

THE MAKING OF AN ENGINEER:
EXAMINING THE PLANNING PROCESS AND EDUCATIONAL OUTCOMES

By

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THE MAKING OF AN ENGINEER

Abstract

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This quantitative study uses data from the Educational Longitudinal Study of 2002 (ELS: 2002) to examine how aspiration levels of planning (or intention) and action (or choice) affect degree attainment for college students who expressed interest in pursuing an engineering degree. Utilizing Social Cognitive Career Theory as derived from Bandura's (1986) social cognitive theory, I investigated whether students' self-efficacy along with personal aspects of motivation and their aspirations influence educational attainment outcomes. These attributes are indicative of future intentions, and essential in students' persistence to overcome barriers toward completing an engineering degree. Data analysis includes descriptive statistics to compare Aspiring-engineers of three aspiration levels (High, Medium, Low) by a set of factors (e.g., socio-demographics, pre-college, postsecondary), and multivariate statistics to determine the likelihood of engineering-related outcomes (e.g., degree completion, science and engineering [S&E] credential).

Findings suggest the proposed aspiring-engineer typology differentiates the sample with respect to socio-demographics, pre-college and postsecondary factors, and was also a main predictor of student outcomes. The results show students who have a High aspiration level

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toward engineering enter postsecondary education with a greater advantage with respect to preparation and attitudes and are capable of overcoming college barriers, thus increasing their likelihood of high educational attainment and earning of S&E credentials. Medium aspiration students are more likely to attain certificate or associate degrees by age 26 and credentials in non-S&E fields. Low aspiration students are more likely to be non-completers by age 26, attend 2-year or Other postsecondary institutions without evidence of a specific field of study.

In summary, this study demonstrates that the level of aspiration toward an engineering major makes a difference on student outcomes, Aspirations are indicative of commitment and planning and thus influence aspiring-engineers' ability to overcome barriers during postsecondary education and succeed in S&E fields.

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CHAPTER 1

INTRODUCTION

The competency of the United States science and engineering (S&E) workforce has been an ongoing concern for U.S. Congress, educators, policy makers and researchers alike for more than 60 years (Sargent Jr., 2013; Steinberg, 1949). Scientists and engineers are broadly believed to be critical to the US industrial leadership, manufacturing, services, and other public essentials, and thus vital for the US economic strength, security, advancement and global competitiveness (Blue et al., 2005; Geisinger & Raman, 2013; Sargent Jr., 2013). In particular, due to the accelerating technology-driven global economy (Blue et al., 2005), there is a great demand for future engineers to be part of this thriving workforce. Since the end of World War II, the US has relied on engineers (Committee on Prospering in the Global Economy of the 21st Century, 2007) to design and develop new technologies that solve societal problems. A National Science Foundation (NSF) report acknowledges that science and engineering are “essential partners in paving the way for America’s future through discovery, learning, and innovation” (2004, p. 2). There is a great need to produce and educate engineers to sustain and advance the technological enterprise in the United States.

The call to produce more engineers has been supported through a variety of federal programs (i.e., American Competes Act of 2007, Deficit Reduction Act of 2005) to promote incentives for students to pursue engineering and other science related degrees (Sargent Jr., 2013). Higher education institutions have focused on recruiting both US born and foreign-born engineering students. Further, policies such as immigration changes to F-1 visas, H-1B visas and legal permanent residency status focused on attracting foreign-born qualified engineers into the US engineering workforce (Kuenzi, 2008; Sargent Jr., 2013). Though these initiatives and others

sought to address the need for more engineers, some argue (Matthews, 2008) they inadvertently may have affected the development of an US native-born engineering workforce by reducing employment and access to opportunities for US born engineers. As Matthews (2008), a senator and congressional researcher shared, “US workers are adversely affected by the entry of foreign scientists and engineers, who reportedly accept lower wages than US citizens would accept in order to enter or remain in the United States” (p. CRS-2). As suggested, US born engineering graduates have potentially less access to teaching and research opportunities (Matthews, 2008).

A major issue is that the number of US-born students enrolled in S&E programs has not kept pace with enrollment of foreign-born students in these programs (Kuenzi, 2008). Their funding sources are different because foreign students cannot compete for most scholarships and federal aid, so universities support foreign-born students by employing them as research or teaching assistants. Mathews argues (2008) this support is also federally-funded, so in his view US institutions have ‘pushed out’ US-born students from full participation in these fields.

Moreover, reliance on foreign born engineering has become further problematic. For instance, stringent visa requirement changes and increased competition for foreign-born talent nationally and among the developed countries may negatively impact recruitment by US higher education institutions and the technical workforce (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine [NAS, NAE and IM], 2007; President’s Council of Advisors on Science and Technology [PCAST], 2012; Sargent Jr., 2013). These concerns reinforce the need for attracting more US-born students to complete scientific and technical degrees to meet the growing demand for competent US workforce.

The lower production of Science, Technology, Engineering and Mathematics (STEM) degrees in the US has made it difficult to sustain a qualified engineering workforce in order to

remain competitive world-wide (Graham, Frederick, Byars-Winston, Hunter & Handelsman, 2013; Koledoye, Joyner & Slate, 2011; Kuenzi, 2008; PCAST, 2012). The US lags behind other nations having only 15% of all US undergraduates earn science or engineering degrees in comparison to South Korea (37%), France (47%), China (50%), and Singapore (67%) (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007). Further, Machi (2008) reported that the US is graduating around 60,000 engineering students each year in contrast to China and India, both producing approximately 600,000 annually. Also, Geisinger and Raman (2013) noted the relatively low rates of persistence in engineering fields and completion of engineering degrees is insufficient to meet the US workforce need for competent engineering professionals. From 1950s to 2013, despite some enrollment growth in engineering fields nationwide, graduation rates have hovered around 50% showing nearly half of students who entered an engineering program left prior to graduation (Geisinger & Raman, 2013; Graham, et al., 2013; National Science Board [NSB], 2014). There are startling concerns that the US will lack in a competent engineering workforce in future years.

One reason the current engineering pipeline produces insufficient numbers of US-born aspiring-engineers (students who have interest in engineering prior to post-secondary education) that would become future degreed engineering professionals, is possibly the limited interest in an engineering career among high school students. Despite a great call for motivated students nationwide to pursue a science or engineering degree, the number of those who showed interest and actually majored in the field remains stagnant and low (Chen & Soldner, 2013; NSB, 2016; Wang, 2013). Two national college entrance admission testing agencies, American College Testing (ACT, 2016) and Scholastic Achievement Test (SAT, 2016) cited that despite demand for engineers, high school seniors' interest in and readiness to pursuing an engineering major

have been lethargic for the past 5 years. Interest in engineering fields among youth is not high enough to respond to workforce demand.

A second aspect is that high school students who may be interested in engineering either do not enroll or do not major in the field. National Science Board (2012) reported that one-third of freshman college students expressed interest in a STEM major prior to college, but the actual STEM enrollment in those majors was much lower. NSB (2014) stated that the American Freshman survey results showed that although nearly 10% of enrolling freshman college students intended on majoring in engineering in 2005, less than half graduated with a degree six years later. The statistics are alarming because they show that entering college students who express interest in engineering may not pursue a major in the field.

A final issue is that not all students majoring in engineering are finishing their degrees in the field (Mau, 2016; Wang, 2013). NSB (2014) and NSB (2016) stated the overall percentages of students who planned to pursue S&E and later earned bachelor's degrees in these fields are comparable, with the exception of the field of engineering which showed more had planned to enter the field than the actual number that earned the degree. Consistently, national data has shown that more than half of the freshmen who declared STEM majors including engineering at the start of college, left the field before graduation (Chen & Weko, 2009; PCAST, 2012). The PCAST report (2012) emphasized the need to increase the retention of STEM majors by 10% percent (from 40% to 50%), to produce about three quarters of the desired 1 million additional STEM degrees over the next decade.

The current state of the US native-born engineering workforce warrants a review of the process of attracting and retaining future engineers. To fully understand this problem, we must define the meaning of an engineering career, and describe the process necessary to become an

engineer. An engineer is an individual that can use scientific knowledge involving math and science to solve real-world problems (Gereffi, Wadhwa, Rissing & Ong, 2008). Because of its rigor and workload demand, the engineering major requires motivated and interested students who are fully engaged and committed in the pursuit of the degree. I argue that the process of attracting and retaining engineers relies heavily on actions put forth during the students' high school years. Working with knowledgeable guidance counselors, access to effective STEM content-based teaching and curriculum, involvement in science clubs, exposure to extensive enrichment hands-on project activities outside of school are factors that stir interest and encourage student's pursuit of an engineering career (Fantz, Siller & DeMiranda, 2011; Polluck, 2013). Researchers increasingly believe students' action and involvement even prior to high school (e.g., during middle school), affect their ability to successfully compete at the university level (Bystydzienski, Eisenhart & Bruning, 2015; Johnson & Sheppard, 2004). Student engagement with engineering should start earlier during high school, to strengthen interest over time, thus increasing one's motivation and enthusiasm during the process (Adams, et al., 2011).

Previous research has shown that students need to discover engineering early, build a strong academic foundation and develop dispositions toward the field (Adams, et al., 2011; Atman, et al., 2010; Bystydzienski et al., 2015; Engberg & Wolniak, 2013; Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011). Bystydzienski et al. (2015) stated it is not enough to spark interest, but students need support to make the transition from an affinity toward engineering to actually pursuing a college major and embracing an engineering career. Engineering education should be introduced and integrated early in the K-12 education so students are exposed to meaningful and engaging experiences of solving real-world problems (Adams et al., 2011). Research shows that successful preparation and engagement of aspiring-engineer students and

increased degree attainment are the results of initiatives and programs that have incorporated some aspects of early preparation based on intensive hands-on experience, self-learning and discovery, integrated mathematics and science curriculum and tools (Adams et al., 2011; Johnson and Sheppard, 2004; Ralston, Hieb & Rivoli, 2013).

The skill set required for an engineering degree needs to be developed early in the student's pre-college education. Students must have a good foundation in mathematics, science and a wide range of other subjects to ensure success in the post-secondary education. Experts state that students need to complete challenging mathematics and science courses to better prepare for the rigor of engineering disciplines and be given opportunities to think critically and to effectively engage with prominent issues they could face as engineers in their future jobs (Alpay, Ahearn, Graham & Bull, 2008; Johnson and Sheppard, 2004). Other researchers suggest teachers and administrators should be supported to adopt engineering curriculum in their classrooms (Ralston et al., 2013), and to understand how to prepare aspiring-engineer students for a successful journey. Since the engineering pipeline is leaking, there needs to be more effort by stakeholders to engage and prepare future engineers during the early years of schooling. If students planned and developed an interest and capacity to pursue an engineering degree through early preparation, they could complete an engineering degree and become part of the future US-born engineering workforce.

Statement of the Problem

The low number of American high school students who intend to pursue engineering as a career along with the high attrition rate of those who attempt to major in the field, demonstrate the US has a problem in producing a sufficient number of US-born individuals earning engineering degrees (Fantz, Siller & DeMiranda, 2011). Although there is a growing number of

foreign-born students who earn engineering degrees and often become part of the US workforce, this is not a sustainable solution for a growing economy due to the high demand for qualified engineers (PCAST, 2012; Sargent Jr., 2013).

I argue that aspiring-engineer students should be engaged and committed to an engineering major prior to high school graduation. Research consistently shows that an early engagement is helping students with interest in engineering (Adams, et al., 2011) to declare an engineering major during the first year of study, as most colleges and universities require (NSB, 2014). The National Science Board (2014) states, “engineering enrollment data can serve as an early indicator of both future undergraduate engineering degrees and student interest in engineering careers” (p. 2-24). This further marks the importance of encouraging students to plan to pursue engineering as early as possible and thus enroll in college with an intent to pursue an engineering degree. It may also suggest why students who have not planned or committed to pursuing a career in engineering, may experience delays or lack preparedness. As stated by a notable engineer and scientist, Alexander Graham Bell, “Before anything else, preparation is the key to success”.

In addition, the making of future engineers needs to take place early rather than later in the post-secondary education process for students to become ‘engineering minded’ (Adams et al., 2011). Majoring in the field of engineering requires planning and commitment for students, to be better prepared, know the importance of studying mathematics and science, use of these subjects in solving real-world problems, and the engineer’s role in society (Adams et al., 2011). Students need to know what prior preparation and essential skills are required to help them persist toward completing a degree while in college. Since the overall process of making aspiring-engineer students seemingly is less than adequate in American high schools, more

research is needed to understand how students' interest in and planning of an engineering major, prior to starting post-secondary education, affect enrollment, persistence and completion of engineering degrees.

Researcher's Perspective

This study stems directly from my interest and personal experience with engineering. I have always had an interest in math and science subjects (i.e., Chemistry, Physics, Mathematics and Computer Science). As a child growing up in Mississippi I was fascinated with taking apart radios, old televisions or anything I could find, or building such things as my own mini fort outside my grandmother's house, sketching an idea for an automobile of the future, or putting together a model ship. I always enjoyed hands-on experiences and the opportunity to design something which is often indicative of an engineer's interest, curiosity and responsibility. I did not know it then, but I was poised and capable of pursuing an engineering degree.

In high school, after spending time with my uncle helping with various projects, I learned he was an electrical engineer and I was intrigued at the work he did. During my senior year of high school, I met with the counselor to express my desire to go to college and shared of my interest in pursuing engineering. At this point, I did not know much about college as neither of my parents had a college degree. They never talked about college, but they had always advised me to work hard. So, I applied to Texas Christian University (TCU) as an engineering major. Later, I remember getting a call from the admission representative who asked about the classes I was taking that spring. When I explained that I was taking a full schedule of advanced classes – computer science, calculus, physics, etc. he said, 'that's good'. I believe my schedule gave me an advantage amongst other students since many seniors took abbreviated schedules rather than a

full day of classes. Shortly thereafter, I received an acceptance letter to TCU to major in engineering.

After starting college, the fall after graduation, I quickly realized I had no idea of the amount of work I had to complete. I did not know what the field of engineering entailed, or the level of discipline and skills required to be successful. Despite some difficulties like failing several classes, spending extra money to retake classes, being disappointed and often feeling lost or like I did not belong in the program, I was successful in earning a bachelor's degree in engineering five years later.

After working as an engineer for several years, and subsequently earning a master's degree in engineering a few years later, I found my way to the education arena. Looking back over my path to my degree, I realize my road would have been easier and less challenging with better high school preparation. There were several things I could have done to aid my success story, from learning about the engineering field through others e.g., my uncle, attending STEM enrichment programs, taking advanced classes prior to my senior year, or even developing study and time management skills so that I would do better in college overall. Honestly, there were several times I wanted to drop out of engineering and even college but I was supported by my own motivation and the encouragement from my family, a personal mentor who would coach and scold me if I expressed any intention other than finishing with a degree, and also my sincere desire to finish what I started and not give up – I believed if others can do it, so could I.

Therefore, my hope is that this study will provide those who are seeking an engineering degree with added knowledge and tools to help them succeed in the endeavor. I believe it is critical to look at how students, who have the ability and interest in engineering, are being prepared and how they progress through the pipeline to become engineering professionals. I can

identify with students who enjoy solving math problems or who like taking part in figuring out how things work yet may not know that an engineering major could be for them. They may not have had experiences to encourage them or they may lack motivation to sustain them through the process. This study's goal is to provide an enlightening perspective about the *making of an engineer* journey and convey knowledge for others to successfully pursue an engineering degree.

Purpose of the Study

The purpose of this study is to examine how levels of planning (or intention) and action (or choice) affect degree attainment for college students who expressed interest in pursuing engineering majors. Despite numerous studies regarding STEM degree attainment, very little research explores how planning to pursue an engineering major can lead to actual degree completion. The Education Longitudinal Study of 2002 (ELS: 2002) follows students from high school to college graduation and provides information on post-secondary access and persistence. The study sample was selected based on students' information about college planning (intent in pursuing a major) and action (early choice of major) which differentiate them in terms of level of commitment toward obtaining an engineering degree. The study will address the overarching question: *Does the level of commitment toward an engineering degree matter?*

Research Questions

I hypothesize that the intent to pursue an engineering major prior to entrance to college may motivate and/or propel an engineering student to overcome obstacles and persist in obtaining his/her degree. Therefore, the commitment level toward obtaining an engineering degree should be the major factor affecting outcomes. Specifically, this study will address the following research questions:

1. What are the characteristics of three types of aspiring-engineer students who— a. intended and chose the engineering major upon entry, b. did not intend, but chose the engineering major in college, c. intended but did not choose the engineering major?
2. What is the relationship between educational attainment by age 26 and aspiring-engineer groups, socio-demographic factors (i.e., gender, race, parental education, SES), pre-college factors (i.e., parental aspirations, student expectations, math achievement, math self-efficacy, academic achievement, preparation in math/science subjects), post-secondary factors (i.e., engagement, remedial courses, financial issues)?
3. What is the relationship between S&E degree completion by age 26 and aspiring-engineer groups, socio-demographic factors (i.e., gender, race, parental education, SES), pre-college factors (i.e., parental aspirations, student expectations, math achievement, math self-efficacy, academic achievement, preparation in math/science subjects), post-secondary factors (i.e., engagement, remedial courses, financial issues)?

Significance of the Study

With the anticipated shortage of a US qualified engineering workforce in the coming years, it is crucial to grow the interest and participation of the nation's youth in engineering fields as well as to promote persistence in the fields. Motivated and interested US-born students represent a great resource of talent to fulfill the growing demand of a competent future engineering workforce. Stakeholders must have a vested interest to reach and cultivate inspired and eager students for the fields of engineering. This study is significant by offering an examination of factors that can support the developing of engineers in the nation.

Arguably, interest and motivation to enter the field of engineering is a critical first step that will lead to completing a degree (Wang, 2013). Understanding the earlier planning of

aspiring-engineer students, expressed through their intention to pursue an engineering degree, is important to teachers, counselors and parents. Higher education institutions may learn how to address complex issues for a successful degree completion in engineering, by developing adequate recruitment and retention strategies. This research will shed light on how planning to pursue an engineering degree shapes further motivation, and the ability to overcome barriers during the college years, which is significant for the 50% of engineering students who finish their degrees (Geisinger & Raman, 2013; Graham et al., 2013). Educators, parents and other influencing individuals can use information from this study to encourage students to plan earlier during their secondary education and become more motivated and proficient in STEM subjects. Students who seek engineering degrees should embrace opportunities to take appropriate science and mathematics courses in high school, and others closely involved with engineering learning can help them make better educational and career choices.

Further, there are few comprehensive studies that offer evidence-based best practices to retain students notwithstanding circumstances faced when pursuing an engineering major (Geisinger & Raman, 2013). By following students from high school through college, this study provides a comprehensive look at the key factors specifically affecting students pursuing an engineering major, helping to gain insight about intervention measures and supportive structures that are meaningful for their success. An untapped resource in this endeavor are educators and counselors who can be trained to increase student awareness and interest in engineering through relevant curriculum, and improve better perception and knowledge about engineering careers (Adams et al., 2011; Hossain & Robinson, 2012; Pollock, 2013). The study may reveal key tools for improving math and science curriculum and ideas for developing specialized programs and outreach programs that can be instituted to prepare future engineers.

Partnerships and collaboration with educational organizations, local and private sector community and government organizations can support a vision to motivate students entering the engineering pipeline (Hossain & Robinson, 2012). The study promotes a successive venture for students who are seeking engineering degrees by suggesting how to minimize educational pitfalls including dispelling misconceptions about engineering (i.e., the major is too difficult, boring, or for a select group of students).

Additionally, this inquiry provides an opportunity to encourage underrepresented minority students to pursue an engineering major since they are deemed more likely than other students to either avoid an engineering major or leave the field before degree completion (Cole, High & Weinland, 2013; Graham et al., 2013; Moore III, 2006; Toven-Lindsey, Levis-Fitzgerald, Barber & Hasson, 2015). Early information on engineering careers during secondary education should aid all students to discover the field and develop skills and attitudes necessary to overcome academic barriers, thus providing a sustainable foundation for aspiring-engineer students to successfully complete engineering majors.

Overview of Chapters

This dissertation consists of five chapters. Chapter 1 introduced empirical evidence that emphasizes the importance of engineering education, and the main assumption that early interest in and planning for an engineering career play a role in students' postsecondary attainment of an S&E degree. Chapter 2 provides a review of literature focused on challenges related to STEM education and Engineering education, by emphasizing the need for early exposure to the field, the role of competency and learning, and the importance of early planning. The review of the literature identifies main attributes of the aspiring-engineer student such as interest, motivation, and commitment, and various factors affecting educational attainment. It also introduces the

proposed framework of Social Cognitive Career Theory (SCCT) to guide the research and help interpret and discuss the study findings. Chapter 3 details the research methods including data sources, variables and statistical procedures. Chapter 4 presents the findings of the study for each research question and provides a summary of main findings. Finally, Chapter 5 discusses selected findings of the study in relation to research literature. The study limitations, implications for practice and policy, and recommendations for further research are also included.

