AVERTING A LABOR SHORTAGE IN THE U.S BIOMEDICAL ENGINEERING INDUSTRY

by

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ABSTRACT

This study investigated the population of master's in biomedical engineering at a large research institution. The purpose of the study was to describe background characteristics the students in the master's in biomedical engineering program, identify the reasons that the students considered before enrolling in the program, compare them to the students in the master's in civil engineering program at the same institution, and compare the differences in the reasons for enrolling provided by foreign students to domestic students.

A web-based survey was conducted and quantitative methods utilized to collect and analyze the data. The analyses showed that the biomedical engineering and civil engineering samples differed in gender, country of citizenship and age. Internal factors such as educational aspirations, the desire to know more about engineering and academic self-confidence were the most important in the participants' decision to enroll in the master's program. External factors like the participants' undergraduate experience and important individuals such as parents and university professors also played important roles in the participants' decision. Foreign participants did not differ significantly from the domestic students in the factors that influenced their decision to pursue the master's degree. Foreign participants in the biomedical engineering program reported that they came to the U.S. to study because their home countries lack the educational and industry resources to provide proper training.

CHAPTER 1

OVERVIEW OF THE STUDY

Ensuring a "talent pipeline" for the biomedical engineering (BME) workforce is critical to meeting the research and development demands of the U.S. BME industry. There are pressing reasons to maintain the BME pipeline vitality. By 2025 the world population will reach eight billion people (U.S. Census Bureau, 2004). Projections also indicate that the world's elderly population will outgrow any other age group by 2025 due to the increasing life expectancy (U.S. Census Bureau, 2004). As a society ages, quality of life becomes a dominant social concern, impacting policy on priorities for research funding (U.S. Census Bureau, 1998). Medical technology breakthroughs such as magnetic resonance imaging, surgical lasers, cardiac pacemakers and prosthetics have individually contributed to the improvement of human health. The development of such medical devices involves collaboration between physicians and engineers. According to Wazzan (1998), this partnership between engineers and physicians may re-shape the technological future of medicine. Not surprisingly, RAND (2006) cited the continued development of biomedical advances as necessary to address national interests.

The U.S. Bureau of Labor Statistics (2008) has projected that due to the aging trend of the American society, by 2018 the demand for biomedical engineers in the nation will increase by over 20%. Yet a proportionate increase in enrollment in engineering programs has not taken place (National Science Board [NSB], 2002). The growing demand for properly trained biomedical engineers and the flat

enrollment figures in the programs that train them suggest that the U.S. will soon face a shortage in the BME workforce. This study attempted to understand the background characteristics of students in the master of science in BME (MS BME) program at a large, research institution and how the students chose careers in biomedical engineering. The findings from this study may enhance our understanding of the MS BME population and help us device ways to increase the talent pool of the BME pipeline.

The definition of proper training for the workforce has changed over the years. At the turn of the 20th century, an individual who earned an elementary school education was considered to have sufficient academic preparation to get many jobs (Cubberly, 1911). The advances of the Industrial Revolution in the use of steam, steel, and electricity forced to the front new skills and areas of knowledge that only a high school education had the potential to teach, and thus the industry sector made high school completion a requirement for certain technology areas (Cubberly, 1911). Gladieux (2004) noted that forces in the U.S. economy have increased educational requirements beyond high school. In short, as the years have passed, the amount of knowledge required of incumbents by the industry sector has increased.

In the field of biomedical engineering the master of science degree (MS) has become the base qualification for entry-level jobs (U.S. Bureau of Labor Statistics, 2008). Given the importance of biomedical developments to the American quality of life, one of today's most pressing tasks is to keep biomedical engineering students in the education pipeline until they complete the industry-required master's degree.

This study aims to describe the characteristics of students in a master's program in Biomedical Engineering, to document the reasons that students provided for having enrolled in the MS BME program, to determine how the reasons provided by foreign students for enrolling in the MS BME program compare with those of domestic students, and to compare the characteristics of students and their reasons for enrolling in MS BME with those of students in a older engineering discipline, namely the MS program in Civil Engineering (CE).

