majors than typical students.

Racial/Ethnic Trends. The analysis provided information that showed Black students are underrepresented in the exceptional group, whereas Asian students are overrepresented. Male students are overrepresented in nearly all categories than female students. There are more White students than any other ethnic group identified in the typical engineering group and in every category examined in the exceptional student group. With overrepresentation in most categories by White students, the most remarkable difference in gender and ethnicity is in engineering, where more Black women are found than Black men.

Engineering as Choice of Major. Exceptional students studying engineering tend to choose majors that are well distributed throughout the available engineering fields. Those students who complete a FYE program distributed more so than any other group of students. However, it should be noted that MIDFIELD data indicates that exceptional students most often choose engineering majors at matriculation. Returning to the question asked we find that exceptional students, by matter of definition, score the highest on the SAT. This research shows that these same students more frequently choose STEM majors upon matriculation and completion of FYE programs. Therefore, the higher a student scores on the SAT and performs in high school using the GPA as the benchmark, the more likely these students are to choose STEM fields, particularly engineering as their course of study.

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The second question is, “How is the relationship between standardized test scores and choice of major for the typical student different from the relationship observed for exceptional students?” To answer this question a direct comparison of data from the previous question and that from the typical student database is required.

Choice of Major. Typical students regularly chose liberal arts or business majors closely followed by life/biological sciences, health professions, social sciences, and education upon matriculation. Those typical students that completed an FYE program generally chose majors in mechanical, and electrical engineering. Exceptional students most often chose STEM fields at matriculation and after completing an FYE program. The difference between typical and engineering students is that exceptional students most often chose engineering and the typical student does not.

Ethnic and Gender Issues. Further, a disparity between genders and ethnic groups was also noted as sub data containing only students pursuing STM or engineering majors at matriculation or after completion of an FYE program. The data for typical students shows that the initial spread in gender most often mimics the general population. However, the number of males in data as STM students and then engineering students are examined becomes greater; this is also true for white students. When the student data is further broken down into the exceptional students, the ethnic disparity as well as the gender disparity, with the exception of Asian and white students becomes much larger as STM students and then engineering student demographics are examined.

Academic Ability Conclusions

Based upon the information derived from the databases, we can conclude that students identified as exceptional or higher performing on standardized testing such as

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the Scholastic Aptitude Test are more likely to choose engineering or other STM majors upon matriculation at the rate of 74%, while traditional students pursue STEM majors upon matriculation at the rate of 39%. Based upon the information found in the MIDFIELD dataset, we found that exceptional students choose majors across the various majors at their university. This does not provide a direct relationship between a particular score and a choice of major; however we have learned that exceptional students are more likely to choose a STEM major upon matriculation or completion of an FYE program. Further, we have found that if an exceptional student scores in the highest scores of this test, it is very likely that they will major in a STEM field, and most likely in engineering if they are male.

Other studies concluded predicting students that students performing higher on the SAT also have higher high school GPAs (Coyle, Snyder, Pillow, & Kochunov, 2011). This research took this a bit further by asserting that students performing higher on the SAT are more likely to choose a STEM major upon matriculation or completion of an FYE program. Based upon the data and analysis that was performed for this research we found that it is otherwise difficult to predict these choices.

Academic Ability Recommendations for Future Work

The findings regarding the choice of major by exceptional students substantiates the question of value an intervention, such as those used in programs such as SMPY (Benbow & Stanley, 1983; Lubinski & Benbow, 2006). The students in this study are identified as the highest performers on standardized tests. They are then given interventions designed to introduce these students to STEM fields, with the intent of

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providing them with experiences that will support college matriculation decisions. Based upon the findings of this research the relevance of this type of project is in question, particularly when students that are identified by their scores on standardized tests choose STEM and engineering majors without the interventions.