CHAPTER 2

LITERATURE REVIEW

Due to the sheer importance of developing future engineers for the US workforce, there is an increased focus on engineering education. Previous literature offers some insight on issues related to student enrollment, choice of major and attainment of engineering degrees (Geisinger & Raman, 2013; Moore III, 2006; Toven-Lindsey et al., 2015). This literature review will include research related to STEM education, engineering education, aspiring-engineer characteristics, and degree attainment. A final section will present the theoretical framework and identify areas where there are noticeable gaps in research that this study aims to address.

STEM Education

STEM Participation and Degree Completion

National Science Foundation (NSF) includes among STEM fields mathematics, natural sciences, engineering/engineering technology, and computer and information sciences (Chen & Weko, 2009), which encompass the discipline of engineering (2014). National Academy of Science, National Academy of Engineering and Institute of Medicine (2005) collectively resound the importance to explore topics relating to STEM education to meet the call for “strengthening the STEM pipelines” and further to “enlarge the pool of students pursuing degrees and careers in STEM fields” (Chen & Weko, 2009, p. 1). Students who report a major field of study in these areas represent the potential STEM workforce.

There is a need for higher participation and degree completion in STEM fields to meet increasing workforce demand and to maintain US global competitiveness in science and technology (Kuenzi, 2008; Mau, 2016; Wang, 2013). Sargent (2017) stated the Bureau of Labor Statistics (BLS) project that the number of science and engineering (S&E) jobs will grow more

than 850,000 between 2016 and 2026, a growth rate of (1.1%) higher than the overall workforce growth (.7%). BLS anticipate 5.2 million additional S&E will be needed due to those leaving the workforce and profession changes (Sargent, 2017). Bottia, Stearns, Mickelson, Moller, and Parker (2015) remarked that many other developed nations appear to be making swift progress in preparing their youth in STEM subjects while US children's interest and preparation for STEM careers have not grown at the rate of anticipated national needs. NAS, NAE and IM (2007) cited only 30% of students entering college (of whom most are citizens or permanent residents) intend to major in S&E. Additionally, NSB (2014) and American Association of Engineering Societies (2016) confirm that S&E degrees continue to represent about one-third of all bachelor's degrees in the US; in 2010, only five percent of the degrees awarded were in engineering (NSB, 2016; NSB, 2014).

To investigate STEM participation and degree completion, Chen and Weko (2009) used three nationally representative studies – 1995-1996 Beginning Postsecondary Students Longitudinal Study (BPS:96/01), 2003-04 National Postsecondary Student Aid Study (NPSAS:04) and Educational Longitudinal Study of 2002 (ELS:02/06). Using BPS:96/01 as the primary source of data, the authors analyzed a sample of 9,000 first-time students interviewed first in 1996 and again in 1998 and 2001, and six years later after enrolling in post-secondary education. In addition, NPSAS:04 and ELS:02/06 data were used to gain a better picture of participation, persistence, and attainment in STEM amongst undergraduate populations and high school graduates. Chen and Weko's (2009) study examined four issues: 1) STEM entrances (enrollment) of certain student groups, 2) demographic and academic characteristics of those who enrolled in STEM fields, 3) overall rates of persistence and degree completion for those

who enrolled in STEM fields and those who did not, and 4) rates of persistence for STEM enrollees and degree completion in STEM fields.

While results based on NPSAS:04 showed that 14% of all undergraduates enrolled in a STEM field at US postsecondary institutions in 2003-04, findings based on ELS:02/06 showed that 15% in 2006 majored in STEM of which 4% majored in engineering/engineering technology fields (Chen & Weko, 2009). Based on BPS:96/01 data, Chen and Weko (2009) found that 23% of beginning postsecondary students majored in a STEM field, within six years. Regardless of the survey data used, statistics regarding STEM degree completion are not encouraging because they show consistently that only about half of the students persisted to STEM degree completion.

Next, Chen and Weko (2009) looked at the demographics of students entering STEM fields that showed enrollment of male students was higher than female students especially in mathematics, engineering and computer/information sciences. Further, Asian/Pacific Islander students entered STEM fields at 47% and overall foreign-born students outpaced US-born students (34 % to 22%). Similarly, students with higher SES family background, and strong academic preparation (high grade point average) had a higher percentage of STEM field enrollment than others who did not have the same characteristics. However, Chen and Weko (2009) pointed out that generally STEM entrants had better completion and persistence rates than those who were not entering a STEM field. Yet, not all STEM entrants stayed in the same STEM field over years; one-third switched to a non-STEM field and 47% left or did not earn credentials in STEM over the next six years of postsecondary education, results comparable to national statistics provided by NSB (2014).

Additionally, Chen and Weko's (2009) study showed higher completion rates for some STEM entrants such as younger students, White or Asian/Pacific Islander students, those who

had at least one parent with a four-year college degree, and those with high level of academic preparation. Students who entered computer/information sciences and engineering or engineering technologies did not do as well as students in other STEM fields in completing a bachelor's degree (Chen & Weko, 2009). For instance, students pursuing various STEM fields were similar in terms of their demographics, academic preparation/abilities, and enrollment attributes; however, students enrolled in computer and information sciences differed greatly. Results based on BPS:96/01 showed that older students, low-income families and less academically prepared students often enrolled in computer and information sciences (Chen & Weko, 2009), a phenomenon that should also be further investigated. Nevertheless, findings based on these national data inform about factors that negatively affect STEM participation and degree completion and confirm the current shortage of a US potential STEM workforce.

STEM Major Choice

Gottfried and Bozick (2016) sought to show if 'applied STEM courses' (integrated technology and engineering ideas) rather than 'traditional STEM curricular' (science, technology, engineering and mathematics) would predict higher odds of declaring a STEM major in college, the study's premise being that traditional STEM curriculum is fragmented and not connected. As suggested from research by Stone and Lewis (2012) when high school students learn "...the interconnectedness of STEM concepts in 'applied' settings, ...are in better position to develop higher-order reasoning and logic skills required further down the STEM pipeline..." (Gottfried & Bozick, 2016, p. 178).

Using ELS:2002 longitudinal survey and transcript data, the study (Gottfried & Bozick, 2016) examined a sample of 12,000 students who participated in base-year and all follow-ups. The dependent variable was choice of STEM major and a key predictor variable indicated

whether an applied STEM course and various math and science courses were taken in high school. Their findings indicate the percentage of students enrolled in STEM depended on the math and science or applied STEM course taken, the results being consistent with research that show students who took advanced math and science courses enrolled in four-year colleges more than others who took below average math and science courses. However, students who took applied STEM courses, were more likely to not attend college. Gottfried and Bozick (2016) point out these students are those who left the pipeline after taking applied STEM courses but gained a foundation for non-college career path in STEM. Findings showed a relationship between math and science coursework and the odds of declaring a STEM major. Students who take advance levels of math have higher odds of declaring a STEM major while lower levels of science taken yielded a lower odds of declaring a STEM major. Also, students who had taken IT (information technology-specific applied course) have a 2-to-1 odds of declaring STEM major in college. Lastly, the study (Gottfried & Bozick, 2016) found a linkage between applied STEM coursework and declaring of a STEM major in a technology and engineering field. Those who took a combination of integrated STEM courses in high school had much greater odds of declaring a technology or engineering major versus a non-STEM major. The study confirms that rigorous curriculum i.e. applied STEM courses or other integrated curriculum provided an avenue to spark interest for STEM oriented students to pursue S&E degrees such as engineering (Kennedy & Odell, 2014).

Wang (2013) investigated how the high school exposure to the subjects of math and science, motivation and achievement in math, and the early postsecondary experience affected students' decision to major in STEM fields in college. Using ELS:2002 data, Wang (2013) focused on high school graduates from 2004 who had enrolled in postsecondary education by

2006. The data showed that of the 6,300 who reported postsecondary attendance, 19.3% intended to major in STEM upon entering college but only 15.4% declared a major in a STEM field by age 20. Wang (2013) found that 10th grade math achievement and attitudes toward math influenced 12th grade students' math self-efficacy and achievement that in turn affect choice of college major. Secondly, the results showed 12th grade math self-efficacy affected significantly and positively the intent to pursue STEM for all students. The study showed that intent could ultimately influence STEM entrance and major choice. Wang's (2013) study looked broadly at all STEM students and did not focus exclusively on aspiring-engineering students, which is the subject of the proposed research. However, Wang's study does provide some insight on how specific pre-college factors (i.e. exposure to math courses and attitude toward math subjects), self-efficacy along with intent to pursue a STEM field can affect predispositions toward a field and the actual college major choice.

STEM Degree Attainment

There has been research examining access, persistence and degree attainment of college students in general (e.g. Flynn, 2014; Koledoye et al., 2011; Kuh, Cruce, Shoup, Kinzie & Gonyea, 2008). Other studies looked at STEM completion in particular (Mau, 2016), but little research has been conducted specifically for engineering majors. For instance, Mau (2016) conducted a study about postsecondary students who enrolled between 2008 and 2013 and looked at characteristics of students who declared and completed a STEM major examining factors that influenced their persistence to completion. The number of participants in the study included 71,405 students from first year through fifth year, with a slightly higher percentage of females than males from diverse race/ethnicity groups. Three types of independent variables were used in the study: demographics (i.e., sex, race, age first enrolled), pre-college (i.e., high

school GPA, ACT scores), and college variables (i.e., student type—entering freshmen or transfer, institution type, courses taken), considering persistence as the dependent variable.

Mau's (2016) study found differences between students who entered STEM fields and those choosing other majors. For instance, female and minority students, except Asian Americans, were less likely than male or white students to declare STEM majors. The study also showed older students were less likely than younger students to declare a STEM major, and of those declaring STEM majors only 32% chose an engineering major. Next, only 19.2% of the study participants successfully completed a major in STEM, where 41% were in science and 29% in engineering. Lastly, the study examined factors affecting the completion of a STEM major, and it showed that race (i.e., white) and pre-college variables like ACT scores and GPA significantly predicted persistence in these fields. Mau (2016) noted that high school GPA appeared to be the strongest predictor of persistence in completion of STEM major. The study showed there are clear barriers to participation in and completion of STEM majors which include limited students' math and science competencies, personal interest in STEM, lack of support systems, belonging to underrepresented groups, many of these factors being discussed in the literature (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011; Wang, 2013). Mau (2016) concluded that interventions are needed to improve recruitment and guidance of all talented students throughout the STEM pipeline.

To further examine STEM degree attainment, Crisp, Nora and Taggart (2009) looked at characteristics and factors associated with students majoring and earning STEM degrees in a Hispanic serving institution (HSI). A sample closely representative of the national population was selected, having 68.7% full time students and 21.5% STEM majors. The study investigated the outcome variables of: 1) declaring a STEM or non-STEM major, 2) declaring of a non-

STEM major and changing to a STEM major versus persisting in a non-STEM major, and 3) earning of degree in a STEM or non-STEM degree (Crisp et al., 2009). Selected independent variables included demographic, pre-college, environmental, and college variables which were deemed to predict the outcomes. When comparing Hispanic and White students for STEM majors, differences were found in terms of financial support, first generation college status, and enrollment status. Crisp et al. (2009) noted Hispanics typically had higher levels of Pell grant support during college, higher first-generation college status and significantly lower SAT math scores, although no significant difference was seen in terms of high school percentile (class rank) or first semester GPA. The parameter estimates in a logistic regression showed the likelihood of declaring a STEM major was specifically linked to the students' gender, ethnicity, SAT math score, and high school percentile (Crisp et al., 2009). Hispanic students were 1.37 times more likely to declare a STEM major than White students.

The analysis also showed female were less likely to earn a STEM degree than males while the odds were 2.48 times greater for Asian American students in comparison to White students. Additionally, an increase in SAT math scores, high school percentile, or first-semester GPA increased the odds of earning a degree in STEM as compared to non-STEM degree. This study (Crisp et al., 2009) confirms research that STEM degree completion can be affected by a myriad of factors (i.e., demographic, pre-college, environmental, college). For my study, a focus of the research will seek to understand aspiring-engineer students' ability to successfully complete S&E degrees.

STEM Attrition Effect

Despite increased efforts and policy to address the ever-continuing student departure from STEM fields, the number of students who leave is quite steady, being 48% in 2014 (NSB,

2016). Attrition happens when students migrate from declared STEM majors to non-STEM majors, or completely depart post-secondary education, also called “STEM Leavers” (Chen & Soldner, 2013, p. 17). However, some STEM Leavers are replaced by students who initially declared a non-STEM major (NSB, 2016). Researchers have indicated that many STEM Leavers are high achieving students that would have ended up in the STEM workforce if they had stayed in the major (Lowell, Salzman, Bernstein, & Henderson, 2009; Seymour & Hewitt, 1997). Additionally, among the STEM fields in Chen and Soldner’s (2013) study, attrition rates ranged for engineering/technology majors from 41% to 62%, and for mathematics majors from 38% to 78%, when seeking bachelors or associate degrees, respectively.

Also, despite commitment to pursue a STEM degree, some students may switch to other non-STEM majors that seem more appealing due a variety of factors (i.e., lack of interest, knowledge of the major, unwelcoming) (Seymour & Hewitt, 1997). Some faculty consider attrition a necessary unavoidable path for “under-prepared or unmotivated students” who leave engineering majors, which is deemed as “weed out” students (Geisinger & Raman, 2013, p. 917). So, efforts to increase retention by a small percentage can be a cost-efficient measure to substantially contribute to the supply of STEM individuals and specifically engineering workers (Ehrenberg 2010; Haag and Collofello 2008; PCAST 2012). Although attrition rates of similar magnitude have been reported for other majors (Bettinger 2010; Kokkelenberg & Sinha 2010; Lowell et al., 2009), the growing demand for S&E professionals is affected by high attrition in STEM and engineering fields (Chen & Soldner, 2013).

As final thought, due to the greatly changing demographic and the need for the US to remain globally competitive, more effort is needed to address high attrition rates amongst minority groups who participate in STEM. A National Research Council report (2011) stated

that most of the growth in new jobs will require science and technology skills, and the individuals most underrepresented in S&E, being the fastest growing population, are minorities (i.e., African American and Hispanics). Sasso (2008) cited since 1985, Black students have declared a STEM major at a greater rate than their White peers. But, due to their high attrition rate amongst STEM majors, their completion rates have been far below White and other minority groups. Further, the attrition rate is especially high in S&E for Black students (Sasso, 2008). Several groups such as first-generation college or low-income students, women, and underrepresented minorities leave STEM and engineering fields at higher rates than their counterparts (Hill, Corbett & St Rose, 2010; Griffith, 2010; Kokkelenberg & Sinha, 2010; Palmer, Davis, Moore III & Hilton, 2010). Further research is needed to address the attrition of all aspiring scientists and engineers to increase degree attainment.

Engineering Education

Engineering Workforce

Being a segment of the STEM workforce, engineers are trained to be an essential resource for a nation's modern technological advancement; but the lack of individuals in these roles would affect innovation worldwide (Geisinger & Raman, 2013). Engineers are needed to apply scientific concepts to further all aspects of the US infrastructure from transport systems to specific tools used in industry and manufacturing and product aesthetics (Burrell, Fleming, Fredericks & Moore, 2015). Koledoye et al. (2011) stated that during the next decade, the US demand for engineers will exceed four times that of other occupations. Additionally, in 2010, the employment rate for engineering fields rose on average by 3.3% from 2004 to 2008 compared to an average increase of 1.3% for all other jobs (Koledoye et al., 2011). Educating

and developing engineers is crucial to supplement the science and engineering workforce and address future societal mandates.

Early Exposure and Challenges of Engineering Education

Despite considerable and focused investments in engineering education including curriculum resources, faculty and teacher preparation, recruitment and retention strategies to prepare students as future engineering professionals, the impact has been limited and insufficient to produce a satisfactory number of professional engineers (Adams et al., 2011). Traditional college engineering education curriculum usually requires students to acquire key knowledge, assimilate technical concepts, but also be disciplined, handle substantial workloads and master academic challenges, and gain experiences in laboratory or design (Adams et al., 2011).

However, there is evidence these areas are not in sync with engineering professional practice (Sheppard, Macatangay, Colby & Sullivan, 2008) and is challenging for many undergraduate engineering students to adapt easily. Additionally, the engineering education programs' culture presents challenges for students. The focus on competition, lack of faculty contact, mentors or support make it to appear unsupportive, while lack of social relevance or attractiveness may create disinterest with a potential engineering lifestyle (Blue et al., 2005). Even more, because of the declining interest in engineering, lack of diverse representation, and low persistence of current and future students, some propose introducing engineering education early in the students' secondary education to train students for such challenges (Adams et al, 2011; Fantz et al., 2011, Wang, 2013).

Aspiring engineers also need to understand that engineering can solve important, real-life problem situations that require mathematics, science and technology learning (Adams et al, 2011). Dawes and Rasmussen (2007) state that young engineering students can gain a grasp and

appreciation of the problems engineers face, how engineering shapes the world using ideas from mathematics and science, and lastly, how engineering puts the principles of mathematics and science at work.

Some research has explored how early experiences can help instill interest in and encourage preparation for engineering. For example, Fantz et al. (2011) studied the effects on students' self-efficacy (student's belief in one's ability to succeed in situations or accomplish a task) after a pre-collegiate engineering experience. The assumption was that greater the rigor of the experience, the more it would enhance a student's self-efficacy relating to pursuing engineering studies (Fantz et al., 2011). This comparative study of 332 first-year students at Colorado State University looked at experience with pre-collegiate engineering classes, extracurricular engineering programs, engineering-related hobbies, work experiences, and academic environment promoting engineering study prior to post-secondary. Participants were divided into two groups for analysis; one who received engineering exposure formally through engineering-related courses, out-of-school programs and trips, as well as informally exposure to work and personal experiences, and the other group of students who did not have experience with engineering related activities. The students completed surveys about their experiences and were able to include what influenced their decision to study engineering. The results showed that "more exposure to engineering content during the K-12 years is associated with a higher self-efficacy in engineering" (Frantz et al., 2011, p. 12) than the group that did not have experience with engineering. This study is important to show that certain types of exposure contribute more to self-efficacy and provides an area of intervention for high school students prior to college.

Bystydzienski et al. (2015) conducted a study of 131 high-achieving female sophomores who attended an after-school program called The Female Recruits Explore Engineering (FREE) and Pathways Project. The recruited diverse group of young women were involved in yearly guided explorations of engineering, projects and mentoring from 10th grade through high school graduation and were then tracked four years post high school. Observations and informal interviews were used to document their experiences during the three years of high school intervention. The results showed that prior to the project, only 18% of the girls were remotely considering engineering as a possible career, but after the intervention 57% were seriously considering a career in an engineering field (Bystydzienski et al., 2015).

To promote STEM and aid students in overcoming the challenges of pursuing engineering, universities have started offering outreach programs and K-12 STEM initiatives to expose elementary and middle school students to engineering design process, engineering education, and engineering as a career. Ralston et al.'s (2013) study examined a K-12 outreach program whose goal is to increase the number of students interested in and capable of studying STEM fields by implementing engineering curriculum at selected elementary and middle schools that feed high schools with Project Lead the Way, a nationally accredited pre-engineering curricula for aspiring engineers. Results showed the coordination between schools has been effective and provided a strategy to increase the number of qualified and capable STEM participants (Ralston et al., 2013). Research has shown certain activities can support engineering thinking and attitude development critical for students who intend to pursue and succeed in engineering. For instance, engineering education offered during pre-college years through periodic focused engineering activities (Bystydzienski et al., 2015), participation in various forms of engineering exposure and experiences (Fantz, et al., 2011; Ralston et al., 2013),

interaction with engineering “artifacts” (engineering tools or devices) (Adams et al., 2011, p. 61), along with involvement in community or global learning projects (Exter et al., 2014; Zoltowski & Exter, 2014), can benefit. However, preparing students prior to college entry to engage in engineering education requires planning and commitment by students, parents, counselors and teachers to navigate requirements and demands of developing future engineers.

Planning for Engineering Education

Educators must help students plan for the rigor or “academic intensity” (Adelman, 2006, p. 27) of an engineering curriculum through building their academic skills (i.e., time management, study aptitude, utilization of resources) that help them succeed. Despite many aspiring-engineer students being high achieving who required little academic support at the high school level, research has continued to show support systems and interventions (i.e., peer mentoring) contribute to their academic success and retention (Marra, Rodgers, Shen & Bogue, 2012). Further, involvement in enrichment experiences such as pre-college engineering programs or summer camps provide an avenue to prepare aspiring-engineer students for engineering majors. Through early exposure during secondary education to engineering based coursework, summer and outside of school academic programs, and field trips, students gain engineering-related knowledge and abilities helpful in a future engineering major (Frantz et al., 2011; Ralston et al., 2013).