The completion of a college degree is an important personal and social accomplishment (College Board, 2004). Individuals who earn a bachelor's degree earn 73% more than the typical high school graduate over a 40-year working life (Day & Newburger, 2002), have lower unemployment rates (Monthly Labor Review, 2004), report higher levels of health (College Board, 2004), have children with higher cognitive levels (U.S. Census Bureau, 2002), and have higher rates of volunteerism (U.S. Bureau of Labor Statistics, 2003). Earning a graduate degree brings greater economic benefits. The U.S. Bureau of Labor Statistics (2008) lists a 23% salary increase for earning a master's degree over a bachelor's degree. Thus it appears that obtaining education beyond the bachelor's degree is desirable for the individual and society.

Statement of the Problem

Presently the nation faces a shortage in the biomedical engineering workforce (U.S. Bureau of Labor Statistics, 2008). Entry-level jobs in BME require a master's degree in the field (Biomedical Engineering Society [BMES], 2007; U.S. Bureau of

Labor Statistics, 2008). The completion of the bachelor's and master's degrees in BME takes at least five years (BMES, 2007). Given the immediate need for biomedical engineers with master's degrees in the U.S. industry, the improvement of programs that prepare biomedical engineers becomes a policy priority for institutions of higher education (IHEs).

The number of biomedical engineers that the talent pipeline can deliver to industry depends to a large extent on the number, size, and efficiency of the programs that offer the master's degree in BME. According to the National Center on Educational Statistics (NCES) (2007), only 101 IHEs offer graduate BME programs. By comparison, nearly 250 institutions provide graduate-level training in civil engineering (NCES, 2007). Because fewer IHEs offer BME programs, fewer students receive that training each year. How to increase the supply of biomedical engineers remains an unsolved issue that may involve the streamlining of existing programs and the creation of new ones.

The field of engineering continues to lag significantly behind other fields in retention rates, despite several decades of research (Anderson-Rowland, 1997). At the undergraduate level, engineering retention rates are approximately 50% (Anderson-Rowland, 1997). The retention problem exists at the undergraduate level in the form of a net loss of students who defect from engineering to the business, science, and education fields (Astin, 1993). At the graduate level the retention of bachelor's degree recipients in engineering into graduate degrees in the same field is approximately 60% (National Science Foundation [NSF], 1999). The retention

problem continues after graduation, as 35 of the graduates of MS engineering programs work outside of engineering (NSF, 1999).

Moreover, the National Science Board (NSB) (2008) reports that foreign students account for approximately 45% of the graduate engineering enrollment in the U.S. According to the Congressional Research Reports (2007), the presence of a considerable number of foreign students in graduate engineering programs concerns many in the scientific community because many of these students will practice engineering in countries that compete with the U.S. in the scientific and technological markets. Others believe that foreign students benefit U.S. IHEs and can strengthen the U.S. engineering industry (Congressional Research Reports, 2007). Why domestic students do not choose engineering as a college major and as a career remains an area of research, although the low enrollment rates may be partly due to the barriers that exist today in the pipeline (NSF, 2000).

Purpose of the Study

This study sought to describe the background characteristics of students in the master's degree program in biomedical engineering. The study also aimed to identify the factors that students considered in their decision to enroll in the program. Finally, the study attempted to identify the factors that foreign students considered before enrolling in a U.S. IHE. To reduce threats to the study's external validity due to its lack of random assignment, the researcher used students in the master's degree program in civil engineering (MS CE) served as a comparison group.

Research Questions

The study attempts to provide practical information by presenting the decision-making process taken by the individuals who decided to apply and enroll in the MS BME and MS CE programs. The findings will inform the ways in which biomedical engineering program administrators, faculty, and staff recognize and respond to the role of master's degree programs in industry and the quality of such programs at the institution. This study aimed to answer the following research questions:

1. What are the gender, citizenship, age, plans after graduation, parental occupation, parental educational attainment, and SES characteristics of students in the MS BME and CE programs?
2. What are the undergraduate institution types, undergraduate majors and levels of satisfaction with undergraduate education of students enrolled in the MS BME and MS CE programs?
3. What factors influenced their decision to enroll in the MS BME and CE programs?
4. Are factors that influenced the decision to enroll in an MS program different for CE and BME students?
5. How do domestic students' reasons for enrolling in a master's degree program compare to those given by foreign students?