Other findings that became obvious during the examination of analysis for this study included the large disparity of students identified in different ethnic groups. The data that presented itself provides a clear view that minority students are not well represented in student groups choosing STEM fields when they go to college. To further understand this dilemma, qualitative examination as well as review of existing documentation would provide a better idea regarding the challenges that present themselves in minority cultures and communities. The National Action Council for Minorities in Engineering, Inc. (NACME) has provided documentation on these issues (2008) for African-Americans, Latino, and Native Americans. The issues are unique to each culture and group of students, therefore the treatment of the data and findings provide slightly different results.

Further research on these students would provide a better understanding of why students choose their majors. In particular, did a family member, a particular experience, or someone in their lives influence their choice of major or field of study? The MIDFIELD data does not present this type of information; however there has been a great deal of research in how family members or others in a student's environment affect what they think and how they react. This work will help guide the development of those studies and the interpretation of their findings.

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Finally, in the examination of the data it was found that regardless of the dataset, the category of international student was particularly low. Given the dealings with students at a variety of universities, the percentages less than 1% appear to be affected by some unknown factor. Further examination of this data and the results may provide enlightenment as to this otherwise well represented population.

Persistence

Student persistence is measured in many ways (Ohland, et al., 2008). For the purpose of this investigation, we are measuring students' persistence in major, in particular, matriculation or post-FYE major. The questions that are asked in this research are concerned with student academic pathways. The data available in the MIDFIELD datasets include first major, major post-FYE, semester students first change major, the major that they transfer to, and final major. This information was used to make the conclusions and recommendations for future work in this research.

The examination of MIDFIELD data yielded a few issues of interest. The first is that when the STEM majors at matriculation database was analyzed it was found that students in this group and matriculated as an FYE student and transferred most often graduated in business. Further, it was found that 51% of the students matriculating with majors in computer science, life and biological science, and psychology graduated with degrees in business. Similar findings showed that about 40% of the communication and journalism graduates matriculated as life and biological science and psychology majors. 77% of the family and consumer science majors matriculated as life and biological

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science and psychology majors. It was also noted that very few STEM majors at matriculation graduated in law, liberal arts, or library science.

As previously noted, the data and analysis method does not lend itself to an analysis of multiple major changes. Rather the semester of the first change of major, and the new major are available for analysis. These were used to determine the early choices made by students in these programs. The analysis used for evaluating students graduating in STEM fields showed that students in a few different fields persisted at high rates, for example students in agriculture, architectural engineering, aerospace engineering, and chemical engineering.

Only 25% of the civil engineering graduates matriculated in civil engineering. The majority of the other students in this major matriculated in STEM majors, for example architecture, and mechanical engineering. Of students that matriculated into electrical engineering 60 % earned degrees in electrical engineering. While mechanical engineering graduates most often chose this major or general engineering, at matriculation or completion of an FYE program.

The typical data analysis revealed that STEM majors upon matriculation or completion of an FYE program do not always stay in STEM majors, but when exceptional student data was analyzed it was found that they did not move out of STEM at the rates found in the typical student analysis. As a contrast to this, it was found that if a typical student chose a STEM major and did not move to a non-STEM major, they generally persisted in a STEM major.

Further analysis on the exceptional student revealed that this group of students rarely transfers to a business major. These students also matriculated into FYE programs

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and upon completion went into engineering programs. It was also noted that these students chose majors throughout the choice of engineering majors rather than just a few specific engineering majors. The major that benefited the most from exceptional students transferring out of engineering is computer science. Finally, when exceptional students matriculated into FYE programs they often graduated from non-STEM majors such as business, English language and literature, interdisciplinary, and social sciences.

We found that while it is difficult to predict what major a student will choose, persistence is another situation. The observations mentioned above are general and contribute to the research question responses that follow.

Academic Pathways

There are three research questions that address persistence. The first is “What academic pathways do students follow as they progress through STEM degree programs?” This question relates directly to the analysis completed on the datasets for students that chose STEM majors upon matriculation or the completion of an FYE program.