For example, Project Lead the Way (PLTW), a noted leading program for engineering preparation, provides an environment for middle and high school students to explore engineering through integrated curriculum, and activities that simulate the extent, rigor, and training of engineering education (Cole et al., 2013). Also, EPICS a nationally recognized project-based and service-learning program in middle and high school, provides the opportunity for students to

engage in engineering projects that address needs in the student's community and provide a personal connection to engineering (Zoltowski et al., 2014). Additionally, getting students involved in science summer camps or after-school programs along with encouragement to join math and science clubs will provide meaningful experiences and more skill-building for engineering education (Brand & Kannam, 2017; Hossain & Robinson, 2012). Further, universities and other stakeholders have made efforts through outreach programs to increase students' involvement in STEM and the building of an engineering pipeline through student and teacher informational workshops, sponsoring of contests, development of materials and portals that develop self-efficacy and meaningful skills through personal experiences (Ralston et al., 2013). Engineering activities should focus on aspiring-engineer students' motivation, interest, commitment, but also planning, since the intention to pursue the field of engineering will affect the perceived behavior control to enroll and complete an engineering degree (Foltz, Foltz, & Kirschmann, 2015).

Competency and Learning in Engineering Education

Academic competency by aspiring engineers seemingly is essential for successful completion of engineering degrees. Engineering students subscribe to similar learning experiences as other science and mathematics majors, but more often leave the program (Seymour & Hewitt, 1997). Seymour and Hewitt (1997) cited about 50% of engineering switchers or migrators (those who did not complete an engineering degree) stated low interest in the major, and nearly half invoked curriculum overload and fast pace learning as reasons they left the major. Percentages of those leaving were much lower for science and mathematics majors, at 37% and 25%, respectively (Seymour & Hewitt, 1997). Further, Cooper, Jackson, Azmitia, Lopez, & Dunbar (1995) shared that underrepresented minority students in math,

science and engineering even feel alienated since they were the only student of color in the classroom. Engineering students have shown they experienced a higher level of difficulty with the pedagogy, pace of work, practices of evaluation, classes that are highly competitive that discouraged collaboration and supportive study groups (Seymour & Hewitt, 1997).

Atman et al.'s (2010) study, involving a sample of 11,812 students from 247 institutions who responded as first-year students in 2002-2004 and later as prospective graduates in 2005-2007, looked at engagement for seniors. Results showed engineering students made greater gains in practical competence and higher order thinking, but lower gains were evident in personal and social development and general education (Atman et al., 2010). Additionally, by their senior year, engineering students saw problem solving, communications, teamwork, and engineering analysis as key competencies for their profession, and used more engineering specific-language to express technical ideas, which was dramatically different from the first-year and sophomores who did not exhibit great attentiveness to the full aspect of engineering design problems (Atman et al., 2010).

To reiterate, early exposure to STEM related courses, and higher-level STEM and engineering related curriculum have been linked to students taking more STEM courses in college and their decision to pursue STEM related degrees such as engineering (Enberg & Woniak, 2013; Wang, 2013). This is key because to be accepted in an engineering major, students are required to reach high levels of competency and learning skills that would allow them to succeed and be prepared for the future workforce.

Aspiring-engineer Students

I argue that students who aspire to be engineers manifest high levels of commitment to engineering as seen by their intention to pursue an engineering degree and their actual choice of

majoring in the field. Consequently, as stated by PCAST (2010), a former President Barack Obama's advisory group of the nation's leading scientists and engineers, there need to be a two-fold effort to produce more people that are capable and interested in joining the STEM workforce. Bottia et al. (2015) stated, "students must be inspired so that they are motivated to study STEM subjects in school and subsequently excited about the prospect of pursuing careers in STEM fields" (p. 3). Previous research has shown a relationship between STEM aspirations, support and experiences with interest, intent and actual choice of major in STEM (Bottia et al., 2015). I will discuss the notions of aspirations, interest, motivation and commitment as main characteristics for the aspiring-engineer students.

Aspirations

Students with high aspirations have hope or ambition to achieve something in life, to get a good education and pursue a rewarding career. Aspiring-engineer students have a dream or a goal to accomplish and are motivated to pursue an engineering degree. Research has indicated that intent to major in STEM and early career aspirations are closely related with enrollment in a STEM major selected during college (Bottia et al., 2015; Sadler, Sonnert, Hazari, & Tai, 2012). Lent, Brown and Hackett (1994, 2000) explained that aspirations and career choices involve personal characteristics, surroundings and behavior. Thus, students' aspirations can influence their intention and ideally their persistence (Lent et al., 2000). Aspirations toward engineering can be developed in several ways. Students can start aspiring toward an engineering career early in secondary education, influenced by other individuals and their own experiences, or gain this ambition at some point along their educational pathway. Aspirations should be nurtured and encouraged as to overcome barriers (i.e., limited knowledge, insufficient interest, negative secondary or post-secondary education experiences) and persist pursuing an engineering major

(Alpay et al., 2008; Geisinger & Raman, 2013; Hossain & Robinson, 2012). Regardless of their specific engineering education trajectory, aspiring-engineer students need essential support and guidance to pursue their dreams.

Interest

Students having engineering career aspirations must have a keen curiosity for STEM and engineering during their early schooling years through college. According to Noeth, Cruce, and Harmston (2003), potential engineering majors are seemingly better prepared due to the increased focus on high school mathematics and science courses required by many states. However, not all aspiring-engineer students are preparing themselves by taking college-oriented math and science courses that are rigorous. Maltese and Tai (2011) examination of rigorous and higher-level coursework by high school students showed a positive effect on degree attainment. Courses such as advanced placement help to ensure students are deemed ‘college ready’ after successful completion based on standards set forth by testing agencies (ACT, 2016; Noeth et. al, 2003; SAT, 2016). An ACT (2016) publication of the STEM national report showed that interest in engineering careers remained at 25%, similar to previous years, and student’s average benchmark to pursue an engineering degree was 33% falling below recommended college readiness levels of 55%. Noeth et al (2003) explained “to help more students consider, plan, and pursue engineering professions, school districts should: provide challenging science and mathematics curricula and courses that align with postsecondary requirements, and engage qualified individuals to teach these courses, beginning no later than middle school, for all students” (p. 11). Offering rigorous coursework in high school helps students develop and sustain their interests in STEM through high school into college (Adelman, 2006; Maltese & Tai, 2011). Wang (2013) shared research showing that students who have consistent interest to

pursue a STEM major built that interest during their secondary education and sustained it through the post-secondary years. Further, he stated the process through which a student decides to pursue STEM majors is "...best realized through incorporating the effects of these two levels of education (secondary and post-secondary) since they both shape students' entrance into STEM" (Wang, 2013, p.1083).

Motivation

Further, the pursuit of an engineering major by aspiring-engineer students involves motivation and a commitment to obtain the degree (Atman et al., 2010; Wang, 2013). We need to understand how the degree of motivation will shape students' determination to accomplish their goal from an initial interest in engineering to the culmination of degree attainment. Atman et al. (2010) conducted a study to explore six motivational factors using a national sample of 4,266 undergraduate engineering students from twenty-one diverse campuses. They found that behavior and psychological aspects were the top factors that provided moderate to major motivation to students to study engineering; in essence, these two types of factors describe how students "feel when acting and thinking like an engineer" (Atman et al., 2010, p. 33). Further, the study suggested that an important connection for intrinsic motivation could be the pre-college actions and activities of engineering-related hobbies and practices like building, fixing and putting things together during the students' childhood (Atman et al, 2010). Similar results were evident in other studies. Hanrahan's (1998) study of a high school biology class showed higher levels of intrinsic motivation was linked with greater cognitive engagement, and Black and Deci's (2000) study of an organic chemistry class, showed students' self-determined motivation was positively correlated to their persistence in the course.

Seymour and Hewitt (1997) cited ‘intrinsic interest’ as a reason students make college major choices. They stated that intrinsic interest encourages a connection to the major and a sense of direction and feelings of determination through times of difficulty (Seymour & Hewitt, 1997), providing a reason why motivation scores were twice as much for those completing engineering degrees than those who left the major. Aspiring-engineer students need to cultivate their interest in the field to gain the psychological (feeling or motivation) benefits while developing their engineering identity when pursuing an engineering degree. Students’ personal motivation and actual intrinsic interest in engineering can be encouraged through experiences, affirmation by faculty, mentors, peers, etc. and by their own desire for personal fulfillment and achievement (Atman et al, 2010).

Commitment

A final thought about aspiring-engineer students is a discussion about commitment and dedication to the pursuit of an engineering degree. Aspiring-engineer students must have ambition and aspirations to achieve to trigger motivation and commitment to attain their goal. The degree of commitment required to obtain an engineering degree appears to relate to student’s persistence. Atman et al. (2010) states that the extent students identify with the engineering major and the activities that engineers involve themselves in is positively correlated to the commitment to major. Atman et al.’s (2010) Longitudinal Cohort study of 160 undergraduate engineering students (40 at each of four diverse campuses) focused on understanding their commitment and persistence toward engineering. The results showed degree of commitment varied depending on the students’ identification with various engineer work activities. However, a strong relationship between identification with engineering and perception of activities engineers engaged in every day was found. Students were more likely to show firm commitment

to engineering if they identified with or connected with a specific activity (e.g., building things). However, other students who showed weak connection between their engineering-related identity and engineering-related activities had a continual questioning of commitment to engineering (Atman et al., 2010). By being exposed and involved in engineering-related activities early on, aspiring-engineer students will solidify their interest and relation to engineering type activities.

Therefore, early commitment and planning are key to prepare motivated engineering interested students. Atman et al.'s (2010) analysis after interviewing 32 high school aspiring-engineer students showed they enjoyed high school math and science, but they did not know much about engineering. Still, others said they did not consider engineering as a major until senior year in high school. Overall, the study showed only 20% of first-year engineering students had significant exposure to engineering coursework, internships, etc. prior to going to college (Atman et al., 2010). Limited exposure to engineering can lessen interest, participation and the ability to navigate an engineering major.

Typology of Aspiring Engineers

As evidenced in research, the path of degree attainment by engineering degree earners can vary greatly (Johnson & Sheppard, 2004; Seymour & Hewitt, 1997). Some students start early in their education having an intention to pursue engineering degrees, while others decide to pursue the major later in their undergraduate education. Students who have interest in engineering express their intention to pursue an engineering major at any point along the engineering pipeline (educational route through secondary and postsecondary that leads to a degree) (Johnson & Sheppard, 2004). Johnson and Sheppard (2004) state that entry into the engineering pipeline can occur as early as elementary school with a successful exit being the

completion of an engineering degree. All students despite having or no intentions to pursue engineering still face choices and must make critical decisions (e.g., whether to pursue, enroll, declare major in the field, etc.) which will influence their pursuit and completion of an engineering degree.

A typological approach in which students are classified into groups based on specific attributes related to a behavior, can help further explain differences in outcomes. Kuh, Hu and Vesper (2000) described the need to engage in “high stakes” research that seeks to find out patterns of student performance and behaviors (i.e., on what do students spend their time and effort) among groups and link student behavior with outcomes. Utilizing a pioneering work by Clark and Trow (1966) and a more modernized approach by Astin (1993b), Kuh et al. (2000) conducted a study to develop a student typology based upon the patterns of engagement in activities that influence outcomes in college. The survey was administered to 51,115 full-time enrolled undergraduate students at 128 institutions of different types, to examine engagement in college activities and other behavioral characteristics. Students were categorized into eight cluster groups (ranging from personal-social interaction to sports and exercise interaction) for comparison.

Kuh et al.’s (2000) typology approach supports the current study, suggesting that typology clustering can be helpful to examine the characteristics of each distinct group and gain new insights into differences in outcomes in relation to specific group attributes. In this study, aspiring-engineer students are classified according to two primary orientations: stated intention to pursue engineering prior to college and selection of an engineering major. The combinations of these attributes result in three student groups: intention and choice of engineering major,

intention but no choice of engineering major, and no intention but choice of engineering as a major.

Factors Affecting Degree Attainment

Research has identified a number of factors that affect post-secondary degree attainment. Some of these factors are clear barriers specifically for those who seek a STEM or engineering degree. Previous research has revealed that for students who pursue college degrees, factors relating to demographics, pre-college and college should be considered (Geisinger & Raman, 2013; Wang, 2013). Despite mixed information about factors affecting engineering majors overall, the consensus is that attrition factors affecting attainment relate to student characteristics (NSB, 2014), preparation before college (Moore Jr. III, 2006), and the college-going experience (PCAST, 2012).

Demographic Factors

Socio-demographic factors include gender, race/ethnicity, socioeconomic status of the student's family, parents' educational attainment and other individual characteristics that can affect a student's degree attainment (Crisp, et al., 2009; Flynn, 2014). Although research has looked at how demographics relate to participation in STEM (Wang, 2013), there is limited (to no) research about engineering in particular. Students' pursuit and attainment in STEM is affected by age (Mau, 2016), parents' educational attainment, social background (Wang, 2013) and self-assessment (Seymour & Hewitt, 1997; Wang, 2013). Underrepresented students in STEM education face challenges related to low socioeconomic status (Geisinger & Raman, 2013; Mau, 2016; Wang, 2013) and first-generation status (Toven-Lindsey et al., 2015).

Socio-demographic factors can profoundly shape aspiring-engineer student's degree attainment if students lack information and guidance including career goals (Geisinger & Raman,

2013). Factors that can affect attainment for these students are gender and race (Geisinger & Raman, 2013; Mau, 2016; Toven-Lindsey et al., 2015; Wang, 2013), parents' educational attainment (Wang, 2013), family socioeconomic status (Marra et al., 2012; Strutz & Ohland, 2012; Wang, 2013), and first-generation student status (Toven-Lindsey et al., 2015).

Pre-College Factors

Research has shown student's experiences and preparation during the elementary, middle and high school years are important to examine because of their influence on effectively navigating post-secondary education (Crisp et al., 2009; Geisinger & Raman, 2013). Crisp et al. (2009) state that many students must overcome less than positive experiences in secondary education and insufficient preparation during high school, that can negatively shape their college experiences and connection to the institution and selected program. Flynn (2014) resounding Tinto's ideas, by stating that students' learned behaviors during pre-college years determine their ability to engage and persist in college. Other researchers highlight numerous barriers that affect STEM students. Wang (2013) state high school achievement scores, motivation and attitude toward math, subject self-efficacy beliefs and exposure to math and science courses, advanced and rigorous work as barriers (Maltese & Tai, 2011; NAS, NAE & IM, 2007). Mau (2016) mentioned college entrance exam scores, high school GPA, class rank, and math and science identity; and Hall et al. (2011) specify interest in STEM, student perception, and STEM learning experiences as pre-college factors. Even more, factors can include poor classroom experiences relating to teacher enthusiasm, everyday context or unstimulating lessons and lack of discussion about careers in math and science (Maltese & Tai, 2011). Hossain and Robinson (2013) state that inadequate teacher support, curriculum issues, inadequate teacher training and professional development are barriers to attainment.

Overall, the journey of aspiring-engineer students could be affected by low student expectations (Geisinger & Raman, 2013), low parental expectations (Moore Jr. III, 2006), inadequate high school preparation/performance in STEM subjects (Geisinger & Raman, 2013; Mau, 2016; Toven-Lindsey et al., 2015; Wang, 2013), low college entrance scores (Geisinger & Raman, 2013; Mau, 2016), low math self-efficacy (Fantz, et al., 2011; Geisinger & Raman, 2013; Toven-Lindsey et al., 2015; Wang, 2013), and lack of interest in math and science subjects (Geisinger & Raman, 2013; Toven-Lindsey et al., 2015; Wang, 2013).

Finally, Geisinger and Raman (2013) reviewed a “plethora of studies” (p.914) over the last five decades on attrition and retention of students to understand what factors can affect degree attainment of engineering majors. They conducted a meta-analysis of literature using databases categorizing a variety of pre-college and post-secondary factors. The research yielded evidence-based strategies for increasing retention based on 50 relevant and rigorous studies that related to the reason why students leave engineering and another 25 studies providing information on ways to improve retention rates. In particular, Geisinger and Raman (2013) identified 27 studies that used longitudinal data to examine pre-college factors of high school class rank, grade point average, entrance test scores (SAT/ACT), college major persistence and/or college stop out, and the effect of gender and race in some instances. The results yielded that inadequate high school preparation, little interest in or commitment to the field of engineering, lack of confidence, and low math and science grades in high school affected engineering student’s degree attainment (Geisinger & Raman, 2013).

Wang (2013) explained that by looking at capable students during pre-college years, one can get a full understanding of the factors that affect their “choices of enrollment and college major” (p. 1089). He found that the transition from high school to college was critical in

maintaining an interest in engineering (Wang, 2013). Chen and Soldner (2013) point out the concerns that minorities especially Black students, who pursue science and engineering, have higher attrition rates than other engineering students. Further, Geisinger and Raman (2013) reported that women and minorities underperform and leave engineering at greater rate than their White male counterparts, despite having the same or higher levels of pre-college preparation. Further, because minorities may not respond to competition and encouragement the same as other groups, it appears teaching and advising toward S&E may be more harmful than it is to other student groups (Geisinger & Raman, 2013).

Post-Secondary Factors

Flynn (2013) confirms the notion by Tinto that academic and social engagement matter for college students. Post-secondary factors that affect students during their college experience can include limited academic and social engagement, no integration or collaborative learning, unsupportive campus environment, and poor educational experience (Flynn, 2013). Additionally, STEM majors have a host of challenges during their college experience. Wang (2013) stated lack of support and financial resources, parental negative outlook, institutional selectivity/type, poor faculty quality and diversity, limited classroom experiences and academic interaction (Ehrenberg, R.G., 2010; Toven-Lindsey, 2015) and degree of racial isolation (Chang, Sharkness, Hurtado & Newman, 2014) for underrepresented groups were such factors. Mau (2016) stated intensity of STEM courses, remedial courses taken, first year GPA, and credits earned are affecting factors, while Hall et al. (2011) pointed out personal interest as a factor, and Crisp et al. (2009) stated lack of engaging pedagogy that promotes active participation can affect STEM majors. Lastly, Haag and Collofello's (2008) results identified less approachable professors, low

morale due to competitive culture, and lack of peer support, while Geisinger and Raman (2013) stated classroom experiences were deterrents for STEM majors.

For aspiring-engineer students, limited post-secondary support factors may alter attainment. Such factors could be less welcoming college environment (Geisinger & Raman, 2013; Kuh et al., 2008; Mau, 2016; Toven-Lindsey et al., 2015), less approachable academic and advising support during major (Haag & Collofello, 2008; Marra et al., 2012), requirement of taking remedial course(s) (Mau, 2016; Toven-Lindsey et al., 2015), enrollment intensity (Wang, 2013), lack of student-learning engagement (Graham et al., 2013; Toven-Lindsey et al., 2015), lack of campus connection (Geisinger & Raman, 2013; Hurtado et al., 2007), financial difficulties (Hurtado et al., 2007; Koledoye et al., 2011; Kuh et al., 2008), and curriculum difficulty (Crisp et al., 2009; Marra et al., 2012).

Geisinger and Raman's (2013) findings showed problems with unwelcoming academic climate and advising for the engineering programs, lack of support, difficulty with courses, lack of self-efficacy, poor teaching, conceptual understanding, lack of engagement in class, lack of sense of belonging, racism, or sexism are all challenges once the student enters college. Geisinger and Raman (2013) stated that the six broad factors of classroom and academic environment, conceptual understanding and grade performance, sense of worth and self-confidence, high school planning, major interest and career goals, and race and gender, as summarized from 27 studies examined, can have detrimental effect causing students to leave engineering. It was suggested that retention can be increased by addressing at least one of the six areas of factors (Geisinger & Raman, 2013).

Marra et al. (2012) conducted a study about students that had transferred from a large engineering college. The study identified factors affecting 113 undergraduate engineering

students who were mostly white and who left the institution during the years 2004, 2007, and 2008. Information gathered included the length of time in the program, intended major and GPA, reasons for pursuing engineering, high school preparation, career plans after college, activity involvement, etc., and questions about the reason for leaving engineering. Three main factors were evident for why students left the engineering program: 1) poor teaching and advising; 2) challenging curriculum; and 3) lack of belonging.

Gaps in the Literature

As seen with the studies by Geisinger and Raman (2013), Wang (2013) and Mau (2016) and others, the previously stated factors can affect college student enrollment, completion of STEM majors and also be considered as affecting aspiring-engineer students. However, more research is needed on factors that are specific to aspiring-engineers' degree attainment.