Hypotheses

1. Parental educational attainment and parental occupation will be related to enrollment in the MS BME and MS CE programs.
2. BME and CE are distinct, specialized fields in engineering. Undergraduate majors will be different for the two studied populations. GPA and level of satisfaction with undergraduate education will be high for both groups.
3. Family support, self-confidence, degree requirements by employers, financial aid availability, the amount of time required to complete the degree, the prospect of getting a better job are significant considerations for students when they make the decision to enroll in MS BME and MS CE programs.
4. The reasons provided by the students in the MS BME program are significantly different to those stated by the MS CE students.
5. There are significant differences in the reasons provided by the domestic students and the foreign students.

Significance of the Study

Answers to the research questions above are significant because they help us understand biomedical engineering students and may suggest new ways to improve biomedical engineering recruitment practices. Additionally, the scarcity in literature in the area of biomedical engineering makes this study valuable. The information provided by the study may be of benefit to national engineering organizations, national higher education policy makers, higher education institutional leaders, biomedical engineering program administrators, and faculty. Similarly, institutional

leaders and program administrators may use the findings of the study to ease the path from undergraduate to graduate biomedical engineering programs. For example, if we learn that students decided to pursue a master's degree because of encouragement from a faculty member, then institutional leaders, program administrators, and faculty may opt to create more opportunities for interactions between students and instructors in undergraduate programs.

This study also highlighted the similarities and differences between students in the relatively-new field of biomedical engineering and students in civil engineering, a well-established engineering discipline. Lastly, the study focused on foreign students in the MS BME and MS CE programs. Studies of foreign students have overlooked the master's degree population and focused on doctorate degrees awarded to foreign students.

Limitations

The selection of the institution for the study posed a limitation, as the researcher works at the institution and has occasional contact with graduate students. The researcher also had access to the student information system database. To protect student privacy, the researcher enlisted the assistance of the university's institutional researcher (IR) to identify the population for the study. The recruitment of participants into the study also posed a limitation. Participants in the study were volunteers who agreed to complete the researcher's survey. The participants may not fully have represented the norm for all MS BME and MS CE students at the institution. Similarly, the participants in this study possibly differed from the

domestic and foreign graduate engineering populations across U.S. colleges and universities, thus the findings likely only applied to the participants themselves. In addition, the study took place at the institution that a large foreign student population. Therefore, some of the findings may not apply to institutions with low foreign student enrollment. Lastly, the participants from the MS BME and MS CE programs may not have accurately represented students in other MS engineering programs.

Definition of Terms

1. BME – biomedical engineering.
2. CE – civil engineering.
3. College major – college major, or academic major, refers to the discipline or field of study (Leppel, Williams, & Waldauer, 2001).
4. Domestic students – students who are US citizens or permanent residents.
5. Educational attainment – the levels of schooling completed by an individual.
6. Foreign students – students in U.S. colleges and universities who are non-US citizens and have a temporary visa (NSF, 2008)
7. IHE – institution of higher education.
8. MS – master's in science degree.
9. PhD – doctorate of philosophy degree.
10. Retention – concept that describes the experience of maintaining consistent enrollment figures in colleges and universities (Tinto, 1993).
11. S&E – abbreviation for science and engineering fields (Sax, 2001).

12. SME – abbreviation for science, mathematics and engineering fields (Grandy, 1992).

Organization of the Dissertation

Chapter one presented the introduction, the background of the problem, the statement of the problem, the purpose of the study, the research questions that guided the study, the research hypotheses, the significance of the study, limitations and the definitions of terms. In Chapter two the reader will find a review of literature on the reasons why students choose to attend graduate school and why students select the field of engineering. Chapter three outlines the research design employed for this quantitative investigation, the data collection methods used, and a description of the analyses conducted on the quantitative data. Chapter four presents the results of the study. The last chapter provides a discussion of the themes that surfaced from the survey of the students. Chapter five also presents the conclusions of the study and implications for practice and future research.

CHAPTER 2

REVIEW OF THE LITERATURE

The current demand for graduates with master's degrees in BME (MS BME) in the U.S. industry exceeds their supply (U.S. Bureau of Labor Statistics, 2008). As noted in Chapter 1, the demand calls on higher education institutions to train more biomedical engineers with the industry-required MS degree. This study focused on a small critical part of the BME pipeline. The study attempted to understand the process by which students made the decision to enroll in the MS BME program at a large research institution. In order to gain such an understanding, we first need to know who the students are as a population, how the students chose the BME field, and the factors that played a role in the students' decision-making process to pursue a master's degree.