Typical Student – Choice of Major. Typical students who chose a STEM major at matriculation or completion of an FYE program often go into computer science or life and biological sciences, transferring inside the STEM majors. These same students when choosing engineering programs choose those that are considered foundational in nature such as general engineering, civil engineering, mechanical engineering, or electrical engineering.

Typical Student - First Change of Major. Considering when the first change in major occurs for the typical student we found that the average is at approximately 5.5

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terms into their course of study. These students choose majors in fields outside of STEM with one exception, life and biological sciences. Essentially the typical student changes majors latter part of their second year, assuming they are full time students.

Typical Student - Final Major. The typical student was found to graduate most often from business, and computer science. They also graduate most frequently from engineering disciplines that include chemical, civil, electrical industrial systems, mechanical engineering, life and biological sciences, and psychology science. The major with the most typical transfer students is business. Therefore, with this exception we find that STEM students generally stay in majors considered STEM majors.

Typical Student - Dropout and Transfer Rates. Drop out and transfer in rates were examined. The analysis found that typical students dropping out of college most often dropped out of the STM fields, with ENG about 7% less. This may be attributed to the number of students who transfer in and out of the computer science majors, and majors that experience a higher level of student movement As this data is studied it becomes clearer that persistence of the typical student is difficult to predict. However, our evidence shows that if students choose a STEM major at matriculation or upon completion of a FYE program, they generally persist in a STEM major. Overall, students choosing to persist or drop out, regardless of being in the typical or exceptional student database are not determined by SAT scores or high school GPA. Rather it might suggest, per Tinto’s Model of Student Departure (Maruyama, 2012; Tinto, V., 2010), that students in STEM fields are generally provided an environment that is supportive and engaging.

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Typical Students Decision to Continue Study

The second research question regarding persistence is a follow up question to the first, “How do those decisions affect those students’ choices to continue study in STEM fields?” This is where the answer becomes much more complicated. Data found in the MIDFIELD dataset was collected after the student graduated, dropped out, or changed majors. The data is quantitative and tells us that the typical STEM student will most often continue in STEM fields. They transfer into other STEM areas, leave to move into business or computer science, or drop out. If they continue to study in STEM fields, the MIDFIELD data provides the evidence of this choice.

Therefore, the decisions that the students make as they follow their academic pathway extends the length of time they are in college. This is particularly true since they do not change majors until after their basic courses have been completed and they begin on courses related to their major. That leads us to believe that students did not really know what their chosen major was until they began courses in that field and they decided to leave.

Exceptional Student Academic Pathways

The third question of this section and the final question for this body of research is “How are pathways and outcomes of exceptional students different from those of the typical student?” Exceptional students choose STEM majors more often than typical students do; they also transfer from STEM majors into non-STEM majors far less often than typical students. Exceptional students are more likely to graduate as a STEM major

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than other majors. This work identified potential paths for future work in this area, a description follows.

Persistence Recommendations for Future Work

There is a great deal of work to be done in this area. Based upon this research there are two areas that should be pursued with an anticipated generation of further research questions in persistence.

The first is based upon the findings that most STEM students who change majors stay in STEM fields. However, when STEM students leave STEM fields they often move into business majors. The data in the MIDFIELD dataset does not lend itself to answering "why" questions. Therefore, a qualitative study may yield more data as to why students who chose STEM majors at matriculation transfer and graduate with business degrees. This information will further our understanding of the issues these students may have felt insurmountable or just too difficult to deal with.

Secondly, there is the question regarding students transferring after the beginning of their 5th semester. This too would lend itself to a qualitative study on how well the students that transfer at this time understood the academic and career requirements. Further investigation with these students may also yield other reasons for this change, leading to further research in this area.

Summary

In review of this chapter we found that there is not a clear relationship between SAT scores and exact majors; rather, the evidence presented that shows that students performing at the highest levels on the SAT will most likely choose a STEM major, and

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within that most likely an engineering major. The specific major in the category cannot be defined given the results of the analysis.