For instance, little information has been found about student's intentions to pursue engineering and their ability to overcome negative circumstances to lead to degree attainment (Mau, 2016; Wang, 2013). Related research includes studies exploring the influence of the math and science learning on student attrition (Geisinger & Raman, 2013; Mau, 2016), recruitment and academic preparation of STEM and engineering majors (Mau, 2016), participation and interest to enter STEM (Maltese & Tai, 2011; Wang, 2013) and engineering, and whether the characteristics of engineering students are different from non-engineering students (Mau, 2016). Further, there are limited comprehensive studies that offer research-supported best practices to retain students who pursue engineering majors (Geisinger & Raman, 2013) by identifying the stage in which student who have an interest in engineering, might give up and not enroll in an engineering major. My dissertation will seek to understand influencing factors and their effect on completing S&E credentials and thus attempt to address research gaps mentioned here.

Theoretical Framework

This study is based on the assumption that successful completion of an engineering degree is affected by student's level of aspiration as indicated by the intention and the actual choice to pursue a particular field of study or career, while underscoring pre-college and college experiences. I will seek to use a theoretical framework that incorporates aspects of the Social Cognitive Career Theory (SCCT) (Lent, Sheu, Gloster & Wilkins, 2010; Wang, 2013; 2012) to understand how prior intention influence student outcomes while incorporating concepts of self-efficacy, motivation, and choice-making (Lavigne, Vallerand & Miquelon, 2007).

Derived from Bandura's (1986) social cognitive theory, the Social Cognitive Career Theory (SCCT) has been utilized as a theoretical lens for understanding STEM-associated academic and career behavior (Lent et al., 2010). SCCT mechanisms provide an avenue to study STEM (Lent, Brown & Hackett, 1994; 2000) having been applied to examine STEM-related academic choice intentions (Bottia, 2013; Lent, Lopez, Lopez & Sheu, 2008;) and specifically engineering major choice (Inda, Rodríguez & Peña, 2013; Lent, Brown, Schmidt, Brenner, Lyons & Treistman, 2003). SCCT describes four interconnected ideas of interest growth, choice making, accomplishment, and fulfilment (Lent et al., 2010). Further, SCCT focuses on explaining three areas: 1) academic and career interest development, 2) understanding how educational and career choices are made, and 3) understanding how academic and career success is accomplished (Lee, Flores, Navarro & Kanagui-Muñoz, 2015). Useful SCCT key measures for this study are self-efficacy, outcome expectations, interests, and student and parent expectations (Wang, 2013) to explain the interrelated aspects of prior influences, academic choices, and the degree attainment outcome.

This study will also seek to understand how motivation toward a career can lead to behaviors indicative of future intentions which is key in students' persistence to overcome barriers toward completing engineering education (Lavigne et al., 2007; Ryan & Deci, 2000). Motivation and self-efficacy are important factors shaping aspirations toward pursuit of goals and outcome expectations (Lent et al., 1994). The concept of motivation will help understand a student's drive, which stems from Bandura's (1986) ideas of self-efficacy and explains how it leads to an increase in the effort to achieve goals, to persistence and success (Lavigne et al., 2007; Seymour & Hewitt, 1997; Wang, 2012). Additionally, SCCT points out the role of a host of environmental support and barriers in influencing student major choices.

This study will examine factors along the path toward degree attainment from initial interest in engineering to post-secondary completion and S&E credentialing. The conceptual model proposed in Chapter 3 incorporates elements of SCCT, and is based on a typology of aspiring-engineer students (i.e., who express intent in and make a choice of engineering major) and its relationship with educational outcomes, when controlling for background and contextual factors.

CHAPTER 3

RESEARCH METHOD

The purpose of this study is to examine the educational attainment and STEM degree completion of students who aspire to major in engineering and to understand how outcomes are affected by the typology of aspiring-engineer students (i.e., differentiated by their intention for and choice of engineering major) in addition to socio-demographic characteristics, pre-college and college factors.

This study addresses the following research questions:

1. What are the characteristics of three types of aspiring-engineer students who— a. intended and chose the engineering major upon entry, b. did not intend, but chose the engineering major in college, c. intended but did not choose the engineering major?
2. What is the relationship between educational attainment by age 26 and aspiring-engineer groups, socio-demographic factors (i.e., gender, race, parental education, SES), pre-college factors (i.e., parental aspirations, student expectations, math achievement, math self-efficacy, academic achievement, preparation in math/science subjects), post-secondary factors (i.e., engagement, remedial courses, financial issues)?
3. What is the relationship between S&E degree completion by age 26 and aspiring-engineer groups, socio-demographic factors (i.e., gender, race, parental education, SES), pre-college factors (i.e., parental aspirations, student expectations, math achievement, math self-efficacy, academic achievement, preparation in math/science subjects), post-secondary factors (i.e., engagement, remedial courses, financial issues)?

Data

ELS: 2002 Surveys

This quantitative study utilizes data from the Educational Longitudinal Study (ELS:2002), which was designed to study the transition from high school into postsecondary education and work. High school sophomores (10th graders) were surveyed during the base year (BY, 2002), when surveys were also administered to parents, teachers and school administrators. Additionally, information was gathered from students' assessments and transcripts in math and English during the sophomore and senior grades, in 2002 and 2004 (The Institute of Education Sciences, 2000; 2002; NCES, 2002). First follow-up (F1) data was collected in 2004, when students were expected to be seniors in high school. Students who were not identified as sophomores in 2002 but were seniors in 2004, were included as a high school senior two years later. The second follow-up (F2) survey was administered in 2006 to all base-year and F1 participants. In 2006, students may be either in college or part of the workforce. The third follow-up (F3) was conducted in 2012, eight years after expected high school graduation. The last survey data encompasses information regarding college completion and employment. Additionally, information on family, community involvement and college transcript history was collected.

ELS:2002 is an appropriate data set for this study because it provides an empirical description of student experiences relevant to high school and college years. Data sampling consisted of 750 schools and over 16,000 students, making this a nationally representative sample. Lastly, the longitudinal nature of the data provides a holistic perspective of the relationship between student interest in a specific discipline and choice-making decision to pursue a field of study (Wang, 2013).

Research Design

Data

The current study employs longitudinal data from the base-year, and the three follow-up ELS surveys, from public-use data files downloaded from the NCES website. First, the study is based on the 2002 information from student and parent questionnaires that were administered in the base-year (BY). The BY student questionnaire focused on experiences in secondary school, and included various information on demographics, future plans, finances and work, academic achievement, and values and beliefs. The experiences in school included specific questions related to participation in advanced curriculum coursework, college access programs, and extracurricular and academic activities. The plans for future education included specific questions on college preparation, education expectations and occupation aspirations. The BY parent questionnaire included family background information, parental education, and parents' perspective on future education plans with specific questions about expectations for the educational attainment of their children.

Second, the study uses data from each subsequent follow-up survey (2004, 2006, 2012). The first follow-up survey (2004) when students were in Grade 12, extended the focus to include information on planning post-secondary education transition. The second (2006) and third follow-up survey (2012) when students are about 20 and 26 years old, addressed college access and choice, college graduation, employment and workforce market outcomes. Variables were selected from BY and follow-up surveys relating to the proposed analysis: Socio-demographics (e.g., gender, race, socioeconomic status, level of parental educational attainment) based on BY and F1 surveys; Pre-college factors (e.g., academic preparation, self-efficacy, student and parent expectations) based on BY and F1 surveys; Post-secondary factors (e.g., meeting with advisor,

high impact activities, remediation, financial challenges) and outcomes based on F1, F2 and F3 surveys (Geisinger & Raman, 2013; Mau, 2016; PCAST, 2012; Toven-Lindsey et al., 2015).

Conceptual Framework

The conceptual models proposed in this study explore how a typology of aspiring-engineer students (i.e., differentiated by their intention for and choice of engineering major) affect educational attainment (i.e., bachelor, masters, etc.), and S&E degree completion (e.g. engineering major) while controlling for socio-demographics, pre-college factors, and post-secondary factors (Table 3.1).

Table 3.1: Conceptual Framework

Individual Characteristics	Aspiring-engineer Typology (Intention-Behavior)	Educational Outcomes	
Socio-demographics -Gender -Race/Ethnicity -Parental Educational Attainment -SES	<ul style="list-style-type: none"> • High (Intended and chose engineering major) • Medium (Did not intend but chose engineering major) • Low (Intended but did not choose engineering major) 	Educational Attainment	S&E Credential Completion
Pre-College Factors -Parent Aspirations -Student Expectations -Math Test Scores -Self-Efficacy-Math -GPA-all courses -High School Preparation for Math/Science Subjects		<ul style="list-style-type: none"> • PSE Non-completers • Certificate or Associate Degree • Bachelor or Graduate Degree 	<ul style="list-style-type: none"> • Unknown field of study or non-completer • Credential in Non-S&E • Credential in S&E
Post-Secondary Factors -Academic Engagement (4 items) -Enrollment Gap -Sector of 1 st Postsecondary -Remediation (Math/Others) -PSE Loans			

This conceptual framework is based on the assumption that the combination of intention and choice to pursue an engineering degree that defines the aspiring-engineer type of student affects educational outcomes, such as attainment and S&E degree completion. In addition, the models include any effects of socio-demographics, pre-college and post-secondary factors shown in research to affect educational outcomes (Geisinger & Raman, 2013; Mau, 2016; Wang, 2013). Socio-demographics, pre-college and post-secondary factors are hypothesized to control the relationship between aspirations and outcomes (i.e., educational attainment and credentialing).

Sample

Two variables captured during the second follow-up year were selected to define the aspiring-engineer typology (Table 3.2). More details are presented in Appendix A.

Table 3.2: Sample Selection

Variable	Codes	Selection
Intention -Field of study most likely to pursue upon entering (F2B15)	1-3= Business, Health, Education/teaching; 4=Engineering or engineering technology; 5-15= Computer or information sciences, natural science or mathematics, environmental studies, social science/social work, architecture, design, fine arts, humanities, communications, university transfer, vocational programs, other	Code=4
Choice (behavior) -Major in 2006 (F2MJR2)	1-10= Agriculture, architecture services, arts, biological, business, communication, computer sciences, education; 11=Engineering technologies/technicians 12-33= English, family/consumer sciences, foreign language, health professions, legal, mathematics, parks, personal, philosophy, physical sciences, psychology, public, security, social sciences, other (categories with low cell counts), liberal arts	Code=11

A sample of N=760 students was selected for this study, representing varying degree of intention/choice in pursuing engineering that reflect high/medium/low aspirational levels to becoming engineers.

Variables

The dependent or outcome variables for this study are educational attainment and S&E degree completion by 2012. Other variables were included as independent variables. Table 3.3 provides details about variable name, type, codes and categories.

Table 3.3: Variables and Constructs

Variable/Construct Name	Type	Codes/categories
Aspiring-engineer Typology		
Intention/Choice (F2B15; F2MJR2_P)	Categorical 3-category variable (derived)	1= High (Intended and chose engineering major) 2= Medium (Did not intend but chose engineering major) 3= Low (Intended but did not choose engineering major)
Socio-demographic Characteristics		
Gender (F1SEX)	Categorical 2-category variable	0= male 1= female
Race/Ethnicity (BYRACE)	Categorical 5-category variable (derived)	1= White 2= Black/African American 3= Hispanic/Hispanic not specified 4= Asian/Hawaii/Pac. Islander 5= Others (Multiracial/Amer. Indian/Alaska Native)
Parental Educational Attainment (BYPARED; F1PARED)	Categorical 4-category variable (derived)	1= High school or less 2= 2-year college attend/complete 3= 4-year college attend/complete 4= PhD, MD, or other advanced degree
SES ¹ (F1SES1QU)	Categorical 4-category variable	1 = First quartile (lowest) 2 = Second quartile 3 = Third quartile 4 = Fourth quartile (highest)
Pre-College Factors		
Parent Aspirations (BYPARASP)	Categorical 4-category variable	1= Anything below 4-yr credential 2= Graduate from college 3= Master's degree or equivalent 4= PhD, MD, or other advanced degree

Table 3.3: Variables and Constructs (continued)

Variable/Construct Name	Type	Codes/categories
Student Expectations (F1STEXP, BYSTEXP)	Categorical 4-category variable	1= Anything below 4-yr credential 2= Graduate from college 3= Master's degree or equivalent 4= PhD, MD, or other advanced degree
Math Quartile scores (F1TXMQU; BYTXMQU)	Categorical 4-category variable	1 = Lowest quartile 2 = Second quartile 3 = Third quartile 4 = Highest quartile
Self-Efficacy-Math (F1MATHSE; BYMATHSE)	Continuous variable	Range (-2, 2)
GPA in All Courses (9 th – 12 th) (F1RGPP2)	Categorical 5-category variable Used as Ordinal variable (0-4)	0= 0.00-2.00 1= 2.01-2.50 2= 2.51-3.00 3= 3.01-3.50 4= 3.51-4.00
High School Math Prepared for First Postsecondary School (F2B17A)	Categorical 3-category variable	1= Not at all 2= Somewhat 3= A great deal
High School Science Prepared for First Postsecondary School (F2B17B)	Categorical 3-category variable	1= Not at all 2= Somewhat 3= A great deal
Post-Secondary Factors		
Academic Engagement (F2B18A, F2B18B, F2B18C, F2B18D)	Categorical 3-category variables	1= Never; 2= Sometimes; 3= Often
Gap in Enrollment (F2ENRGAP)	2-category variable	0= No gap in enrollment 1= Gap in enrollment
Sector of First Postsecondary Institution (F3TZPS1SEC)	Categorical 4-category variable	1= 4-year public 2= 4-year private, not for-profit 3= 2-year public 4= Other (2-year private for-profit; less than 2-year private for profit; other)
Taking Remedial Course (F2PS1REM) and Math Remedial Course (F2B16C)	Categorical 3-category variable (derived)	1= None 2= Non-math remedial courses 3= Math remedial course

Table 3.3: Variables and Constructs (continued)

Variable/Construct Name	Type	Codes/categories
PSE Loans (F3STLOANEVR; F3FEDCUM3)	Categorical 2-category variable	0= No 1= Yes
Outcomes		
Educational Attainment in 2012 (F3TZHIGHDEG and F3ATTAINMENT)	Categorical 3-category variable	1 = PSE/Non-completers 2 = Certificate or Associate degree 3 = Bachelor or Graduate degree [ref cat]
Credential in Science & Engineering Field in 2012 (F3SCENCRED)	Categorical 3-category variable	1= Unknown field or completion 2= PS credential in a non-S&E field 3= PS credential in a S&E field [ref cat]

¹SES is a composite variable of family income, mother/father highest education, mother/father occupation

Educational Attainment: During the third and final follow-up, students' information on post-secondary completion was reported from college transcripts and follow-up interview. I will use a 3-category derived variable (Some PSE / Non-completers; Undergraduate certified/diploma or Associate degree; Bachelor or Post-baccalaureate or Graduate degree).

Science/Engineering (SE) Credential: The third follow-up survey includes a S&E credentialing variable that provides information on the type of degree obtained and on whether it is a S&E credential/degree or non-S&E field degree. The categories are based on the National Center for Education Statistics (NCES) (2000) Classification of Instructional Programs (CIP). The 3-category variable will indicate if the student obtained a S&E bachelors or graduate degree (Undergraduate credential in S&E field, undergraduate or graduate credential, or graduate only in S&E field), or obtained No PS credential in a S&E field, or had no information on the field of study or completion status.

Aspiring-engineer Typology is the design variable of the study. It indicates three levels of intention/choice in pursuing an engineering degree. I propose to define them in terms of level of aspirations as High aspiration (Intended and chose engineering major), Medium aspiration (Did

not intend, but chose engineering major) and Low aspiration (Intended, but did not choose engineering major).

Control Variables: Control variables are socio-demographics characteristics, pre-college and post-secondary factors. First, gender, race/ethnicity, socio-economic status and parental education describe the socio-demographic characteristics of the student. Gender is a 2-category variable (male/female). Race/ethnicity is a 5-category variable: White; Black/African American; Hispanic; Asians/Hawaii/Pacific Islander; others (i.e. Multiracial/ American Indian/Alaska Native). Socio-economic status is reported as quartile data (4-category variable). Parental education is based on the highest level of education attained by either parent. For the study, a 4-category variable will be used (High school or less; 2-year college attended or completed; 4-year college attended or completed; Advanced degree). Socio-demographic data reported in the Base Year (BY) and F1 surveys are combined to reduce missing information.

Pre-college factors include information on parent aspirations for their child's educational attainment, student educational expectations, self-efficacy in mathematics, GPA in all courses during high school, math test scores, and student perception of preparation in high school math and science subjects. Post-secondary factors describe access to and experiences in higher education such as gap in enrollment, sector of first post-secondary institution attended, taking math-related or other remedial courses, academic engagement during studies (e.g., college advisor and faculty meetings, use of library and other resources), and student loan utilization.

Missing Data

I used two strategies for dealing with missing information for the selected ELS sample and variables. First, ELS longitudinal database allowed to reduce the missing information by corroborating similar data from different questionnaires. For instance, missing information based

on F1 survey was replaced with corresponding information from BY survey for parental education, student expectations, math quartile scores and math self-efficacy variables. Second, imputation techniques were used to complete the remaining missing information for math self-efficacy (9.9% missing), high school GPA (6.3% missing), PSE loans (3.9% missing) and perception of high school science preparedness (1%). All missing information was replaced after 5 imputations, and the entire sample of N=760 respondents was subsequently used for analysis.

Data Analysis

The Statistical Package for Social Science (SPSS) version 23 was used to analyze the data, and conduct descriptive analysis, bivariate and multivariate analyses. The research plan is presented in Table 3.4 that includes the variables and statistical procedures used to answer each research question. In order to answer research question 1, descriptive statistics was performed to provide an overview of the sample and compare the aspiring-engineer groups by other student factors. Cross-tabulations and chi-square tests were utilized to assess the degree of association between the aspiring-engineer groups and demographic factors (e.g. gender, race/ethnicity, etc.), pre-college factors (e.g. parent aspirations, student expectations, etc.) or the post-secondary factors (e.g. engagement, taking of remedial course, etc.). Analysis of variance (ANOVA) was used to compare means of continuous variables (e.g., math self-efficacy and GPA) among the aspiring-engineer groups (Tabachnick and Fidell, 2007).

To answer research questions 2 and 3, multinomial logistic regression models were developed to estimate the likelihood of outcomes when independent variables are included. Multinomial logistic analysis was chosen due to the multiple categories of the two dependent variables: educational attainment (3 categories, Bachelor/Graduate=reference category) and S&E degree completion (3 categories, S&E credential=reference category). The predictors include

both continuous and categorical variables. Categorical variables were accordingly recoded to place the reference category as the last category. The odds ratios in the multinomial logistic regression models indicate the likelihood of the outcome (e.g., being a postsecondary non-completer rather than obtaining a university degree) for a given category (e.g., female) relative to the reference category (e.g., male).

All analyses are conducted with normalized weights that are computed from the survey weights provided in the ELS data. Normalized weights preserve the counts in the sample but reproduce the proportions in the population.

Table 3.4: Research Analysis Plan

Research Question	Variables	Data analysis
RQ 1. What are the characteristics of types of aspiring-engineer students who: a. intended and chose the engineering major upon entry, b. did not intend, but chose the engineering major in college, c. intended but did not choose the engineering major?	Aspiring-engineer Typology Socio-Demographic Factors Pre-College Factors Post-Secondary Factors	Descriptive statistics Cross-tabulations ANOVA
RQ 2. What is the relationship between educational attainment by age 26 and aspiring-engineer groups, socio-demographic factors, pre-college factors, post-secondary factors?	Educational Attainment Aspiring-engineer groups Socio-Demographic Factors Pre-College Factors Post-Secondary Factors	Multinomial Logistic regression
RQ 3. What is the relationship between S&E degree completion by age 26 and aspiring-engineer groups, socio-demographic factors, pre-college factors, post-secondary factors?	S&E Degree Completion Aspiring-engineer groups Socio-Demographic Factors, Pre-College Factors, Post-Secondary Factors	Multinomial Logistic regression

Definitions of Terms

Key definitions and terminology used in this study is provided for clarity.

Engineering Major: Termed ‘Engineering Technologies/Technicians’ are instructional programs that prepare individuals to apply basic engineering principles and technical skills in support of engineering and related projects. ‘Engineering Technology General’ are programs that generally prepares individuals to apply basic engineering principles and technical skills in support of engineers engaged in a wide variety of projects. All programs include instruction in various engineering support functions for research, production, and operations, and applications to specific engineering specialties -- code 15.0000 according to the Classification of Instructional Programs (CIP) taxonomy (NCES, 2010).