This chapter provides the necessary background by presenting a brief history of how graduate programs took on the role of research-based, professional training endeavors in the United States. Subsequently, the discussion turns to an analysis of the variables found to date that appear to influence students' decisions to pursue graduate education generally and engineering specifically. In particular, I review the influences of sociological factors and self-efficacy in educational attainment and career choice.

Understanding the consequences of factors such as SES, parental socialization, faculty-student interactions, and self-efficacy becomes critical to the

discussion of educational theories on persistence to graduate school and engineering programs.

History of Graduate Programs in the U.S.

Graduate education programs in the United States emerged in the late part of the nineteenth century as progressive academics embraced the philosophy that the mission of higher education institutions was to solve social and health problems (Lucas, 2004). The shift in thinking called for changes in curricular practices, as courses that focused on research and instruction in the sciences, rather than on conventional moral philosophy, would better prepare students to solve society's problems (Lucas, 2004). University scientists called for discipline specialization, both on the part of the professor and students, as the only means to produce a population that possessed the advanced knowledge and skills to contribute to the economic development of the nation. According to Geiger (1986), reformers deemed that advanced study in the U.S. should follow the completion of the bachelor's degree. Conferral of the advanced degree became the function of the research university.

In the early 1940s, World War II became the highest priority for the U.S. federal government. Federal authorities commissioned scientific personnel from many institutions to conduct war-related research projects (Geiger, 1986). The two most important research and development efforts of the war, the Manhattan Project and the Radiation Laboratory, were led by scientists from various research universities across the U.S. (Geiger, 1986). The federal government and research

university relationship evolved as a result of World War II, as the former became reliant on the university-based scientific community to contribute to the advancement of research in various areas. Graduate programs, with their heavy focus on research, delivered the highly-trained workforce demanded by the government (Geiger, 1986).

The Importance of Graduate Programs

Today, graduate education programs supply the professionals that society needs (Geiger, 1986). Society as a whole benefits from the productivity of highly-educated individuals (College Board, 2004). Individuals with high levels of education contribute more to the tax revenues of federal, state, and local agencies (Internal Revenue Service, 2003). Additionally, high levels of education correlate with lower levels of unemployment and poverty (Monthly Labor Review, 2004). Lastly, one's level of education correlates with participation in volunteer work, voting, and blood donation (College Board, 2004).

Students and their families also accrue benefits from higher education: the graduate degree clears the way to prestigious, high-paying job opportunities that are unavailable to undergraduate degree holders (Ballinger, 2007; Cappell & Pipkin, 1990; Hearn, 1987; Useem & Karabel, 1990). According to the U.S. Census Bureau (2004), an individual who holds a master's degree earns, on average, 19% more than a bachelor's degree recipient. The larger economic return for a graduate degree allows the individual to recover the cost of tuition and forfeited earnings while enrolled in the program (College Board, 2004). Given the aging dynamic of the

American population and the heightened need of the U.S. industry for individuals with a master's degree in BME discussed in Chapter 1, as well as the societal and personal benefits to obtaining such a degree, it seems that identifying the factors that graduates of BS engineering programs consider in their decision to stay in the educational pipeline is a matter of relevance to the country as a whole.

In the biomedical engineering industry, the MS and PhD degree recipients have different professional roles. MS degree holders design and manufacture devices while PhD degree recipients teach and conduct research (BMES, 2007). The master's and the doctorate degrees also differ in the length of time they take to complete, between one and two years of full-time enrollment for the former after the bachelor's degree and four to five years for the latter after the bachelor's degree (NCES, 2004). The relatively short duration of a master's program suggests a difference in the extent to which financial and occupational factors affect the decision to pursue the degree. Master's degrees take about half the time as doctorate degrees (Nevill & Chen, 2007), and therefore require fewer financial resources and opportunity costs than doctorate degrees. On the other hand, master's-level students generally receive less financial aid than doctorate students (Hauptman, 1986; Malaney, 1987). The financial investment, professional function, and financial assistance differences between the degrees suggests that MS and PhD student populations may be different. The factors that contribute to the decision to go to graduate school may not apply equally to students MS and PhD programs.