The exceptional student performing at the higher levels of SAT scores is most likely to choose a STEM field. When we ask if there are differences, we can say the high SAT performers will most likely choose STEM fields. However, that is not always the case. It was also found that students performing at the higher levels of the SAT chose majors in a greater distribution than the rest of the students.

When considering the academic pathways of both exceptional and typical students it is evident that there are some differences. Most of the exceptional students choose STEM majors, while typical students choose STEM, but a large number of these students choose non-STEM majors. Changes in majors usually resulted in changes within the categorization of STEM and non-STEM.

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Zwick, R., & Himelfarb, I. (2011). The effect of high school socioeconomic status on the predictive validity of SAT Scores and high school grade-point average. *Journal of Educational Measurement, 48*(2), 101-121.

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VITA

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VITA

Anne M. Lucietto
anne.lucietto@sbcglobal.net
lucietto@purdue.edu

EDUCATION

Purdue University, W. Lafayette, IN
PhD - Engineering Education
The Role of Academic Ability in Choice of Major and Persistence in STEM Fields
Matthew Ohland, PhD, Adviser

Lewis University, Romeoville, IL
MBA – Masters in Business Administration
Finance

Marquette University, Milwaukee, WI
BSME – Mechanical Engineering
Design, Materials and Thermodynamics

TEACHING EXPERIENCE

Oakton Community College, Des Plaines, IL
Adjunct Instructor 2009-Present
"Statics," "Dynamics," and "Strength of Materials"
Developed and managed courses and administered all grades; taught hybrid and on-line.

McHenry County College, Crystal Lake, IL
Adjunct Instructor 1997-2001
"Statics," "Dynamics," General Physics, and Engineering Graphics
2014-Present
Developed and managed Courses and taught them via a televised system to five different locations.
Also teach Physics and Engineering graphics online.

Waubonsee Community College, Sugar Grove, IL
Adjunct Instructor
"Elementary Algebra" and "Intermediate Algebra" 1987-2011

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RESEARCH EXPERIENCE

Research Assistant
Purdue University (Graduate School), W. Lafayette, Indiana
Department of Engineering Education **2013-Present**

Perform data evaluation on the Multi-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD).

- Using various techniques and statistical packages to evaluate and describe data found in the database.
- Develop suggestions for future papers and topics of study.

Research Assistant/Consultant **2011-2013**
School of Engineering Education, Purdue University
Institute for P-12 Engineering Research and Learning (INSPIRE)
Manage projects and develop research skills while working with professors and other grad students researching engineering education. Prepare IRB proposals, renewals, reporting and tracking. Work with various teams by performing literature searches and participating in the development of methodologies to analyze data

Technology Enhanced Sustainable Aina Project (TESAP):
Evaluation of 2011-12 School Year - Student Data

- Analyzed the data using descriptive and inferential statistics.
- Prepared final report for school district for inclusion in their final report.

Conducting research with the Teacher Professional Development Team for the NSF-funded DR K-12 Project

Context Maps to Analyze Elementary Students Conceptual Development in Engineering - A Study in an Integrated Implementation Project at Park Tudor, Indianapolis and across schools at Plymouth School District, IN

- Data Analysis
- Writing of Discussion

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PUBLICATIONS

Yoon, S. Y., Dyehouse, M., Lucietto, A., Diefes-Dux, H., & Capobianco, B. (in press). The effects of integrated science, technology, and engineering education on elementary students' knowledge and identity development. School Science and Mathematics Journal: Special Issue on Integrated STEM Education.

Dyehouse, M., Yoon, S. Y., Lucietto, A., & Diefes-Dux, H. (2012). The effects of an engineering teacher professional development on elementary students science/engineering content knowledge and engineering identity. Proceedings of the 2nd P-12 Engineering and Design Education Research Summit, Washington, DC.

Lucietto, A., Gajdzk, E.A.., & Strobel, J. (2012). Technology Enhanced Sustainable Aina Project (TESAP): Evaluation of 2011-12 School Year Student Data. West Lafayette, IN: INSPIRE, School of Engineering Education, Purdue University.