NCES: National Center for Education Statistics is a major federal agency involved in collecting and analyzing data useful to educational research. The ELS: 2002 and other databases and resources are available through NCES for research purposes.

Science and Engineering (S&E): Policies and programs have been instituted for promoting Science, Technology, Engineering and Mathematics (STEM) education, and “adequate” participation in the S&E workforce (Sargent, 2017, p.1). The National Center for Education Statistics (NCES, 2010) published the fourth revision for CIP -- a taxonomic coding scheme of instructional programs which provides a concise reporting of major and minor fields of study, including various S&E programs. Additionally, the National Science Board (NSB, 2016) stated that S&E includes six occupational groups comprised of closely related detailed occupations: computer and mathematical occupations, engineers, life scientists, physics scientists, and science and engineering managers.

Underrepresented groups in S&E: Term used to describe groups with limited participation in academia or S&E fields that have been historically and systematically marginalized, due to various reason often associated with lack of access to resources, low-

income, inadequate preparation, first-generation college student (ACT, 2016). For instance, historically, Blacks and Hispanics are severely underrepresented as bachelor's degree earners of engineering degrees. In 2015, only 4.2% and 10.9% of engineering degrees were earned by Black and Hispanic graduates, respectively in comparison to 66% of degrees earned by White graduates (NSB, 2018).

CHAPTER 4

FINDINGS

This chapter presents the findings of this study. The results were obtained through data analysis using SPSS to address each research question, as detailed in Chapter 3. SPSS techniques include bivariate statistics (i.e. cross-tabulations and chi-square tests) to describe the data and test the association among categorical variables. Also, ANOVA statistic is used to evaluate differences amongst continuous variables by the three different aspiring-engineer group. Then, multinomial logistic regression models are applied to predict the likelihood of educational attainment and S&E credentialing outcomes by the set of factors included in the model. Each regression analysis model is based on the same set of predictors that include Socio-demographic, Pre-College, Post-Secondary factors as previously specified.

Aspiring-engineer groups

A sample of 760 respondents were identified based on student responses on the intention for and choice of engineering majors in 2006. A ‘high aspiration’ level is associated with 42.4% of respondents who intended to pursue an engineering degree and also chose an engineering major. A ‘medium aspiration’ level is associated with 8.9% of respondents who did not intend to pursue an engineering degree but chose an engineering major. Finally, a ‘low aspiration’ level is associated with 48.7% of respondents who intended to pursue an engineering degree but did not choose an engineering major. A brief examination of Table 4.1 that includes the overall distribution of the sample (last column) indicates that 88.8% of the sample selected on students’ intention for and choice of engineering majors, are male. Also, 64.5% are White students and 41.6% of them are coming from high SES backgrounds. Almost two thirds of the sample have parents who have attended or completed university degrees.

Research Question 1

What are the characteristics of types of aspiring-engineer students who— a. intended and chose the engineering major upon entry, b. did not intend, but chose the engineering major in college, c. intended but did not choose the engineering major?

Aspiring-engineer Group Typology and Socio-demographic Factors

Table 4.1 also presents the counts and percentages of the three aspiring-engineer groups by socio-demographic factors. In the first column which includes the variable name, the statistical significance of the chi-square test of association between aspiring engineer-group typology and each of the socio-demographic factors is also presented.

Table 4.1: Socio-Demographic Factors by Aspiring-engineer Group Typology (Counts / column %)^a

Variables	Aspiring-engineer Group Typology			ALL
	High Aspiration	Medium Aspiration	Low Aspiration	
Gender (*) ^b				
Male	283 (87.9%)	54 (79.4%)	338 (91.4%)	675 (88.8%)
Female	39 (12.1%)	14 (20.6%)	32 (8.6%)	85 (11.2%)
Race/Ethnicity (**) ^b				
White	220 (68.3%)	34 (50.0%)	236 (63.8%)	490 (64.5%)
Asian	26 (8.1%)	7 (10.3%)	17 (4.6%)	50 (6.6%)
Black	47 (14.6%)	14 (20.6%)	53 (14.3%)	114 (15.0%)
Hispanics	20 (6.2%)	8 (11.8%)	52 (14.1%)	80 (10.5%)
Others	9 (2.8%)	5 (7.4%)	12 (3.2%)	26 (3.4%)
SES (***) ^b				
First Quartile (lowest)	33 (10.2%)	11 (16.2%)	49 (13.3%)	93 (12.3%)
Second Quartile	43 (13.4%)	18 (26.5%)	100 (27.1%)	161 (21.2%)
Third Quartile	79 (24.5%)	16 (23.5%)	94 (25.5%)	189 (24.9%)
Fourth Quartile (highest)	167 (51.9%)	23 (33.8%)	126 (34.1%)	316 (41.6%)
Parental Educational Attainment (***) ^b				
High school or less	40 (12.4%)	18 (26.5%)	72 (19.5%)	130 (17.1%)
2 yr. attend/complete	46 (14.2%)	7(10.3%)	84 (22.7%)	137 (18.0%)
4 yr. attend/complete	140 (43.3%)	30 (44.1)	126 (34.1%)	296 (38.9%)
Graduate degree	97 (30.0%)	13 (19.1%)	88 (23.8%)	198 (26.0%)
ALL	322 (42.4%)	68 (8.9%)	370 (48.7%)	760 (100%)

^a Counts are rounded to the nearest tenth. Percentage totals may not equal 100% due to rounding.

^b Chi-square tests of association between aspiring-engineer groups and other factors *p<.05 **p<.01

***p<.001

Gender. Not surprising, the data reveals a greater representation of males than females in the sample, with more than 3 out of 4 participants are male for each of the aspiring-engineer groups: High (87.9%), Medium (79.4%), and Low (91.4%) aspirations. For each aspiring-engineer group, representation varies slightly by gender. Females are proportionally higher represented in the Medium aspiration group (20.6%), although this group is the least represented among women only. There is a statistically significant association between gender and aspiring-engineer group typology, as indicated by the chi-square test ($p < .05$).

Race/Ethnicity. White students consist of almost two thirds of the students in the sample and represent at least half of High, Medium and Low aspiring-engineer groups. White students represent more than two thirds (68%) of the High aspiration group who intended and chose engineering major. Additionally, White and Asian students are overrepresented in the High aspiring-engineer group and the sample, as compared to Black, Hispanic and other racial groups. Only Asian students have higher proportional representation in both High and Medium aspiring-engineer groups. Conversely, Hispanic students have higher proportional representation in both Medium and Low aspiring-engineer groups. The Black student group representation is only higher within Medium aspiring-engineer group (20.6% as compared to 15% representation in the sample). Overall, there is a statically significant association ($p < .01$) between race/ethnicity and aspiring-engineer groups.

Socio-economic Status. Two-thirds of the sample selected on intention for and choice of engineering majors are students coming from the two highest SES quartiles. As expected, the highest SES quartile group of students has an even higher representation with more than half of them (51.9%) belonging to the highest SES background. Meanwhile, the high SES students are less likely to be represented in the other two aspiring-engineering groups (about 34%).

Conversely, the Medium and Low aspiration groups have an overrepresentation of students coming from the first and second SES quartiles. As previously mentioned, students from more affluent families may have more access and opportunities to resources so students' awareness and ability to pre-plan for an engineering major is enhanced.

Interestingly, the distribution of the third SES quartile (second highest) of students is nearly evenly distributed throughout all groups and replicates the ratio of students within the sample. Also, the second SES quartile group of students follow an increased representation toward lower aspirations, from High (13.4%) to Medium (26.5%) and Medium to Low (27.1%) aspirations. The first SES quartile shows a higher representation in the Middle aspiring-engineer group that include students who did not intend to pursue an engineering degree but chose it, possibly due to fortunate circumstances outside the family and high school environments. This pattern is expected due to the nature of students who may be low-income and/or dis-advantaged (i.e., first and second quartiles), who may lack college preparedness and access to resources as those in third and fourth quartiles. Overall, there is a strong statistically significant association between socioeconomic status and aspiring-engineer groups ($p < .001$).

Parental Educational Attainment. Table 4.1 distributions indicate that within each aspiring-engineer group, more than half of the students have parents who attained a 4-year college or advanced degree. Within the High aspiring-engineer group, parental educational attainment is upwards (70%) for university degrees. Meanwhile, the representation of students with highly educated parents is lower among the Medium aspiring-engineer group (a total of 63.2%) and especially among the Low aspiring-engineer group (a total of 57.9%). Interestingly, among the Low aspiring-engineer group, the representation by parental education attainment is nearly evenly distributed from high school (19.5%), 2-year college degree (22.7%), 4-year

college degree (34.1%), to graduate degrees (23.8) possibly speaking to the idea that these parents will have varying backgrounds, knowledge, and career interest goals for their children. Lastly, students whose parents have graduate degrees represent 30% of the High aspiring-engineer group and 23.8% of the Low aspiring-engineer group, but are less represented in the Medium aspiring-engineer group (19.1%) which is lower in intention and planning. Overall, there is a strong statistically significant association between parental educational attainment and aspiring-engineer groups ($p < .001$).

Aspiring-engineer Group Typology and Pre-College Factors

Another set of variables that are hypothesized to play a role in mediating education outcomes for the aspiring-engineer groups, are several pre-college factors. Family expectations and student academic preparedness were captured to evaluate aspects of the pre-college experience as indicated on student questionnaire in 2002 and 2004 (Appendix B). Table 4.2 presents the counts and percentages of pre-college categories within each aspiring-engineer group that can be compared to the percentages for all students in the sample. The first column which includes the variable name, also indicates the significance of the chi-square test of association between categorical variables or ANOVA tests when comparing the means of continuous variables by the aspiring-engineer groups.

Parental Aspirations. Nearly all parents in the sample (94.3%) wanted their children to obtain university degrees, and this pattern is noticeable within each aspiring-engineer group (High, Medium, or Low). The High aspiring-engineer group showed the lowest percentage of parents having expectations less than college graduation (2.2%), followed by Low aspiring-engineer group (8.1%) and lastly, Medium aspiring-engineer group (8.8%). It is noticeable that a large percentage of parents in the Low aspiring-engineer group hope their children will graduate

from college (43.8%) even if they lag behind the other two aspiring-engineer groups when it comes to more advanced degrees. Lastly, an advanced degree (e.g., PhD) is less a parental aspiration for Low aspiring-engineer group (19.2%) than for Medium (25%) and High (26.2%) aspiring-engineer groups. Overall, there is a significant association between Parent Aspirations and aspiring-engineer groups ($p<.01$).

Table 4.2: Pre-College Factors by Aspiring-engineer Group Typology (Counts / column %)^a

Variables	Aspiring-engineer Group Typology			ALL
	High Aspiration	Medium Aspiration	Low Aspiration	
Parental Aspirations (**) ^b				
Below 4-yr. credential	7 (2.2%)	6 (8.8%)	30 (8.1%)	43 (5.7%)
Graduate from college	125 (38.8%)	20 (29.4%)	162 (43.8%)	307 (40.4%)
Master's degree or equivalent	105 (32.6%)	25 (36.8%)	107 (28.9%)	237 (31.2%)
PhD, MD, or other adv. deg.	85 (26.4%)	17 (25.0%)	71 (19.2%)	173 (22.8%)
Student Expectations (***) ^b				
Below 4-yr. credential	25 (7.8%)	12 (17.6%)	78 (21.1%)	115 (15.2%)
Graduate from college	117 (36.4%)	23 (33.8%)	146 (39.5%)	286 (37.7%)
Master's degree or equivalent	113 (35.2%)	16 (23.5%)	124 (33.5%)	253 (33.3%)
PhD, MD, or other adv. deg.	66 (20.6%)	17 (25.0%)	22 (5.9%)	105 (13.8%)
Math Quartile scores (***) ^b				
Lowest quartile	11 (3.4%)	3 (4.5%)	41 (11.1%)	55 (7.2%)
Second quartile	22 (6.8%)	16 (23.9%)	69 (18.6%)	107 (14.1%)
Third quartile	57 (17.7%)	21 (31.3%)	78 (21.0%)	156 (20.5%)
Highest quartile	232 (72.0%)	27 (40.3%)	183 (49.3%)	442 (58.2%)
High School Math Preparedness (**) ^b				
Not at all	6 (1.9%)	4 (5.9%)	32 (8.6%)	42 (5.5%)
Somewhat	113 (35.1%)	28 (41.2%)	145 (39.2%)	286 (37.6%)
A great deal	203 (63.0%)	36 (52.9%)	193 (52.2%)	432 (56.8%)
High School Science Preparedness (***) ^b				
Not at all	23 (7.1%)	14 (20.6%)	71 (19.2%)	108 (14.2%)
Somewhat	139 (43.2%)	26 (38.2%)	158 (42.7%)	323 (42.5%)
A great deal	160 (49.7%)	28 (41.2%)	141 (38.1%)	329 (43.3%)
Self-Efficacy-Math [-2,2] (***) ^c	.71	.38	.42	.54
High school GPA [0-4] (***) ^c	3.17	2.53	2.37	2.72
ALL	322 (42.4%)	68 (8.9%)	370 (48.7%)	760 (100%)

^a Counts are rounded to the nearest tenth. Percentage totals may not equal 100% due to rounding.

^b Chi-square tests of association between aspiring-engineer groups and other factors * $p<.05$ ** $p<.01$

*** $p<.001$

^c One-way ANOVA test comparing aspiring engineer groups * $p<.05$ ** $p<.01$ *** $p<.001$

Student Expectations. Student expectations are lower than parental aspirations since only about 85% of respondents expect to obtain university degrees. Expectations to earn below 4-year credentials gradually increases from High (7.8%) to Medium (17.6%) to Low (21.1%) aspiring groups, and nearly a quarter of the students in the Low aspiring-engineer group do not expect to earn a 4-year credential. As anticipated, High aspiring-engineer group students have the highest expectations for graduation from college (92.2%) and higher than the other groups for each type of university credential. For instance, an advanced degree (e.g., PhD) is highly expected by High aspiring-engineer group (20.6%) as compared to the Medium (25%) and Low (5.9%) ones. Overall, there is a significantly strong association between Student Expectations and aspiring-engineer groups ($p < .001$).

Math Achievement. It is evident, the High aspiring-engineer students have much higher math achieving rates with 72% scoring in the highest quartile and outperforming Medium aspiring-engineer group (40.3%) and Low aspiring-engineer group (49.3%), and nearly 20 percentages higher than the sample overall (58.2%). Medium and Low aspiring-engineer students are more evenly distributed between the math quartiles than High aspiring-engineer group which have a majority of the students represented in the Highest (72.0%) and Third quartile (17.7%). Meanwhile, Medium and Low aspiring-engineer groups have nearly the same total percentage (71.6%) and (70.3%) added up from the Highest and Third math quartiles. Overall, there is a significantly strong association between Math achievement and aspiring-engineer group typology ($p < .001$).

High School Math Preparedness. Students' perception of their math preparation in high school is seen to contribute building the aspiration towards engineering degrees. Table 5.2 shows that math preparedness is evaluated as being 'a great deal' by 63% of High aspiring-engineer

students, and more than the other aspiring-engineer groups. In addition, only 1.9% of the High aspiration group stated math preparation did not help at all, while this was the opinion of 5.9% and 8.6% of the Medium and Low aspiration groups, respectively. Overall, 56.8% of the sample recognized the importance of mathematics preparation that contributed ‘a great deal’ to their post-secondary success. Data show there is a significant association between the aspiring-engineer group typology and students’ perception of how high school math prepared them for post-secondary education ($p < .01$).

High School Science Preparedness. Similarly, respondents evaluate how high school science prepared them for post-secondary education. Thus, about 49.7% of the High aspiring-engineer students stated they were prepared ‘a great deal’ in science, as compared to 41.2% and 38.1% of the Medium and Low aspiring-engineer groups, respectively. Conversely, only 7.1% of the High aspiration group stated science preparation did not help at all, while this was the opinion of 20.6% and 19.2% of the Medium and Low aspiration groups, respectively. Overall, there is a strong significant association between the aspiring-engineer group typology and students’ perception of how high school science prepared them for post-secondary education ($p < .001$).

Math Self-Efficacy. ANOVA analysis was done to compare Math Self-Efficacy means between the three aspiring-engineer groups. Math self-efficacy standardized are a continuous variable measured on a scale from -2 to 2, and the entire sample score of .54 indicates an above average level of self-efficacy. Higher mean values were seen for High aspiring-engineer group (.71), then Low aspiring-engineer group scores were .42 and Medium aspiring-engineer group scored at .38. Overall High aspiring-engineer students Math Self-efficacy values were higher overall as seen. There is a statistically significant difference among math self-efficacy means

between the three aspiring-engineer groups, with particularly higher scores by the High aspiration students ($p < .001$).

High-school Grade Point Average (GPA). Finally, an ANOVA analysis was conducted to compare average GPA scores based on all high school courses between the three aspiring-engineer groups. GPA information is reported on an ordinal scale, with few students (6.2%) scoring between 0.0 and 2.0, then being distributed on a .5 increment scale between GPA equal 2.0 and 4.0. I chose to treat GPA as a continuous variable with values between 0 and 5. The GPA for the whole sample at 2.72 indicates that the majority of students have a GPA of about 3.0. However, the High aspiration group scored closer to 3.5 GPA, while the Medium and Low aspiration groups are falling below 3.0. There is a statistically significant difference among GPA means between the three aspiring-engineer groups, with particularly higher scores by the High aspiration students ($p < .001$).

Aspiring-engineer Group Typology and Post-secondary Factors

Student characteristics including academic engagement, enrollment gap, institution selection, and finances during college years were captured to evaluate their post-secondary experience as indicated on student questionnaire in 2006 (Appendix B). Table 4.3 presents the counts and percentages of for all categorical variables within each aspiring-engineer group and for the entire sample. First column also indicates the significance of the chi-square test of association between aspiring-engineer group typology and each of the post-secondary factors.

Table 4.3: Post-secondary Factors by Aspiring-engineer Group Typology (Counts
/column %)^a

Variables	Aspiring-engineer Group Typology			ALL
	High Aspiration	Medium Aspiration	Low Aspiration	
Academic Engagement:				
a. Talk with Faculty (*) ^b				
Never	53 (16.5%)	7 (10.3%)	83 (22.4%)	143 (18.8%)
Sometimes	197 (61.2%)	38 (55.9%)	212 (57.3%)	447 (58.8%)
Often	72 (22.4%)	23 (33.8%)	75 (20.3%)	170 (22.4%)
b. Meet with Advisor (**) ^b				
Never	31 (9.6%)	11 (16.2%)	65 (17.6%)	107 (14.1%)
Sometimes	219 (68.0%)	32 (47.1%)	231 (62.4%)	482 (63.4%)
Often	72 (22.4%)	25 (36.8%)	74 (20.0%)	171 (22.5%)
c. Access Library (***) ^b				
Never	60 (18.6%)	14 (20.3%)	118 (31.9%)	192 (25.2%)
Sometimes	138 (42.9%)	36 (52.2%)	143 (38.6%)	317 (41.7%)
Often	124 (38.5%)	19 (27.5%)	109 (29.5%)	252 (33.1%)
d. Web-Access Library (**) ^b				
Never	49 (15.2%)	8 (11.8%)	86 (23.2%)	143 (18.8%)
Sometimes	130 (40.4%)	26 (38.2%)	110 (29.7%)	266 (35.0%)
Often	143(44.4%)	34 (50.0%)	174 (47.0%)	351 (46.2%)
Gap in Enrollment (***) ^b				
No gap in enrollment	316 (98.1%)	62 (91.2%)	333 (90.0%)	711 (93.6%)
Gap in enrollment	6 (1.9%)	6 (8.8%)	37 (10.0%)	49 (6.4%)
Sector of first Postsec. (***) ^b				
4-year public	197 (61.2%)	36 (52.9%)	177 (47.8%)	410 (53.9%)
4-year private, not for profit	55 (17.1%)	14 (20.6%)	46 (12.4%)	115 (15.1%)
2-year public	57 (17.7%)	15 (22.1%)	84 (22.7%)	156 (20.5%)
Other (2yr private, etc.)	13 (4.0%)	3 (4.4%)	63 (17.0%)	79 (10.4%)
Taking Remedial Course (ns) ^b				
No Remedial courses	221 (68.6%)	48 (70.6%)	243 (65.7%)	512 (67.4%)
Non-math remedial course	25 (7.8%)	7 (10.3%)	29 (7.8%)	61 (8.0%)
Math remedial course	76 (23.6%)	13 (19.1%)	98 (26.5%)	187 (24.6%)
PSE Loans (ns) ^b				
No	111 (34.5%)	25 (36.8%)	148 (40.0%)	284 (37.4%)
Yes	211 (65.5%)	43 (63.2%)	222 (60.0%)	476 (62.6%)
ALL	322 (42.4%)	68 (8.9%)	370 (48.7%)	760

^a Counts are rounded to the nearest ten. Percentage totals may not equal 100% due to rounding.