At the time this study occurred, no research had been conducted on students in a MS BME program. Scant research has been conducted on the biomedical engineering pipeline. To inform this study, the researcher opened the literature review to more widely-researched areas, such as descriptive studies of students in graduate school; students in engineering programs, at the undergraduate and graduate levels; and students in the science, engineering, and mathematics (SME) field. Common themes became apparent across the studies in the review of literature. Although the studies treated graduate students as a single entity, without differentiating the MS and PhD students, the themes found may affect the biomedical engineering pipeline into the MS program. The following section presents each of the themes.

Parental Resources and Parental Socialization Frameworks

In spite of the progress the United States has made in widening educational access, participation in higher education differs according to family income, parental educational level, and ethnic characteristics (Ballinger, 2007; Carnevale & Rose, 2004; College Board, 2004; Gladieux, 2004). The recognized disparity in enrollment in postsecondary education across different groups has prompted extensive sociological research on educational attainment through college. Sociologists have based much of their research on two sociological frameworks: parental resources and parental socialization. According to the parental resources framework, parents' socioeconomic status (SES) impacts their children's level educational achievement

(Bidwell & Friedkin, 1988; Choy, 2002; Sewell, Hauser, & Featherman, 1976; Stolzenberg, 1994).

Parental financial status affects their children's likelihood of attending college and the quality of the higher education institution the latter select (Ballinger, 2007; Gladieux, 2004). As a result, children of high SES families are more likely to go to college and more prestigious institutions than children of poor families. The parental resources framework suggests high SES students who earn a bachelor's degree and have unmet academic goals or vocational calls in careers that require graduate education have the option of pursuing such interests.

The parental socialization framework, on the other hand, holds that parents serve as role models who teach their children social norms and values (Bandura, 1986; Grusec & Kuczynski, 1997). In this framework, children learn certain values from their parents through observation. Parents influence the way their children experience the world (Teachman & Paasch, 1998). The assumptions that parents make about education and the school-related encouragement they give to their children affects the educational desire of the latter (Teachman & Paasch, 1998). The parental socialization process facilitates children's formation of educational aspirations or goals in early life based on their parents' modeling (Stolzenberg, 1994). According to Sewell and Hauser (1980), educational aspirations have the strongest effects on an individual's subsequent educational attainment. In short, children adopt the parents' educational goals and career values.

Choy (2002) found support for parental socialization in her review of the findings of research conducted the National Educational Longitudinal Study (NELS) on college access and persistence. The NELS entailed four surveys of the same population: the first survey was administered to eighth graders in 1988, the second 1992, in 1994, and finally in 2000. The NELS provided a rich dataset for researchers to analyze student backgrounds and educational experiences across middle school, high school, and college (Choy, 2002).

The NELS revealed that children of parents who finished college have much higher educational aspirations than students whose parents did not attend college (Choy, 2002). When comparing the most highly qualified high school graduates for college, 99% of the students whose parents completed college went on to college, compared to 87% of the academically-prepared students whose parents lacked college experience (Choy, 2002). Choy reported that the college-educated parents provided better college guidance for their children, attended more college opportunity events, requested financial aid information, and participated in curricular decisions.

Sociologists agree that parental education mediates SES and parenting behaviors (Davis-Kean, 2005). Parents who succeeded academically can provide a healthier psychological balance of stimulation and demand for their children (Davis-Kean, 2005). Parents with a higher education have higher expectations of their children's academic achievement, and the expectations relate to the children's achievement in school (Halle, Kurtz-Costes, & Mahoney, 1997).

While sociologists concur that parental resources and socialization have a profound effect in the early stages of a person's education, the research is less clear on the effects of parental resources and socialization on graduate-level education. Researchers such as Blossfeld and Shavit (1993), Grusky (2000), Mare (1981), and Stolzenberg (1994) have found that the effects of SES and parental socialization attenuate by the time individuals reach graduate school. These researchers have provided various explanations for the waning influence of SES and socialization on graduate degree attainment: Mare posited that the sons of wealthy families view the bachelor's degree as terminal and do not need to obtain an advanced degree to find lucrative employment; Stolzenberg suspected that the undergraduate experience allows students the opportunity to re-assess their socialized attitudes and make plans of their own; Blossfeld and Shavit suggested that as human beings enter adulthood they free themselves from parental influences and find other sources of influence; and Grusky argued that the graduate school students identify more with their occupation than with social class, therefore graduate programs attract students with specific professional interests rather than a social group. However, a voluminous body of research suggests that SES and socialization play key roles in graduate school attendance, including the studies reviewed in this section.