Yoon, S. Y., Lucietto, A., Gajdzk, E. A., & Strobel, J. (2012). Technology Enhanced Sustainable Aina Project (TESAP): Evaluation of 2011-12 School Year Teacher Data. West Lafayette, IN: INSPIRE, School of Engineering Education, Purdue University.

Diefes_Dux, H., Dyehouse, M., Yoon, S. Y., & Lucietto, A. (March, 2012). Examining student learning of science through engineering and engineering design (Paper set; Presider: B. Capobianco). National Association for Research in Science Teaching (NARST) 2012 Annual Conference, Indianapolis, IN.

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PRESENTATIONS

“Adjunct Faculty Positions: a Second Job, an Alternate Career Path, or a Transition”, D. Peters, A. Lucietto, C. Hanzlik
SWE Conference – Houston, TX November 2012

“Transition from Industry to Graduate School“, K. Brenneman, D. Peters, M. Vaicik, A. Lucietto
SWE Conference – Chicago, IL October 2011

“Leading By Serving”, Anne Lucietto
Illinois Valley Community College, Ogelsby, IL November 2009

“Success and Challenges as a Returning Student”, D.L. Peters, A.M. Lucietto
SWE Conference – Long Beach, CA October 2009

“Zebra Mussel Abatement”, Anne Lucietto
2007 DOE Contractor Fire Protection Workshop,
DOE – Office of Health, Safety and Security April 2007

“Women in Engineering Day”, A.M. Lucietto
Sauk Valley Community College (High School Audience of 75 students), Dixon, IL
March 2006

“Returning to School – Try It Online”, A. Lucietto
SWE-CRS Professional Development Conference, Round Lake, IL
March 2005

“How Common Sense Benefits in Facilities Management”, Anne Lucietto
National Manufacturing Week, Chicago, IL March 2004

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INDUSTRY EXPERIENCE

International Titanium Powder (Cristal Global US, d/b/a), Ottawa, Illinois
Sr. Project Manager/Construction Manager/Maintenance Manager
Managed and developed all construction and maintenance activities, including outside and engineering interface.

- Performed all construction management/contract tasks related to the installation/startup of new facility.
- Managed construction activities day-to-day and strategic planning.
- Developed and managed the Maintenance Department (procedure development and SAP-PM establishment).
- Developed and managed the Site Warehouse.

Caterpillar, Inc., Aurora, Illinois
Sr. Project Manager/Manufacturing Engineering Supervisor
Provide project management direction/leadership to manufacturing engineering, facilities/construction engineering and layout planning. Coordinated and controlled capital expenditures for various equipment construction projects.

- Managed equipment installation projects including demolition, restoration and equipment moves. (>120,000+ sq. ft.; $5M)
- Led teams of engineers in the updating of corporate specifications and changing technical requirements to current standards.
- Managed the facility layout planners.

Fermi National Accelerator Laboratory, Batavia, Illinois
Sr. Project Manager/Mechanical Systems Engineering/Facilities Engineering Services Section – Operations/Engineering

- Managed and supported facility and maintenance functions in various mechanical, electrical, chemical and environmental issues. Responsible for adhering to maintenance, code and operational issues related to facility and utility operations.
- Led subgroups for site wide committees on Subcontractor Safety, Mechanical Safety, Sustainable Design and Environmental Issues
- Consulted in all areas of mechanical, electrical, chemical and construction issues confronting various areas of the site
- Managed service and specialized contracts for facility; including the Reliability Program (savings >$800K) and Crane/Hoisting programs ($750K).
- Led multiple construction projects from inception through implementation (including facilities, construction, equipment installation and testing)

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Driv-Lok, Inc., Sycamore, Illinois
Sr. Manufacturing Engineer/Applications Engineer and Cost Estimating Supervisor
Oversaw and performed outside technical interface, production/manufacturing engineering, facilities and cost estimating functions.