^b Chi-square tests of association between aspiring-engineer groups and other factors *p<.05 **p<.01 ***p<.001

Academic Engagement. Four category variables were selected to understand the academic engagement of the student during their postsecondary years:

- a) Talk with faculty about academic matters outside of class: Interestingly, almost equally, High and Low aspiring-engineer groups stated they ‘often’ talked with faculty outside of class, 22.4% and 20.3% respectively, and similarly, same groups stated they talked ‘sometimes’ with faculty (61.2 % and 57.3%). The Medium aspiration group was different with 10 points higher (33.8%) for ‘often’ talking with faculty, and fewer students (10.3%) ‘never’ talking with faculty. There is some statistically significant association ($p<.05$) between this academic engagement item and the aspiring-engineer typology.
- b) Meeting with Advisor about academic plans: The trend continued with the Medium aspiration group being more likely to interact ‘often’ with the advisor. However, 68% of the High aspiration group stated to meet ‘sometimes’ with the advisor, and only 9.6% of this group ‘never’ had such interaction. Relatively large percentage from the Medium and Low aspiration groups (16.2% and 17.6%) never met the advisor to discuss academic plans. Overall, there is statistically significant association ($p<.01$) between this academic engagement item and the aspiring-engineer typology.
- c) Work on coursework at school library: High aspiring-engineering group are more likely than the other two groups to work ‘often’ on coursework at school library (38.5%). At the other extreme, we find that 31.9% of the Low aspiring-engineer students ‘never’ work on coursework at school library. Same answer is given by about 20% of the Medium and High aspiration groups, showing that overall, working on coursework at the library is not common among students. There is a strong statistically significant association ($p<.001$) between this academic engagement item and the aspiring-engineer typology.

- d) Use the web to access school library for coursework: Students from all groups are more likely to use the web to access library resources. Differences among groups are less pronounced when stating the ‘often’ use, ranging from 44.4% for the High aspiration group to 50.0% for the Medium group. On the other hand, Medium aspiring-engineer group had the lowest percentage (11.8%) who never used the web to access school library for coursework, while Low aspiring-engineer group had the highest percentage (23.2%) in this category. Overall, there is statistically significant association ($p<.01$) between this academic engagement item and the aspiring-engineer typology.

In summary, each group of aspiring-engineer students manifested academic engagement of varying degree through interaction with faculty, advisor and/or with coursework activities.

Gap Enrollment. For this variable, High aspiring-engineer group had the highest percentage 98.1% with no gap in enrollment, while Medium aspiring-engineer group had 91.2%, and Low aspiring-engineer group 90.0% transitioning directly from high school to post-secondary education. There is a strong significant association between Gap in enrollment and the aspiring-engineer group typology ($p<.001$).

Sector of First Post-secondary Institution. Almost 54% of the sample first attended a 4-yr public institution, other 21% attended a 2-yr public institution, and 15% attended a 4-yr private non-profit institution. However, percentages of High aspiring-engineer students were higher than for the sample (61.2% and 17.1%) for attending a 4-year public and 4-yr private postsecondary institution, respectively. Meanwhile, Medium and Low aspiring-engineer groups were more likely to attend 2-yr public institutions (22.1% and 22.7%, respectively). The most surprising number is the large percentage of Low aspiration students (17%) attending Other postsecondary institutions that included for-profit and less than 2-yr colleges. It is possible that this group

lacked academic preparation to attend from the beginning 4-yr colleges or 2-yr public institutions. Overall, there is a strong significant association between first known postsecondary institution of attendance and aspiring-engineer group typology ($p<.001$).

Remedial Courses. Each of the aspiring-engineer groups had at least 2/3 of students who did not need remedial courses of any kind in beginning postsecondary education. These percentages varied from 70.6% to 68.6% and to 65.5% for Medium, High and Low aspiring-engineer groups, respectively. High and Low aspiring-engineer groups had higher percentages who needed math remedial course (23.6% and 26.5%), while Medium aspiring-engineer group had higher percentage of 10.3% enrolled in non-math remediation classes. Overall, there is no significant association between enrollment in remedial course and aspiring-engineer group typology.

Post-secondary Education Loans. Finally, an examination of crosstabulations showing the postsecondary loan patterns by aspiring-engineer-group typology shows no association between the two variables. About 62.6% of the sample took loans for postsecondary education, with a slightly larger percentage (65.5%) among the High aspiration group. Meanwhile, only 60.0% of the Low aspiration group took postsecondary loans – since this is the group who did not choose engineering even if intended to, we can assume they pursued other less expensive degrees.

Aspiring-engineer Group Typology and Outcomes

Outcome variables for the study are Educational attainment and Credential in Science and Engineering field as reported from ELS third-year follow-up (F3) in 2012 (Appendix B) when respondents were 26 years old. In developing models for each of these variables, the aspiring-engineer group typology serves as main independent variable. This section presents bivariate

statistics to demonstrate the association between the outcome variables and the design variable of the study. Table 4.4 presents the counts and percentages within each aspiring-engineer group that can be compared among them and with the percentages for all students in the sample. The first column which includes the variable name, also indicates the significance of the chi-square test of association between aspiring engineer-group typology and each outcome variable.

Table 4.4: Outcome variables by Aspiring-engineer Group Typology (Counts / column %)^a

Variables	Aspiring-engineer Group Typology			ALL
	High Aspiration	Medium Aspiration	Low Aspiration	
Educational Attainment in 2012 (***) ^b				
PSE/Non-completers	37 (11.5%)	10 (14.9%)	100 (27.0%)	147 (19.3%)
Certif. / Associate degree	34 (10.5%)	19 (28.4%)	82 (22.2%)	135 (17.8%)
Bachelor or graduate degree	252 (78.0%)	38 (56.7%)	188 (50.0%)	478 (62.9%)
Credential in S&E Field in 2012 (***) ^b				
Unknown field/ completion	59 (18.3%)	16 (23.9%)	124 (33.5%)	199 (26.2%)
PS cred in a non-S&E field	51 (15.8%)	23 (34.3%)	144 (38.9%)	218 (28.7%)
PS cred in a S&E field	212 (65.8%)	28 (41.8%)	102 (27.6%)	342 (45.1%)
ALL	322 (42.4%)	67 (8.9%)	370 (48.7%)	759 (100%)

^a Counts are rounded to the nearest ten. Percentage totals may not equal 100% due to rounding.

^b Chi-square tests of association between aspiring-engineer groups and other factors *p<.05 **p<.01 ***p<.001

Educational Attainment. The education attainment was captured for all ELS respondents from the third follow-up survey and the 2013 transcripts. Overall, 62.9% of the sample completed a degree at the bachelor level or above, 17.8% completed 2-yr institution degrees, and 19.3% attended post-secondary education but were non-completers. High aspiring-engineer group had the highest percentage of students with bachelor or graduate degrees (78%) being twenty or more percentage points higher than Medium and Low aspiring-engineer groups. On the other hand, Medium aspiring-engineer group (28.4%) led for those with certificate or associate degrees and lastly, Low aspiring-engineer group had the most who did not complete a

post-secondary degree altogether (27.0%). In all, High aspiring-engineer group students achieved higher levels of postsecondary education. Additionally, there is a significantly strong association ($p < .001$) between educational attainment and aspiring-engineer group typology, which suggests the typology variable could be a good predictor for attainment.

Credential in Science or Engineering Field. Based on the third follow-up survey and 2013 transcripts, information on the type of postsecondary credential was captured, with focus on obtaining a S&E credential. Table 5.4 shows that 45.1% of the sample oriented toward engineering completed a postsecondary credential in an S&E field while 28.7% completed a degree in a non-S&E field. The percentage of S&E degrees is significantly higher (65.8%) among the High aspiring-engineer group who has nearly 2/3 of the students succeeding in S&E field. Meanwhile, only 41.8% of the Medium aspiring group and 27.6% of Low aspiring group (27.6%) obtained credentials in this field. An opposite trend is noticeable for the Non-S&E fields with 15.8%, 34.3% and 38.9% of respondents in the High, Medium and Low aspiration groups, respectively, completing credentials. Similar pattern is observed for the unknown field of study or completion status category that is populated by 18.3%, 23.9% and 33.5% of respondents from the High, Medium and Low aspiration groups, respectively. There is a significantly strong association ($p < .001$) between completion of a S&E credential and aspiring-engineer group typology, which suggests the typology variable could be a good predictor for S&E credential completion.

Research Question 2

What is the relationship between educational attainment by age 26 and aspiring-engineer groups, socio-demographic factors (i.e., gender, race, parental education, SES), pre-college factors (i.e., parental aspirations, student expectations, math achievement, math self-efficacy,

academic achievement, preparation in math/science subjects), post-secondary factors (i.e., engagement, remedial courses, financial issues)?

A Multinomial Logistic Regression analysis was conducted to examine whether the hypothesized factors (i.e. aspiring-engineer group typology, socio-demographic, pre-college and post-secondary factors) are good explanatory variables for educational attainment. The multinomial logistic regression analysis presents the likelihood of a particular post-secondary completion status by age 26 (e.g., either non-completers or completers of certificate and associate degrees) compared to completing a Bachelor or graduate degree (reference category). Table 4.5 presents the odds ratios for each category of the proposed explanatory variables. For instance, students with Low engineering aspirations are about two times ($OR=1.918$) more likely to be non-completers than to obtain a Bachelor or graduate degree compared to students with High engineering aspirations. The Nagelkerke's R^2 coefficient shows that 64% of the variance in the outcome is explained in the model. The effect of each independent variable is further discussed.

Aspiring-engineer Group Typology. As shown in Table 4.5, Low aspiration students are nearly twice as likely to be post-secondary education non-completers while Medium aspiration students are two and half times as likely to complete certificate or associate degrees, compared to obtaining a Bachelor or graduate degree by age 26 (although the latter effect is not statistically significant). On the other hand, odds ratios less than one indicate that Medium aspiration students are less likely to be post-secondary non-completers while Low aspiration students are less likely to earn a certificate or associate degree compared to obtaining a Bachelor or Graduate degree by age 26.

Table 4.5: Multinomial Logistic Regression Model for Educational Attainment (Bach. or Grad. degree=ref.)

Variables/categories	Odds Ratios	
	PSE Non-completers	Certificate /Assoc. Degree
Aspiring-eng. Grp Typology (High=ref)		
Medium Aspiration	.743	2.461
Low Aspiration	1.918*	.884
Gender (Male=ref)		
Female	.452	2.129
Race (White=ref)		
Asian	.864	.110*
Black	4.089***	.939
Hispanic	1.495	.205**
Others	1.185	1.310
Parental Educational Attainment (Grad=ref)		
High School or less	.198*	3.559
2-yr college complete/attend	.454	4.753*
4-yr college complete/attend	.562	2.603
SES (Highest / 4 th quartile=ref)		
1st Quartile (lowest)	5.947**	2.393
2nd Quartile	4.831**	2.059
3rd Quartile	4.050***	.874
Parent Aspirations (Ph.D.=ref)		
Below 4-year	1.393	1.889
Graduate from college	1.009	1.373
Master's degree or equivalent	.966	.656
Student Expectations (Ph.D.=ref)		
Below 4-year	.248*	2.296
Graduate from college	.446	2.161
Master's Degree or equivalent	.204**	2.067
Math Quartile (Highest/4 th quart=ref)		
1st Quartile (lowest)	.299	.326
2nd Quartile	.689	.597
3rd Quartile	.561	.318**
HS Math Prep (A great deal=ref)		
Not at all	4.798*	.106**
Somewhat	1.191	.513
HS Science Prep (A great deal=ref)		
Not at all	.327*	6.480***
Somewhat	1.246	1.435
Talk with faculty/Acad. (Often=ref)		
Never	1.037	.555
Sometimes	.868	.311**

Table 4.5: Continued

Variables/categories	Odds Ratios	
	PSE Non-completers	Certificate /Assoc. Degree
Meet with Advisor/Acad. (Often=ref)		
Never	4.328**	3.186*
Sometimes	1.180	2.096
Work on coursework/Lib (Often=ref)		
Never	1.583	3.217
Sometimes	1.977*	1.615
Use the web/access (Often=ref)		
Never	.929	1.123
Sometimes	.850	.653
Gap in Postsecondary Enroll (No Gap=ref)		
Gap in enrollment	18.502***	13.862***
Sector Postsecondary Inst. (4-year public=ref)	1.403	.732***
4-year private, not for profit	2.071*	1.953
2-year public	2.685	9.014***
Other		
Remedial Courses (No remedial=ref)		
Math Remedial course	.863	.732
Non-math remedial course	2.652*	.889
PSE Loans (No=ref)		
Yes	.200***	.982
Self-Efficacy - Math		
Range [-2, 2]	1.229	1.063
GPA in all courses		
Range [0.00 - 4.00]	.253***	.305***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The opposite odds ratios pattern obtained for Low and Medium engineering aspiration groups is interesting. For instance, Low Aspiration students (those who intended on majoring in engineering but did not choose the engineering major) had probably overall preparedness issues that did not allow them to complete a degree in any postsecondary field. On the other hand, Medium aspiration students (those who did not initially intend to pursue an engineering degree but later chose to do it) may not have had preparedness issues, but the lack of intention led to delays and difficulty navigating the engineering major, so they decided instead to complete a certificate or associate degree by age 26. The certificate and associate degree programs provided

an alternative path to complete an engineering degree for Medium aspiration students. Student's engineering aspiration level is a good indicator of educational attainment.

Gender. Compared to males, female students are about twice less likely to be non-completers, but twice more likely to earn a certificate or associate degree rather than a Bachelor or graduate degree. However, none of the odds ratios is statistically significant.

Race. Several odds ratios are statistically significant for the racial categories. Compared to White students, Black students are four times more likely to be postsecondary non-completers rather than obtaining a Bachelor or graduate degree. Meanwhile, Asian and Hispanic students have comparable low odds ratios of completing a certificate or associate degree compared to obtaining a Bachelor or graduate degree. However, the similarity of low odds ratios for Asians and Hispanics to earn certificate and associate degrees is interesting. Some insight could be that Asians are more likely to complete Bachelor or graduate degree rather than being non-completers (OR=.864), but also unlikely to obtain a certificate or associate degree (OR=.110). Meanwhile, Hispanics are more likely to be non-completers (OR=1.495) but less likely to obtain certificate or associate degrees (OR=.205) which places them to a greater disadvantage. Overall, being Black, Hispanic or other race increases the likelihood of not completing postsecondary education, while Asian students are the most likely to complete a Bachelor or graduate degree.

Parental Educational Attainment. There are some statistically significant effects of Parental level of education on student educational attainment. For instance, it is about 5 times more likely for students whose parents have less than high school education to be non-completers compared to obtaining a Bachelor or graduate degree. Meanwhile, students with less educated parents are more likely to complete certificate or associate degrees. Examining the odds ratio for certificate and associate degree earners, the odds are nearly three, four, and five times

higher for all lower levels of parental education. The highest odds ratio of 4.753 that is also statistically significant corresponds to parents who earned two-year degree and possibly encouraged their children to do the same. Overall, parental education appears to be more significant in differentiating those students who seek certificate and associate degrees.

Socio-economic Status. It is evident that family socioeconomic status has a consistent effect in the Non-completer model as indicated by large and statistically significant odds ratios for each SES category. For instance, compared to students with highest SES background, those from the first (lowest), second and third SES quartiles are almost 6 times, 5 times and 4 times more likely to be non-completers rather than obtain a Bachelor or graduate degree. Although odds ratios are not statistically significant, compared to students with highest SES background, those from the first (lowest) and second quartiles are about two times more likely to complete certificate and associate degrees rather than Bachelor or graduate degrees. Overall, the lower the SES level, the greater the likelihood that student would not complete postsecondary education or would opt for a 2-year degree. In contrast, the higher the SES level, the greater the likelihood a student will complete Bachelor or graduate degrees.

Parent Aspirations. There is no statistically significant odds ratio for the categories describing parental aspirations for children's post-secondary education. It is however noticeable that lower parental aspirations correspond to students being more likely to be non-completers or earn certificate or associate degrees rather than Bachelor or graduate degrees, For instance, for non-completers, parental aspirations toward less than 4-year degree, graduate from college, or complete a master's degree rather than obtaining a PhD degree, correspond to odds ratios of 1.393, 1.009 and .965, respectively. Similarly, odds ratios of 1.889, 1.373, and .658 describe the likelihood of students earning certificate or associate degrees rather than Bachelor or graduate

degrees. Overall, parental aspirations variable has no statistically significant effect on educational attainment.

Student Expectations. There are some statistically significant odds ratio for the categories describing student post-secondary education expectations. Higher expectations require more time to be achieved, so it is more likely to still be a non-completer by age 26 if you aspired toward a PhD degree. For instance, those expecting less than a PhD are two to five times less likely to be non-completers by age 26. In contrast, those expecting less than a PhD are about two times more likely to obtain a certificate or associate degree rather than Bachelor or graduate degree (even if odds ratios are not statistically significant). Overall, student expectations have some statistically significant effect on educational attainment.

High School Academic Factors. Three variables indicate possible effect of academics on the post-secondary attainment of aspiring-engineer students: Math Quartile scores, and students' perception of their Math and Science preparedness. For Math Quartile scores, most odds ratios are not statistically significant. However, compared to those achieving in the highest quartiles, all other groups are less likely to be non-completers or attain certificate/associate degrees which does not have a plausible explanation since we would expect poor math achievers to be more likely in the non-Bachelor attainment groups. Since descriptive data showed that about 60% of the students in the sample were high achievers in math, the variable may not produce much variability in the outcome which explains not being an influencing factor of educational attainment for aspiring-engineers.

Student perception of high school math preparation has varying odds ratios for non-completers and certificate or associate degree earners showing essentially that those who thought high school math preparedness was 'not at all' useful for postsecondary education, were more

likely to be non-completers (OR=4.798) but less likely to obtain a certificate or associate degree (OR=.106). There was no statistically significance in odds ratios for students who thought they were ‘somewhat’ prepared for postsecondary education.

Finally, with respect to student perception of high school science preparedness, odds ratios are also statistically significant only for those who thought they were ‘not at all’ prepared for postsecondary education, However, these students were less likely to be non-completers (OR=.327) but more likely to obtain a certificate or associate degree (OR=6.480). Odds ratios for students who thought they were ‘somewhat’ prepared for postsecondary education were not statistically significant. Overall, math and science-related pre-college academic factors had some limited effect on educational attainment.

High School Math Self-Efficacy and GPA. In addition to categorical variables, two continuous pre-college variables were included in the model. Math self-efficacy had no statistically significant effect on educational attainment. However, there is a strong effect of the GPA for all high school coursework, showing that higher GPA makes it less likely for students to be non-completers (OR=.253) and certificate or associate degree earners (OR=.305), compared to obtaining a Bachelor or graduate degree by age 26.

College Academic Engagement. It is important to look at student engagement in college to understand how it can influence postsecondary attainment. Factors considered indicate the frequency of engagement in various activities. First, I examined the impact on outcome of how often students talk with faculty about academic work. The only statistically significant effect shows that those who interacted ‘sometime’ rather than ‘often’ were less likely to obtain certificate or associate degrees compared to those completing Bachelor or graduate degrees. No significant effect was obtained for non-completers. Second factor is the frequency of meetings

with advisors to discuss academics. Those who never met advisors were about four times more likely to be non-completers rather than attain a Bachelor or graduate degree. Similarly, those who never met advisors were three times more likely to obtain a certificate or associate degree rather than Bachelor or graduate degree. Third, frequency of working on coursework in the school library is a good predictor of educational attainment. Odds ratios are all greater than one for categories that show lower use of library resources, showing that students who are ‘never’ going to library are three times more likely to attain certificate or associate degrees, while those who only ‘sometime’ went to library are about two times more likely to be non-completers. Finally, frequency of accessing coursework library resources through internet is not a good predictor of educational attainment since none of the odds ratios were statistically significant. Overall, the most useful form of engagement supporting student educational attainment consists in meeting often with advisor to discuss academic aspects, and to some extent in meeting with faculty and using coursework resources at school library.

Gap in Postsecondary Enrollment. The gap in enrollment has a dramatic effect on educational attainment for both non-completers and certificate or associate degree earners alike. Having a gap in enrollment increases 18 times the likelihood of being a non-completer and about 13 times the likelihood of obtaining a certificate or associate degree rather than Bachelor or graduate degree. Results show that a gap in postsecondary enrollment may drastically affect educational attainment.