Gropper and Fitzpatrick (1959) used a sample of 3,581 men from thirty-five colleges across the U.S. and found that most graduate students were males who earned high grades as undergraduates. The students reported high occupational and educational statuses for their fathers, although family income levels varied. Forty-

nine percent of the students in the sample indicated that they pursued a graduate education for career reasons, 21% because of educational objectives, and 14% due to influence from people and undergraduate experiences. The researchers also found that availability of funds, vocational necessity, and encouragement from family and peers also weighed in the decision to go to graduate school (Gropper & Fitzpatrick, 1959). Gropper and Fitzpatrick concluded that due to the important role of personal finances in graduate education, SES correlated with graduate school attendance. This study provided the first illustration of the direct relation between SES and graduate school attendance.

Through funding from the Educational Testing Service, Hilton and Schrader (1987) conducted a large-scale, seven-year longitudinal study of the pathways into graduate school. The study relied on data from the National Longitudinal Study of the High School Class of 1972. Of 23,451 high school seniors from the class of 1972, approximately 6% of the sample had enrolled full-time in a graduate school program by 1979. According to Hilton and Schrader, the pathway each student in the sample took depended on individual characteristics including SES and environmental variables.

Hilton and Schrader (1987) discovered several important patterns in graduate school enrollment. Pertinent to the current study, Hilton and Schrader found that SES had a strong effect on the educational attainment of the participants. Approximately 31% of high SES students followed a rigorous academic high school curriculum compared to 9% for low SES students. The curriculum followed in high

school predicted graduate school enrollment in the study, as 53% of graduate students from the sample took the rigorous curriculum. Hilton and Schrader defined such curriculum as one in which students who took at least two years of mathematics, science, social studies, and foreign language courses. Nearly 62% of high SES students entered a four-year college, compared to 20% of low SES students. Approximately 49% of high SES students earned a bachelor's degree, compared to 10% for the low SES comparison group (Hilton & Schrader, 1987). The researchers concluded that SES and the curriculum taken during high school related to graduate school attendance.

Mullen, Goyotte, and Soares (2003) found that family educational background affects graduate school enrollment. The longitudinal study followed 10,080 high school seniors for five years to find the family characteristics of students who go on to graduate school. The significantly larger presence of high SES students in graduate programs indicates that the advantages of such students do not stop after the bachelor's degree. The greatest difference observed occurred in the first-professional and doctoral programs, in which students with high SES and high parental education accounted for the majority of the enrollment (Mullen, Goyotte, and Soares, 2003).

Schleef (1997) interviewed 79 first-year law and master's students in business administration (MBA) at an elite university to find their motivation for enrolling in graduate programs. Analysis of the students' background characteristics revealed that SES and parental socialization affected their students' graduate school

enrollment. Descriptive analyses showed that the level of parental education, or socialization, was the best predictor of graduate school attendance for law and business students, although the students did not mention it as a factor in their decision.

In their accounts of the decision-making process, the MBA students disclosed that intellectual challenge, occupational status, and maintenance of their upper-middle-class lifestyle were the principal factors (Schleef, 1997). Schleef admitted that the results do not reflect the decision factors of the broader master's-level student population, since MBA students do not require the earlier career commitment of a discipline such as engineering. The law students stated that their primary factor for law school enrollment was the desire to contribute to social justice (Schleef, 1997).

The conflicting results found by researchers make it difficult to ascertain if and how SES and parental socialization relate to enrollment in graduate school. The contradictory results researchers reported may have occurred due to differences in the samples used (Patton, 2004). Samples may produce divergent results because of differences in institution-specific elements like demographics and admission selectivity. Given that parental resources and parental socialization have influenced graduate school enrollments differently across samples, the roles of SES and socialization in the MS BME student population remain unclear and necessitate further study.

The Role of Educational Experiences

Another large body of literature has addressed the importance of educational experiences before and during the undergraduate college years in graduate school enrollment. Educational experiences, for the purpose of this study, include academic and social experiences that result from the academic environment, academic performance, faculty-student interactions, and satisfaction with the undergraduate institution. This section presents the components of educational experiences.