- Supervised estimating/quoting department as well as manufacturing engineering function.
- Developed and implement a revised cost estimating system; saving an estimated $100,000 annually.
- Provided reverse engineering functions for a variety of customer requirements, saving $50,000 annually in external costs.

IBIDEN Circuits of America, Elgin, Illinois
Project Manager/Facilities & Maintenance Engineering Supervisor
Managed and established all facility and maintenance functions.

UNICOM INCORPORATED (Now Exelon), ComEd, Chicago, Illinois
Project Manager/Principal Mechanical Engineer, Materials Engineering Group
Revised, specified and evaluated testing for metallic, elastomeric, plastics, petroleum and chemical components. Performed engineering analysis and consulted on various mechanical, electrical and chemical issues.
Project Manager/Principal Engineer, Stores and Materials Management
Oversaw corporate inventory control, reliability issues, procurement activities and centralization of chemical purchases. Advised and reviewed inventory procedures and practices with regard to corporate and plant procurement activities. Managed the receiving facility and associated functions.
Project Engineer/General Engineer, Outage Management and Cost Control
Assessed needs and developed solutions to corporate work schedule issues. Wrote and supported computer programs using a variety of computer languages (i.e. SAS, Clist, JCL, P/2, Basic and FORTRAN)
Systems/Modification Engineer, LaSalle County, Technical Staff
Performed all tasks related to the surveillance, operation and maintenance of plant heating, ventilation and air conditioning (HVAC) systems. Provided assistance in all other plant facility's needs.

AWARDS

Tau Beta Pi, Engineering Honor Society, Indiana - Alpha	2014
Golden Key International Honour Society	2012
Fellow Grade, Society of Women Engineers	2008

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MEMBERSHIPS

SWE - Society of Women Engineers, F.SWE (Fellow)	**1993-Present**

National
Outreach Committee
FY96-Present
Audit Committee Chair
FY08-FY11
National Treasurer
FY05-FY06
Strategic Planning Committee
FY05-FY06
Finance Committee Chair
FY03-FY04
Section – Chicago Regional Section
President
FY03
Vice President
FY02

ASME - American Society of Mechanical Engineers, M.ASME	**1983-Present**
ASM - International, M.ASM	**1983-Present**
ASEE – American Society of Engineering Educators, M.ASEE	**2011-Present**

CERTIFICATIONS/LICENSURE

Illinois On Line Network - **Master On Line Teaching Certificate** - 2006
Substitute Teacher – State of Illinois – Type 39 Sub Certificate 2505896
Illinois Educator Identification Number 970316
FE – Illinois 1992

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OTHER ACTIVITIES

Volunteer
Moderator
American Society of Engineering Educators Annual Conference, Indianapolis, IN 2014

Volunteer
Paper Reviewer
Reviewed papers for FIE 2013 & 2014 Annual Conference 2013-2014

Volunteer
Subject Matter Expert for ASME
Fundamentals of Engineering Exam Study for NCEES (National Council of Examiners for Engineering and Surveying) 2012

Volunteer
Paper Reviewer
Reviewed Papers for Women in Engineering Division for 2013 ASEE Annual Conference 2012

Volunteer
SWE-Freshman Scholarship Judge
Judged freshman scholarships for the Society of Women Engineers. 2012

Volunteer
STEMfest
A program designed for the people of northern Illinois with the intent to increase public awareness of STEM. This program was held at Northern Illinois University 2011

Volunteer
SWE Invent It! Build It!
Workshop for Middle School Girl Scouts, SWE Conference, Chicago IL 2011

Mentor
Mentor Net
Work with students that are matched to you using professional and educational criteria. 2011-2014

Judge
ECybermission (US Army)
Technical Project Competition Nationwide - Online 2005-2014

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Mentor
GEM-SET – E-mentoring – Supported by University of Illinois at Chicago 2002-2014
Supported organization by hosting gatherings with students and interacting with students via email.