Sector of Postsecondary Institution. Compared to starting postsecondary education at a public 4-year institution, those who start at a public 2-year institution are two times more likely to be non-completers by age 26, possibly because they attempted to transfer before completing an associate degree. Meanwhile, those who started at Other higher education institutions are

about nine times more likely to obtain a certificate or associate degree by age 26. Other odds ratios are not statistically significant. Although not statistically significant, an odds ratio greater than one indicates that starting at a 2-year public institution leads to an increased likelihood to obtain a certificate or associate degree. Overall, findings show that starting at a public 4-year institution increases the likelihood to complete a Bachelor or graduate degree by age 26.

College Remedial Courses. We expected that taking math remedial courses at college may impact educational attainment. There is no effect of taking either math-related or non-math related remedial courses on the likelihood to complete a certificate or associate degree. However, those who are taking non-math remedial courses are more than two times more likely to be non-completers rather than obtain a Bachelor or graduate degree by age 26. Overall, there is a limited effect of taking remedial courses on educational attainment.

Postsecondary Loans. The only statistically significant odds ratio appears for non-completers and indicates that those taking loans are about 5 times less likely to be non-completers. However, there is no effect of loans on completing a certificate or associate degree compared to completing a Bachelor or graduate degree. Being able to fund their education, even by taking postsecondary loans clearly differentiates the non-completers from those who complete any type of degree by age 26.

Research Question 3

What is the relationship between S&E degree completion by age 26 and aspiring-engineer groups, socio-demographic factors (i.e., gender, race, parental education, SES), pre-college factors (i.e., parental aspirations, student expectations, math achievement, math self-efficacy, academic achievement, preparation in math/science subjects), post-secondary factors (i.e., engagement, remedial courses, financial issues)?

The second Multinomial Logistic Regression analysis was completed to examine whether the hypothesized factors (i.e., aspiring-engineer group typology, socio-demographics, pre-college and post-secondary factors) are good explanatory variables of the outcome: completing a credential in science and engineering (S&E). The analysis presents the likelihood of not earning an S&E credential by age 26 either because field of study (FOS) is unknown (e.g., not yet declared by non-completers) or because a degree in a non-S&E field was completed. Table 4.6 presents the odds ratio for each category of the explanatory variables. For instance, students with Low engineering aspirations are about three times (OR=2.986) and about five times (OR=4.698) more likely to report an Unknown FOS or a credential in a Non-S&E Field, respectively, compared to students with High engineering aspirations. The Nagelkerke's R^2 coefficient shows that 51% of the variance in the outcome is explained by the overall model. The effect of each independent variable is further presented.

Aspiring-engineering Group Typology. Compared to obtaining an S&E credential, Low aspiration students are nearly 3 times as likely to report an Unknown FOS rather than an S&E credential compared to High aspiration students. Similarly, Low aspiration students are almost 5 times more likely to complete a non-S&E credential. In comparison, Medium aspiration students are almost as likely to report an Unknown FOS as High aspiration students, but are more than twice (OR=2.465) more likely to obtain a non-S&E credential than the High aspiration students. This suggests that Medium aspiration students (who did not intend to pursue engineering but later did so), may have switched to other majors before completing the degree. Overall, level of engineering aspiration has an impact on S&E credentialing outcome, particularly for the Low aspiration students.

Table 4.6: Multinomial Logistic Regression Model for S&E Credentialing (Postsecondary Credential in S&E field=ref.)

Variables/categories	Odds Ratios	
	Unknown FOS	Non-S&E Field
Aspiring-eng. Grp Typology (High=ref)		
Medium Aspiration	1.251	2.465*
Low Aspiration	2.986***	4.698***
Gender (Male=ref)		
Female	1.032	1.217
Race (White=ref)		
Asian	.997	.614
Black	2.913**	1.839
Hispanic	1.500	.952
Other	1.699	1.067
Parental Educational Attainment (Grad=ref)		
High School or less	.241*	1.231
2-yr college complete/attend	.833	1.285
4-yr college complete/attend	.701	1.051
SES (Highest / 4 th quartile=ref)		
1st Quartile (lowest)	1.354	.583
2nd Quartile	1.397	.877
3rd Quartile	1.429	.634
Parent Aspirations (Ph.D.=ref)		
Below 4-year	1.764	2.532
Graduate from college	.451*	.630
Master's Degree or equivalent	.827	.753
Student Expectations (Ph.D.=ref)		
Below 4-year	.590	1.351
Graduate from college	.668	1.397
Master's degree or equivalent	.391*	1.283
Math Quartile (Highest/4 th quart=ref)		
1st Quartile (lowest)	3.202	5.858*
2nd Quartile	1.742	4.160**
3rd Quartile	1.022	1.055
HS Math Prep (A great deal=ref)		
Not at all	3.492*	.445
Somewhat	.752	.780
HS Science Prep (A great deal=ref)		
Not at all	.301**	.512
Somewhat	1.250	.904
Talk with faculty/Academic (Often=ref)		
Never	5.257***	3.256**
Sometimes	1.929*	1.640
Meet with Advisor/Acad. (Often=ref)		
Never	1.520	1.087
Sometimes	.572	.611
Work on coursework/Lib (Often=ref)		

Table 4.6: Continued

Variables/categories	Odds Ratios	
	Unknown FOS	Non-S&E Field
Never	1.428	1.478
Sometimes	2.415**	2.193**
Use the web/access (Often=ref)		
Never	1.705	1.462
Sometimes	.549*	.607
Gap in Postsecondary Enroll (No gap=ref)		
Gap in enrollment	3.212*	1.271
Sector in Postsecondary (4-year public=ref)		
4-year private, not for profit	.949	.610
2-year public	1.361	.629
Other	.428*	.395
Taking Remedial (None=ref)		
Math Remedial course	1.045	.535*
Non-math remedial course	3.994**	1.370
PSE Loans (No=ref)		
Yes	.394***	1.131
Self-Efficacy - Math		
Range [-2, 2]	.788	.668**
GPA in all courses		
Range [0.00, 4.00]	.454***	.659**

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Gender. Compared to males, females are slightly more likely to report an Unknown FOS or a credential in a non-S&E field, although corresponding odds ratios are not statistically significant.

Race. Similar to previous findings for educational attainment in Table 4.5, with White students being reference category, Black students have the highest odds ratio in reporting an Unknown FOS. Although not statistically significant, odds ratios greater than one for Hispanics and Other races indicate the likelihood to report an Unknown FOS. Meanwhile Asian students (OR=.614) are less likely to complete non-S&E credentials compared to White students, in contrast to Black students who are more likely to complete non-S&E credentials (OR=1.839). Overall, race has limited impact on the S&E credentialing outcome.

Parental Educational Attainment. Interestingly enough, students whose parents completed their education at the minimum level (high school or less) are less likely to report Unknown FOS. None of the other odds ratios is statistically significant which suggest a very limited effect of parental education on the S&E credentialing outcome.

Socio-economic Status. None of the odds ratios for SES categories is statistically significant. However, all odds ratios are greater than one for the Unknown FOS group, and less than one for the non-S&E credentials. This suggests that aspiring-engineer students from lower SES backgrounds are more likely to report Unknown FOS by age 26, but less likely to report a non-S&E credential, when compared to students from highest SES. There is evidence in the literature that S&E fields of study could be a preferred choice for low SES students (Strutz & Ohland, 2012) if they are well prepared to succeed academically.

Parent Aspirations. This variable has a minimal effect on S&E credentialing outcome. One odds ratio is statistically significant indicating that it was almost half as likely to report Unknown FOS by students whose parents wanted children to graduate from college. Although not significant, the model leads to odds ratios greater than one for students whose parents have very low aspirations and want their children to obtain below 4-year postsecondary education. Students are about two times more likely to declare an Unknown FOS and 2.5 times more likely to declare a non-S&E credential. Meanwhile, higher levels of parental aspirations lead to an increased likelihood that students report S&E credentials.

Student Expectations. Similar to parental aspirations, student educational expectations have limited effect on the S&E credentialing outcome, since most odds ratios are not statistically significant. Odds ratios less than one indicate that students with lower expectations are less likely to report Unknown FOS which suggests they made a choice. Compared to students who expect

PhD degrees, those who expect a masters are less likely to report Unknown FOS rather than S&E credential (OR=.391 is statistically significant). Although not significant, odds ratios are greater than one for those reporting a non-S&E credential. It is almost 1.5 times more likely to report a non-S&E credential rather than S&E credential for the aspiring-engineer students who have not expected to earn doctoral degrees.

High School Academic Factors. Three variables indicate effects of high school academics on the S&E credentialing outcome for aspiring-engineer students: Math Quartile scores, and students' perception of their Math and Science preparedness. For Math Quartile scores, all odds ratios are greater than one which show that lower math achieving students were more likely to report either Unknown FOS or non-S&E credentials rather than S&E credentials. The effects are not statistically significant for those reporting Unknown FOS. However, compared to those achieving in the highest Math quartile, students who achieve in the second quartile and in the first (lowest) quartile are about four and six times more likely, respectively, to report non-S&E credential. There is a clear effect of high school math achievement on the likelihood to obtain S&E credentials by aspiring-engineer students.

Student perception of high school math preparation has varying odds ratios for those reporting Unknown FOS and non-S&E credentials, showing essentially that those who thought high school math preparedness was 'not at all' useful for postsecondary education, were more likely to be unable to declare a FOS for their credential (OR=3.492) but less likely to have completed non-S&E credentials (OR=.445). Only the first effect was statistically significant. Odds ratios for students who thought they were 'somewhat' prepared for postsecondary education were not statistically significant.

With respect to student perception of high school science preparedness, the only statistically significant odds ratio of .301 indicates that those who thought they were ‘not at all’ prepared for postsecondary education were less likely to have reported Unknown FOS rather than S&E credential, a result that is not easy to interpret. As shown by descriptive analysis, the group of aspiring-engineer students reporting their math and science preparedness in high school was ‘not at all’ useful is relatively small (i.e., 6% for math and 14% for science), which may affect the results. Overall, math and science-related pre-college academic factors had some limited effect on S&E credentialing outcome.

High School Math Self-Efficacy and GPA. In addition to categorical variables, two continuous pre-college variables were included in the S&E credentialing model. Odds ratios for Math self-efficacy are less than one suggesting that higher levels of self-efficacy lead to decreased likelihood to be either in the Unknown FOS or the non-S&E credential groups. However, the effect is statistically significant only for the non-S&E credential classification. However, there is a strong effect of the GPA for all high school coursework on the outcome, showing that higher GPA makes it less likely for students to report Unknown FOS (OR=.454) or non-S&E credential (OR=.659), compared to obtaining S&E credential by age 26.

College Academic Engagement. As previously discussed, student engagement in college can influence not only educational attainment but the field of study in which student pursues the degree. Factors considered in the model indicate the frequency (never, sometime, often) of engagement in various activities. First, I examined the impact on the FOS credentialing outcome of how often students talked with faculty about academic work. It is remarkable that those who never or sometime talked to faculty, are about five times and two times more likely, respectively to report Unknown FOS compared to those who often interacted with faculty and were more

likely to have selected S&E credentials. This effect is also strong for those who never talked to faculty about their academic work and reported a non-S&E credential (OR=3.256). Interacting with faculty on academic work has a strong effect on completing S&E credentials. Second, for engagement through meetings with an advisor, there is no statistically significant odds ratio which suggests that interaction with advisors is less important than interaction with faculty in successfully pursuing S&E credentials. Third, for engagement involving working on coursework in the school library, all odds ratios are greater than one suggesting that aspiring-engineer students who never or only sometime went to library were more likely to report Unknown FOS or non-S&E credential. The odds ratios are greater than 2 for those who used the library resources, but only ‘sometime’ instead of ‘often’ which increased the likelihood of pursuing a field of study other than S&E. Lastly, students who never utilized web to access coursework were more likely to report an unknown FOS credential or non-S&E credential (although odds ratios were not statistically significant). However, those who sometimes participated in use of the web, had half likelihood for either reporting Unknown FOS or non-S&E credential rather than S&E credential. This may suggest that use of web resources is not most common way of learning when pursuing S&E credentials. Overall, the most useful form of engagement supporting the pursuit of S&E credential appears to be the frequency of interaction with faculty and use of coursework resources in the school library.

Gap in Postsecondary Enrollment. The gap in enrollment variable shows a statistically significant effect only for those who reported Unknown FOS. Aspiring engineer students who took time off from study were about three time more likely to be undeclared or undecided (Unknown FOS) rather than obtaining an S&E credential.

Sector of First Postsecondary Institution. None of the odds ratios associated with first postsecondary institution is statistically significant. However, when starting at a 2-year public institution, it is more likely to report Unknown FOS rather than S&E credential. Since all other odds ratios were less than one, this may suggest the public 4-year institution is the best route to pursuing an S&E credential.

College Remedial Courses. Results show some influence remedial course-taking has on the earning of credentials in a particular field of study. Those who took non-math remedial courses are almost four times more likely to report Unknown FOS credential rather than S&E credential compared to those who never took remediation. Meanwhile, those who took math remedial courses are two times less likely to report a non-S&E credential rather than an S&E credential. This suggests that, when math remediation is needed, it is done with the intention to pursue an S&E degree.

Postsecondary Loans. Aspiring-engineer students who pursued either non-S&E or S&E degrees are similar in terms of likelihood to borrow money for postsecondary education. However, students who receive postsecondary loans are about twice less likely to report Unknown FOS which suggests that those completing S&E credentials are more likely to need to borrow money for their education.

Chapter 4 Summary

I will summarize the main results based on the analyses presented in Chapter 4. Research question 1 explored the sample to understand differences between the three aspiring-engineer groups, a typology that represents the design variable of the study. Chi-square and ANOVA tests show the proposed typology successfully differentiates the sample with respect to socio-demographic, pre-college and postsecondary factors. Some noteworthy results:

- Socio-demographic factors are strongly associated with the aspiring-engineer typology groups. Not surprisingly, only 1 in 10 are females in a sample focused on aspirations toward an engineering degree, and most of them end up being mostly represented in the Medium aspiration group (no early intention, but choice of the engineering major). Two-thirds of the sample are White students, mostly represented in the High (early intention and choice of major) and Low (early intention but no choice of major) aspiration groups. Meanwhile, Black students are mostly represented among the Medium aspiration group and Hispanics among the Low aspiration group. SES is highly associated with the aspiring-engineer typology, with two-thirds of the sample coming from the third and fourth SES quartiles. However, this percent is up to 75% among the High aspiration group and as low as 57% and 59% among the Medium and Low aspiration groups. Similar disproportional results are observed for Parental educational attainment that is matching closely the SES distribution among engineer-aspiration groups. Overall gender, race/ethnicity and both SES and parental education, are important factors that support the continuing debate about underrepresented groups' and first-generation students' access and success in S&E fields.
- Our conceptual model stipulated that pre-college factors should both differentiate the aspiring-engineer groups and have an impact on student outcomes. Not surprising, parent aspirations and student expectations for attaining postsecondary credentials are quite high, parents aiming higher than students do. Indeed, about 95% of parents want their children to graduate from college and obtain advanced degrees while 85% of students expect to do so. These percentages are much higher among High aspirations students, although only 20% of the Low aspiration students do not expect to complete a 4-year

credential. As aspiring-engineer students, their math and science preparedness as well as math achievement matter. About 56% of students believe their high school math prepared them for postsecondary education a great deal, while only 43% believe this about science preparation. These percentages are significantly higher for the High aspiration students. There is no surprise that math achievement is also high for this sample (58% in the math highest quartile), and much higher (72%) for the High aspiration students. This group also shows the highest level of math self-efficacy and an overall GPA of about 3.2. Pre-college factors, particularly achievement and confidence in math and science are expected to be meaningful factors in predicting student postsecondary outcomes.

- However, equally important in determining success is aspiring-engineer students' college experience. My conceptual model stipulated that academic engagement levels should differentiate the groups as indeed supported by the often interaction Medium aspiration students have with faculty and advisors possibly in search for more information about programs. Meanwhile, the Low aspiration students are the most likely to show no engagement with faculty, advisors and coursework (either at library or online). Entering postsecondary education was also different for the three aspiration groups. While 98% of the High aspiration students had no enrollment gap, only about 90% of the other two groups started college after high school graduation. If 78% of the High aspiration group started at a 4-year institution, only 60% of Low aspiration students did so. Surprisingly, there are no differences in need for remediation or for loans among the groups. Some of the group differences in early postsecondary experiences may be attributed to differences in pre-college factors (e.g., GPA, low expectations).

- The aspiring-engineer typology is clearly associated with the outcome variables, educational attainment and S&E credentialing. Almost two-thirds of the sample obtained Bachelor or graduate degrees by age 26, and this percentage was up to 78% for the High aspiration students. While only 45% of the sample obtained an S&E degree, this percentage reached 66% for the High aspiration students. There is a strong relationship between these variables showing that the degree of aspiration toward engineering affects postsecondary outcomes.
- Many of the factors described above as differentiating the aspiring-engineer groups, have been found statistically significant in modeling educational attainment. Some multivariate analysis results are outstanding. Non-completers by age 26 are more likely to be the Low aspiration students, Black students, those from low SES backgrounds, those who think they did not receive a good math preparation in high school, had a low high school GPA, did not interact with advisors in college and did not work on coursework at the library, experienced an enrollment gap, but were less likely to take loans. Holders of certificate and associate degrees by age 26 are more likely to be Medium aspiration students, whose parents have lower levels of education and who come from low SES backgrounds. They are more likely to believe high school science preparation was not important for postsecondary education, although they have a more positive attitude toward math, and had a low high school GPA. They did not interact with advisors in college, did not work on coursework at the library, and experienced an enrollment gap. All these factors contributing to explain 64% of the variance in the outcomes, which is very significant.
- Finally, many of these factors have been found statistically significant in modeling the S&E credentialing outcome, in a model that explained 51% of the variance. The effect of

factors appear to be more consistent when comparing the undecided students who reported an Unknown FOS and those who obtained non-S&E credentials, with holders of S&E credentials. In the first category (Unknown FOS), it is likely to find Low aspiration students, Black students, those from lower SES backgrounds, but not those whose parents want children to graduate from college. They are more likely to believe they did not receive a good high school math preparation, but think the opposite about science, and more likely to have a low high school GPA. Unknown FOS students did not interact with faculty, did not work on coursework at the library, experienced an enrollment gap, and took non-math remedial courses. They were less likely to take postsecondary loans. Meanwhile, holders of non-S&E credentials are more likely to be both Medium and Low aspiration students, with low high school math achievement, and low GPA and low math self-efficacy. They did not interact with faculty in college, and have not worked much on coursework at the library, but did not take math remedial courses. Holders of non-S&E credentials may have had a start toward an engineering career, through interest and/or choice of major, as well as high school preparedness, but switched postsecondary fields.

As the results above indicate, each aspiring-engineer group exhibits specific attributes that plays specific role in modeling student outcomes. Namely, students who have a High aspiration toward engineering enter postsecondary education with greater advantage with respect to preparation and attitudes and are capable to overcome college barriers by also using available resources. As a result, they attain higher levels of education and are more likely to persist and complete S&E credentials. Medium aspiration students are more likely to attain certificate or associate degrees by age 26. They are also more likely to complete credentials in non-S&E

fields. Low aspiration students are more likely to be non-completers by age 26 -- they also have the highest percentage with an enrollment gap, but are also more likely to go to 2-year or Other postsecondary institutions. As a result of these circumstances, Low aspiration students may experience delay in completing their studies and in identifying or declaring a field of study.

The following chapter will discuss selected study findings in relation to current literature to specifically emphasize the usefulness of the aspiring-engineer typology and its relationship to socio-demographics factors, high school academic preparedness and perception of preparedness, college behaviors, and postsecondary outcomes.

CHAPTER 5

DISCUSSION

The *Making of an Engineer* is a notion entirely based on the idea that students should start to plan early to achieve a degree and an ultimate career in engineering. This involves overcoming a surmountable number of barriers, so intention and planning would support students to successfully navigate the process and achieve the desired educational outcome.

In order to examine this process, this study focused on a sample of 760 students for whom longitudinal data from high school to postsecondary education was available. This sample was classified based on student interest in engineering and choice to pursue this major in postsecondary education. This study is guided by the Social Cognitive Career Theory (Bandura, 1986; Lent et al., 2010) that places aspirations, motivation, interests, and intention to achieve career goals at the center of student goals attainment. This research utilizes a rich national dataset to fully explore aspiring-engineer student's barriers and/or support prior and during college leading to degree completion. The conceptual framework posits student's characteristics, behaviors, and environmental factors as important factors in an individual's academic choice and attainment. The main assumption of the study is that an aspirational typology has a crucial effect on outcomes, after controlling for student attributes, pre-college and post-secondary factors.

This chapter includes a summary and discussion of key findings of the study in relation to previous research, followed by a presentation of implications for policy, practice, and recommendation for future research. Additionally, strengths and limitations of this study are discussed, as well as the significance of this study in emphasizing the need to cultivate student aspirations.