Based on a longitudinal study of college students, Ethington and Smart (1986) studies why students attend graduate school. Student background characteristics and academic and social experiences were measured. The background characteristics Ethington and Smart used included parental education level, family income, high school grades, academic self-confidence and social self-confidence. The sample consisted of 6,242 students who responded to the Cooperative Institutional Research Program (CIRP) in 1971 and 1980.

The results showed that the undergraduate academic and social experiences, through integration, were the primary influences in graduate school enrollment (Ethington & Smart, 1986). The greater the academic and social involvement of students in the undergraduate institution, the greater their likelihood of attending graduate school (Ethington & Smart, 1986). Ethington and Smart found that the selectivity of the undergraduate institution has a strong, positive effect on graduate school enrollment for men; while for women, the size of the institution is influential. The researchers also found an overrepresentation of high SES students (Ethington &

Smart, 1986), which gives support to the effect of parental resources on graduate school enrollment. Contrary to expectations, despite the high SES level sample, the participants reported that they considered the availability of financial aid to pursue graduate school attendance an important factor in the decision-making process (Ethington & Smart, 1986).

Werts (1967) collected survey data on 127,212 freshman students at 248 four-year institutions, approximately 17% of all freshmen in the U.S., to determine the combined effect of father's education and student's high school grades on career choice. The engineering students reported father's education level below the mean for the sample, or equivalent to completion of high school. According to Werts "able, lower class students tend to gravitate towards technological careers" (Werts, 1967, p. 352). Werts attributed the pattern to social-class-specific factors, orientation toward independent work, or the opportunities for upward mobility offered by engineering careers.

Although the women had the necessary performance accomplishments to build engineering self-efficacy, many lacked the social persuasion component. The S&E-inclined students reported that parents and teachers encouraged the chosen career choice (Dick & Rallis, 1991). From their analyses Dick and Rallis concluded that socializers, in the form of the attitudes and behaviors of parents, educators, peers, and friends, affected students' career choice prior to the high school senior year.

Faculty and student interactions in and out of the classroom also contribute to the academic experience of students. Faculty-student interactions form an important component of sub-environments within higher education institutions (Kuh & Hu, 2001; Pascarella, 1980, 1984). Of particular interest is the finding that the more contact students have with faculty, the greater the students' intellectual development and satisfaction (Astin, 1993). Kuh and Hu randomly selected the results of 5,409, or 10%, respondents of the CSEQ between 1990 and 1997 to determine the effects of faculty-student interaction on student satisfaction. As expected, Kuh and Hu found that students interacted more with faculty members in upper division courses.

The students reported that student-faculty contact had positive effects on student satisfaction and intellectual gains (Kuh & Hu, 2001). The researchers also found that the effort students invested in their academic mediated the positive effects of the interaction (Kuh & Hu, 2001). In other words, faculty-student interactions alone did not increase student satisfaction. Kuh and Hu acknowledged that it is unclear whether better academically prepared students sought out faculty members or vice versa. Institutional type and selectivity did not affect the way in which faculty-student interactions influenced student satisfaction (Kuh & Hu, 2001).

Umbach and Porter (2002), Pike (1991), Bean and Bradley (1986), and Liu and Jung (1980), reported that a close relationship exists between academic performance, defined by grades, during one's undergraduate education and student satisfaction. Ekstrom, Goertz, Pollack, Rock (1986), whose study is reviewed in detail in a subsequent section of this literature review, found that grades strongly

predict aspirations for graduate school enrollment. Baird (1985) added that grades earned as an undergraduate determine important outcomes such as one's chances of successfully completing all degree requirements and, subsequently, gaining admission to graduate and professional school. From these studies, it seems that undergraduate academic performance may be related to student satisfaction with the institution, completion of the bachelor's degree, graduate school aspirations, and graduate school enrollment. It is important to determine whether undergraduate academic performance and student satisfaction play a role in the enrollment in the MS BME program.

Self-efficacy and the Choice of Major

Self-confidence appears to play a role in the choice of college major. Due to the vocational nature of engineering coursework in college, declaring a major in engineering implies choosing an engineering career (Frehill, 1997). According to social cognitive theory, behavior avoidance results from an individual's level of self-efficacy in a specific domain (Bandura, 1977). Bandura originally proposed self-efficacy as the series of expectations or beliefs that an individual has in his / her ability to succeed in a given task. Low levels of self-efficacy in a given behavior result in avoidance of the behavior, low performance, and task abandonment (Bandura, 1977). When applied to vocational behavior, low levels of self-efficacy affect the educational majors and careers a person will attempt and can result in avoidance of other majors and careers (Betz & Hackett, 2006).