Volunteer
SWE Girl Scout Program at SWE Conference, Long Beach, CA 2009

Program Coordinator and Developer
Fermilab Badge Design and Workshop
Developed a Fermi Lab Badge for Girl Scouts
Researched information to create and hold a badge workshop at DOE Lab - FermiLab
(800 girls/175 adults/75 volunteers) 2007
(500 girls/100 adults/50 volunteers) 2006

Program Coordinator and Developer
Thinking Day Girl Scout Badge Workshops
Provided Girl Scout badge workshops to study other lands and cultures.
(800 girls/175 adults/75 volunteers) 2006
(550 girls/125 adults/50 volunteers) 2005
(450 girls/100 adults/45 volunteers) 2004

Special Judge
Regional Science Fairs in Northern Illinois – Special SWE Awards Presented 1997-2005

SWE **Science Fair** Volunteer Coordinator
Coordinated and provided science fair judges in Northern Illinois and Indiana.
Middle and High School level; supplied 102 volunteers 2005
Middle and High School level; supplied 85 volunteers 2004
Middle and High School level; supplied 72 volunteers 2003
Middle and High School level; supplied 65 volunteers 2002
Middle and High School level; supplied 52 volunteers 2001
Middle and High School level; supplied 47 volunteers 2000
High School level; supplied 34 volunteers 1999
High School level; supplied 27 volunteers 1998
High School level; supplied 16 volunteers 1997
High school level; supplied 10 volunteers 1996

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Consultant and Technical Volunteer Coordinator

Girl Scout Science Badge Workshop for Will, McHenry, Kane and Kendall Counties held in Joliet, IL,

After holding two successful Math and Science Badge Workshops provided organizational support and volunteers. Grades 1-9, 500 girls/145 adult leaders/49 volunteers 2004

Program Coordinator and Developer

Math and Science Girl Scout Badge Workshop – Northern Illinois

Provided opportunity for girls to learn and explore topics in Math and Science

Potential for each girl to earn up to 4 badges at one event

Grades K-12 – 1200 girls/150 adult leaders/125 volunteers 2004

Grades K-12 – 750 girls/75 adult leaders/85 volunteers 2002

Program Coordinator

SWE Certificate of Merit Program 1996-2004

Enhanced a program already being administered in New England; this program was intended to recognize students as they succeeded in STEM areas at the end of a period of study. Students participating in this programs were from Northern Illinois and Northern Indiana and included Grades K-12. Follow up on the program indicated that this recognition encouraged the students to investigate the STEM fields with a higher than normal rate, ultimately studying engineering. Resources were provided to students on who they could contact with questions.

Program Coordinator and Developer

SWE Essay Contest 1998-2004

Created and ran a contest for all schools in Northern Illinois and Northern Indiana to enhance the
understanding of who engineers are, what they do and how they do it. The contest was for students
in Grades 4, 6, and 8.

IT Empowerment for Women and Girls Initiative 2001-2003

Supported this short lived group by hosting a meeting and interacting with students via email.

Featured in Diversity Careers Magazine 2002

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Special Judge 1997-2001
Illinois State Science Fair at the University of Illinois – UC – Special SWE Awards Presented
National Program Liaison and Local Coordinator

COMMUNITY INVOLVEMENT

United City of Yorkville, Yorkville, IL
Yorkville Planning Commission, Yorkville, IL 1990-2011
Deputy Chair 1990-2007
Chair 2007-2011
  Initiated a county wide collaborative project to work out joint issues (i.e. open space, bicycle paths and general planning.)
  Led community driven development of a new Comprehensive Plan
Yorkville Public Library Board, Secretary/Treasurer
1988-1990

Girl Scouts – Fox Valley Council, Aurora, IL (now Girl Scouts of Northern Illinois)
Multi-Level Troop Leader 2001-2014
Large Program Coordinator (Math and Science; International) 2001-2010
Service Unit Representative to the Board 2007-2010

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