Aspiring-engineer Typology

Several studies in literature have indicated that students' aspiration is critical to enrollment and persistence in the major during college (Bottia et al., 2015; Lent et al., 2000; Sadler et al., 2012). Further, the review of the literature provided evidence that aspirations are related to the students' behavior, environmental factors and personal attributes (Alpay et al., 2008; Bottia et al., 2015, Lent et al, 2000). Using the SCCT framework that incorporates interests, abilities, choices and outcome factors, this study developed an aspirational model toward engineering careers to explore postsecondary educational attainment and S&E credentialing outcomes (Lavigne et al., 2007; Lee et al., 2015). As the key aspect of this study, a typological approach was used to classify students with various aspiration levels toward engineering. The intention to pursue an engineering major combined with the actual choice of an engineering major, led to three distinct student groups hypothesized to have varying levels of aspirations toward engineering. Namely, students who had intention to pursue and later chose an engineering major are deemed to have High aspirations; students who had intention to pursue and later did not choose an engineering major have Medium aspirations; and lastly, students who had no intention to pursue but chose an engineering major have Low aspirations.

Confirming literature, this present study has demonstrated that engineering aspiration levels provide a clear picture of persistence and postsecondary outcomes for students. Findings showed High aspiration students, the group who followed up on their intent and commitment by majoring in engineering, are capable to overcoming factors, utilizing resources and reach their educational goals. Additionally, Medium aspiration students, who had no intention toward an engineering major but chose to do so, are students who likely explored majors and sought various alternatives in pursuit of an engineering career. Lastly, Low aspiration students had

intention or foresight for an engineering major, but did not choose it due to possible circumstances and challenges. The results from the study show students who fall into these aspiration groups have unique characteristics that are related to their socio-demographic background, academic performance and educational experiences which finally translate into different outcomes.

Other factors play their role in differentiating the aspiring-engineer groups. As indicated by research, parent aspirations have an effect on their children intention and choices (Moore Jr. III, 2006, Wang, 2013). The study findings show that most parents have high aspirations for their children. However, parental aspirations toward bachelor's degree which is the typical engineering degree, decline from the High to Low aspiration groups. Only a small percent of parents of students in the High aspiration group have expectations below college graduation, while percentages corresponding to Medium and Low aspiration groups are much higher. Similarly, prior research (Geisinger & Raman, 2013; Wang, 2013) acknowledged that student expectations can affect their confidence to achieve educational goals; the study results show indeed a strong relationship between the aspiring-engineer typology and student expectations, which are decreasing from High to Low aspiration students. Particularly, the findings show nearly a quarter of students with the lowest aspirations do not expect to graduate with a 4-year degree, and very few are expecting advanced degrees. Research literature confirms that parent aspirations is crucial in students' choices to pursue an engineering major and that parental educational attainment also matters since parents who have 4-year degrees or engineering-related credentials are most influential (Alpay et al., 2008).

Aspiring-engineer Typology and Socio-demographics Factors

Prior STEM research points out that in addition to gender and race, parents' educational attainment, socioeconomic status and first-generation status create challenges to completing STEM degrees because they often associate with lack of college information for students (Geisinger & Raman, 2013; Mau, 2016; Toven-Lindsey et al., 2015, Wang, 2013). Our findings suggest that aspiring-engineer typology is strongly related to socio-demographics factors. The study showed that in a sample focused toward engineering, only 1 in 10 are females with most being represented in the Medium aspiration group (those who did not intend to pursue engineering but did it finally). This is consistent with STEM literature showing they are greatly underrepresented in STEM and especially in engineering careers (Mau, 2016; Wang, 2013). Findings also showed Blacks are mainly represented in the Medium aspiration group and Hispanics are primarily represented in the Low aspiration group. In the meantime, White students dominate the High aspiration group (early intention and choice of major). Women and minorities are often identified as underrepresented groups in science and engineering (Chang et al., 2014; Wang, 2013) and the study findings shows one reason could be the lower level of aspirations.

Similarly, students from the third and fourth SES quartiles, which represent the most affluent families who would have access to resources, information, and opportunities to adequately prepare and support their children (Ma, 2009), are better represented in the High aspiration group. This is indicative of research that shows students with low SES (first and second quartile) persist at lower rate than those who are white, male, and have a high SES background (Wang, 2013), particularly in STEM fields. Each sociodemographic factor has a strong association with the aspiring-engineer group typology which supports both research

literature and the on-going discussion about students who are underrepresented in STEM and first-generation students who have less access and success in these fields due to lack of resources and guidance.

Aspiring-engineer Typology and High School Academic Preparedness

As stipulated by SCCT (Bandura, 1986; Lavigne, Vallerand & Miquelon, 2007; Lent et al., 2010) abilities (e.g., academic preparedness) and self-efficacy affect academic outcomes. As prior research has suggested, motivation is also key in shaping STEM interest and positive attitudes toward math and science (Wang, 2013).

This study offers additional empirical evidence of the relationship between aspiring-engineer typology and math and science preparedness as well as math achievement. The research sample has been selected based on engineering related attributes, so it is not surprising that most of the students believe their high school math prepared them for postsecondary education. However, less than half believe this about science preparation with the High aspiration group having significant higher percentages for both subjects. Somehow, the aspiring-engineer students appear to be more focused on math preparation. In particular, many Medium and Low aspiration students feel their science preparation was not helpful.

Not surprising, math achievement is high for the sample, and much higher for High aspiration students, while the Medium and Low aspiring groups are nearly evenly distributed between all math achievement levels. Additionally, math self-efficacy and overall GPA is high for the majority of students, but much higher for the High aspiration group. Due to the rigor of an engineering major and the focus on math subjects, and due to strict admission requirements, students who are considered for an engineering major should have an overall higher GPA and is

not surprising they choose engineering major if they also have high math self-efficacy (Wang, 2013).

Aspiring-engineer Typology and College Experience

As previously mentioned, academic engagement by aspiring-engineer students is an important factor of college experiences. Similar to prior research showing the significance of academic engagement on student performance and persistence (Flynn, 2013; Geisinger & Raman, 2013; Toven-Lindsey, 2015), our findings suggest aspirational groups exhibited various levels of engagement in specific areas. In particular, Medium aspiration students engage with faculty, advisors, and access school library for coursework most often, being more engaged in these areas than the other two groups. The Medium aspiration student's interaction with faculty seemingly is important to them since these students had no intention to pursue an engineering major, but through interaction with faculty they may have developed an interest and confidence to choose the major. Additionally, 1 out of 2 Medium aspiration students utilize the web to access the library for coursework which is more often than the other two groups. Their behavior could show their diligence to access information for class which propelled them toward pursuing the major. High aspiration students worked on classwork in the school library the most often while most of the Low aspiration students never worked in the library. Still, Low aspiration students used web to access library resources for coursework purposes.

Literature mentions that remedial courses are often a barrier for students seeking STEM degrees and can influence the likelihood of declaring and completing a STEM major. However, diverse opinions can be found that taking of remedial courses share no significant effect on outcome while others state students taking these courses will be less likely to persist (Mau, 2016, Wang, 2013). The study findings showed more than 2/3 of the students did not take remedial

courses of any kind as they begin postsecondary education, which is not surprisingly for an engineering-oriented sample. High and Low aspiring-engineer groups had a quarter of their groups requiring math remedial courses, and somewhat more in the Medium aspiring-engineer group required non-math remedial course.

Previous research has pointed out that enrollment intensity and financial aid are postsecondary factors that directly influence STEM enrollment (Wang, 2013). Results from the study showed nearly all aspiring-engineer groups had no gap in enrollment, where High aspiration group had the least percentage of students with an enrollment gap. Additionally, observing student's choice of first postsecondary institution showed more than half of aspiring-engineer students started at 4-year institution with highest percentages among High aspiration group. Meanwhile, Medium and Low aspiration groups showed to be more likely to have started at a 2-public institution. Interestingly, a large percentage of Low aspiration students, who chose to not complete an engineering degree, indicated they attended other types of institutions that included for-profit and less than 2-year colleges, possibly because of lack of preparation or financial aid. Taking postsecondary education loans showed little differences among the three groups. Typically, High aspiration group had the highest usage of loans, although no association between aspiring-engineer typology and postsecondary education loans variables was found.

Aspiring-engineer Typology and Postsecondary Outcomes

Revisiting Bandura (1986) and expanding SCCT ideas through Lent et al.'s (1994) work, one can understand how outcome expectations are influenced by interest and motivation over time (Wang, 2013), and how this can shape aspirations toward an engineering major. Aspiring-engineer typology is evidently associated with educational attainment and S&E credentialing outcomes. The results from the study showed that most of the sample obtained bachelor's or

graduate degrees by age 26 and nearly half earned a S&E degree with better results shown for High aspiration students.

Research has shown many factors that affect STEM student's attainment, but limited research is available for aspiring-engineer students (Chen & Weko, 2009). However, the study findings confirmed the validity of several factors previously proposed in the literature such as various demographics, pre-college and postsecondary factors. Some factors were shown to impede education attainment by age 26, since non-completers are found to be more likely the Low aspiration students, Black students or those from low SES background. Also, holders of certificate and associate degrees rather than a 4-year degree by age 26 are more likely to be those who are Medium aspiration students, have parents with lower levels of education, have lower perception of science preparation despite greater perception of math preparation, or have low high school GPA.

Previous research by Crisp et al. (2009) indicated four main sets of factors (i.e., demographic, pre-college, environmental, and college) that affected the completion of a STEM degree. Similarly, the study findings revealed several factors that were significant in the S&E credentialing outcome model for aspiring-engineers. Among students who indicated Unknown FOS by age 26 (i.e., either did not complete a credential or it was in a general unspecified field), were Low aspiration students, Black students, those from lower SES backgrounds. On the other hand, holders of non-S&E credentials are more likely to be both Medium and Low aspiration students, those with low high school math achievement, and low GPA to name a few factors.

Each of the aspiring-engineer group exhibits attributes that contribute to student outcomes. High aspiration students are highly oriented toward engineering and many enter postsecondary education with greater advantage so will more likely persist and complete S&E

credentials, Medium aspiration students are more likely to attain certificate or associate degrees while mainly in Non-S&E fields. Low aspiration students are more likely to be non-completers, and either did not indicate a field of study or completed non-S&E degrees.

Implications

The main purpose of this study was to identify how various aspirational levels, described by intention and choice of an engineering major, affect degree attainment and S&E credentialing for aspiring-engineers. The lesson learned through this research might serve as a guide for educators, counselors, teachers, parents, students and other stakeholders who seek better ways to support more students in pursuing S&E degrees. I will discuss some implications for policy and practice that I believe would support the making of an engineer and would increase student aspirations toward an engineering career.

Policy

Due to the shortage of a US qualified engineering workforce, a first policy implication would be the identification by teachers and counselors of all students who have a pre-disposition toward engineering manifested in middle school or early high school. After the identification of aspiring-engineers, specific goals can be determined to help direct these students toward learning more about S&E and specifically engineering careers. Additionally, intervention efforts can be created to recruit and guide more students, especially underrepresented minority students, females, low SES and underperforming students to the STEM pipeline (Mau, 2016).

Current school engineering education requires students to assimilate concepts and information quickly and demonstrate high performance level (Alpay et al., 2008). As result, all aspiring-engineers should be prescribed engineering or pre-engineering curriculum, rigorously organized by grade during high school. These classes should help students explore S&E

disciplines, learn about engineering topics during their high school years, and understand advanced math and science, experience applied engineering and participate in hands-on activities involving technology (Cole et al., 2013). Engineering education curriculum would not only increase skills and knowledge, and information about an engineering career, but would increase student self-efficacy to ensure success in this discipline.

In addition, all stakeholders (parents, counselors, teachers, administrators, educators) need to learn more about the engineering careers to understand the demands, barriers and tools to make it possible for students to enter the field of engineering. As a collective body, this will facilitate a more accurate engineering-related perception about the field so that those involved can effectively work with aspiring-engineer students, develop their attitudes to become engineering minded, and encourage their aspirations.

Lastly, a policy can be developed to help educators at secondary and postsecondary levels to go beyond standardized assessment and subsequent placement of students in remedial college courses in order to determine student's academic readiness. Students need support to develop other academic skills (e.g., study skills, time management) and become aware and take advantage of resources available to them. Aspiring-engineer students require additional skill development to meet the demand of engineering majors in college.

Practice

First, practices should be developed and implemented to increase the educational aspirations of high school students toward S&E and particularly engineering. Efforts should be directed to preserve these aspirations during high school and college years.

Further, there is some effort currently made to introduce students to engineering early in their education, but best practices should be embraced and more interventions need to be

initiated. Development of partnerships with local business and companies to provide opportunities for students to see real-world applications and participate in hands-on projects in the engineering discipline should be encouraged. Also, mentoring and career internships to encourage high school students to explore engineering prior to postsecondary are resourceful avenues. Strategic initiatives can involve extracurricular opportunities such as research programs for undergraduates, student organization involvement to engage students in the chosen major and help retaining aspiring-engineers. Also, support is needed for enrollment and participation of students in government sponsored mandated STEM oriented programs by US Department of Education such as Upward Bound Math & Science Centers, whose goal is to identify students with high aptitude for math and science, strengthen their math and science skills and encourage them in pursuit of careers in math and science (US Department of Education, n.d.).

Practices at the postsecondary level must be reviewed to address the campus environment conditions of students who pursue engineering majors. To encourage retention, the philosophy of ‘weeding out’ engineering majors need to be redirected to provide a sense of belonging and create welcoming environments not differential in treatment based on gender, ethnicity or other demographics. Additionally, college administrators and faculty need to adapt their teaching to active learning and provide engaging activities to improve learning, understanding and retention of concepts for all types of learning styles and backgrounds, which would support student motivation and performance. Additional practices may include support through learning communities, study groups, peer-mentoring as behavior role models for newly interested students, and providing of online environments to discuss course content and create a sense of belonging and further learning.

Lastly, college faculty and deans should closely monitor the success of aspiring-engineers including those who are underrepresented and consistently review practices and policies to see if educational contexts detract college experience or favor persistence, and continual improving of self-efficacy, sense of belonging, and confidence in completing an engineering degree.

Limitations of the Study

There were some limitations that should be discussed in relation to the research design including sample size, data availability (ELS: 2002 variables and/or other databases), self-reported data, and research bias. The relatively small sample size may have limited the type of analysis for this study. The sample size was sufficient to perform the bivariate and multivariate analyses, and inclusion of a large set of variables in the regression models. A larger sample would have provided more flexibility to create more detailed categories for some variables.

Second, some issues were related to lack of access to ELS:2002 restricted data that would have allowed for a better classification of S&E degrees. Although I had to rely on the classification based on NSF definition of S&E fields and could not identify whether a degree in engineering was obtained, this provided at least an information of whether degrees were completed in an engineering related area. The findings also accurately yielded reliable results due to the longitudinal nature of the survey data.

Additionally, considering the argument of the study that early preparation matters, it would have been beneficial to have access to other databases that had a greater insight on the student's preparation prior to college which include middle and possibly elementary school years. Other useful college data would have been student work ethic, learning and academic challenges due to teaching style in the classroom, supportive campus environment, socializing and social integration, although some variables used in the study did provide a sense of college

academic engagement. Other data useful for research on aspiring-engineer would have included class rank, motivation and attitudes toward learning.

Additionally, due to the nature of self-reported data as the case with the ELS:2002, there is a potential self-reporting bias due to selective memory, or recollection of events or even less than accurate responses. It would have been helpful to use a comparative data set to confirm results. Finally, due to a personal experience on the topic, there is possible researcher bias in data selection, reporting and discussing results. However, much effort was carried out to address this through critical analysis, confirmation of results, extensive use of research literature, and likely objectivity of quantitative analysis.

Recommendations for Further Study

Despite a growing number of studies on STEM education, more focused research should be conducted in engineering education, specifically to understand a population of students who seek engineering careers. Research is needed to explore the factors that can affect aspiring-engineer students, the inception of aspirations toward engineering, and how level of aspiration (high, medium, low) affect students' performance and choices.

Future research could include further investigation of self-efficacy and other motivational factors to understand their relationship with socio-demographic factors (e.g., gender, race, SES) that are typically related to the underrepresentation of some social groups in engineering. These beliefs factors are crucial to major choice and student outcomes.

Also, more research is needed to examine how rigorous or experimental academic environments affect aspiring-engineer learners during both secondary and postsecondary education. For instance, to understand how advanced high school coursework provides (or not)

greater readiness and preparation for engineering. Scholarship of learning and teaching in engineering education is much needed.

Research at the postsecondary level can explore how engagement plays a part in retention and preservation of aspirations toward an engineering degree. Research on academic engagement will provide greater insight on the importance of practices stakeholders should undertake at all levels.

Significance of the Study

This study contributes to the research on the topic of aspiring-engineers, by proposing a typology based on intention toward and choice of an engineering major in college. The purpose of this study was to understand a multitude of factors that affect the educational attainment and the completion of an S&E credential for aspiring-engineer students. Since there is limited research of this kind in engineering education, study results are relevant to researchers, educators and policy makers in both secondary and postsecondary education.

As mentioned, my hope is that this study provides decision makers, motivators, and those who can influence aspiring-engineers, with added knowledge and tools to help their endeavors. The study demonstrates that aspirations matter and students with high aspirations are greatly oriented to succeed in obtaining an engineering degree. Much effort and tools must be instituted to understand the problem and address the needs of those who are below the level of aspirations that lead to success, those who may lack preparation or positive experiences during their school and college years, or do not have enough motivation at different educational stages, to become engineering professionals.

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APPENDIX A: Sample Selection Student Questionnaire

Student questionnaire: Survey items used to derive the Sample Selection Variable

1. Variable name: F2B15: Field of study most likely to pursue in postsecondary

Variable Name(s): F2B15

When you began at [F2PS1], what field of study did you think you would most likely pursue? (Please choose one)

- 1 = Business or Marketing
- 2 = Health (for example, Medical Technology, Nursing, Pre-Med)
- 3 = Education (for example, Teaching)
- 4 = Engineering or Engineering Technology
- 5 = Computer or Information Sciences
- 6 = Natural Sciences or Mathematics (for example, Biology, Physics, or Statistics)
- 7 = Environmental Studies
- 8 = Social Sciences or Social Work (for example, Psychology, History, Political Science)
- 9 = Architecture, Design, or Urban Planning
- 10 = Fine Arts (for example, Music, Theater, Dance)
- 11 = Humanities (for example, English, Philosophy, Foreign Languages)
- 12 = Communications (for example, Journalism)
- 13 = University Transfer or General Education
- 14 = Other Vocational Programs (for example, Cosmetology, Culinary Arts, or Construction)
- 15 = Other
- 16 = Don't know/Undecided

2. Variable Name: F2MJR2: Choice major in 2006 acquired from student transcript

Category	Label	Frequency	Percent
		UnW ¹	UnW ¹
1	Agriculture/natural resources/related	55	0.34
2	Architecture and related services	88	0.54
4	Arts--visual and performing	389	2.40
5	Biological and biomedical sciences	418	2.58
6	Business/management/marketing/related	1,136	7.01
7	Communication/journalism/comm tech	295	1.82
8	Computer/info sciences/support tech	171	1.06
10	Education	538	3.32
11	Engineering technologies/technicians	404	2.49
12	English language and literature/letters	116	0.72
13	Family/consumer sciences, human sciences	64	0.40
14	Foreign languages/literature/linguistics	61	0.38
15	Health professions/clinical sciences	947	5.85
16	Legal professions and studies	42	0.26
18	Mathematics and statistics	59	0.36
21	Parks/recreation/leisure/fitness studies	61	0.38
23	Personal and culinary services	81	0.50
24	Philosophy, religion & theology	59	0.36
25	Physical sciences	105	0.65
26	Psychology	291	1.80
27	Public administration/social services	60	0.37
29	Security & protective services	212	1.31
30	Social sciences (except psychology)	463	2.86
32	Other	211	1.30
33	Liberal arts/sci, gen studies/humanities	125	0.77

APPENDIX B: Student and Parent Questionnaire (BY, F1, F2 & F3)

Due to the length of each questionnaire, links will be provided to the document online:

- BY: Student Questionnaire: https://nces.ed.gov/surveys/els2002/pdf/StudentQ_baseyear.pdf
- BY: Parent Questionnaire: https://nces.ed.gov/surveys/els2002/pdf/ParentQ_baseyear.pdf
- F1: Student Questionnaire: https://nces.ed.gov/surveys/els2002/pdf/FinalStudent_followup1.pdf
- F2: Student Questionnaire: <https://nces.ed.gov/surveys/els2002/pdf/Facsimile.pdf>
- F3: Student Questionnaire: <https://nces.ed.gov/surveys/els2002/pdf/ELSF3Questionnaire.pdf>