Self-efficacy beliefs develop from four sources: performance accomplishments, vicarious learning, emotional arousal, and social persuasion (Bandura, 1977). The sources are dynamic, and continue to shape self-efficacy and behavior (Bandura, 1977). Specific to engineering, performance accomplishments may represent successful experiences in mathematics and science. Conversely, negative experiences in high school math and science may diminish students' self-efficacy in cornerstone skills for engineering.

Vicarious learning, or changing one's self-efficacy through the successes or failures of a model figure, occurs if the individual perceives similarities with the model. If a model figure failed in the path towards engineering, the individual who looks up to the model may experience low self-efficacy in engineering. The third source of self-efficacy beliefs, emotional arousal, refers to the amount of anxiety the individual experiences in engineering-related activities. Anxiety negatively affects self-efficacy (Betz & Hackett, 2006). Lastly, social persuasion, or encouragement and support from others, increases an individual's efficacy if he / she accomplishes a reasonable goal (Bandura, 1977). In summary, students will choose engineering if they believe they can succeed in it or if they receive support and encouragement from individuals they value.

Hutchinson, Folhman, and Bodner (2006) surveyed 1,387 engineering freshmen at a large research university to determine the factors that influenced their engineering self-efficacy beliefs. The students completed the survey as a class assignment in an introductory course all first-year engineering students took. The

survey was administered early in the semester to collect data on the self-efficacy levels of students in engineering before grades had any influence on the beliefs. Analysis of the results showed several categories of salient factors. The majority of the students believed they understood the required engineering skills, namely problem-solving ability, statistics, and computer software proficiency. The students also reported a strong desire to succeed in engineering, regardless of the effort required. Approximately one-half of the sample reported that they enjoyed, found interest, and gained satisfaction from learning engineering skills. Hutchinson, Folhman, and Bodner concluded that early in their freshman year, most students in the sample showed signs of self-efficacy in engineering. These findings support the application of Bandura's social cognitive theory to the initial college major choice for freshmen.

Lent, Brown, Schmidt, Brenner, Lyons, and Treistman (2003) surveyed 328 students enrolled in an introductory engineering course to determine their levels of engineering self-efficacy, career interests, and supports/barriers. Participants answered questions regarding their beliefs in their abilities to complete engineering majors, their degree of interest in engineering-related endeavors, and perceived environmental supports and barriers. The researchers found supporting evidence for social cognitive theory: self-efficacy contributed to the students' choice behaviors (Lent et al., 2003). Most importantly, Lent et al. concluded that self-efficacy successfully predicted career goals and interests. The engineering students in the

study chose a major that they found interesting and for which they felt academically prepared.

Einarson and Santiago (1996) explored the academic self-efficacy and career expectations of graduate-level science and engineering students of different ethnicities. 289 students entering graduate programs at a research university in science and engineering participated in the survey-based study. The researchers tested the influence of student background characteristics and undergraduate performance on the students' self-efficacy. Contrary to the researchers' expectations and Betz and Hackett's (2006) findings with undergraduates, the gender and ethnicity-controlled groups did not report differences in academic self-efficacy (Einarson & Santiago, 1996). According to Einarson and Santiago, high SES students scored slightly higher on self-efficacy items than low SES students. However, the best predictor of self-efficacy was the students' self-rating of preparedness for graduate course work (Einarson & Santiago, 1996).

The findings from the three studies that applied social cognitive theory to the career choice of engineering students showed the importance of performance accomplishments, vicarious learning, emotional arousal, and social persuasion during high school and the undergraduate years on the self-efficacy of engineering students. The most relevant finding of the self-efficacy studies was the direct relationship of self-belief to enrollment in a graduate engineering program after the undergraduate degree (Einarson & Santiago, 1996).

Choosing Engineering as a Career

According to Erikson (1963), during adolescence people undergo developmental changes in which their vocational calling crystallizes. Dawson-Threat and Huba (1996) and Hearn (1980) informed that the choice of undergraduate major, which occurs as early as freshman year, is the best predictor of career choice. Although the process of career choice varies for each individual (Evetts, 1996), it appears that middle and high school years are critical times in career exploration and career decision-making.

Sax (1994) conducted a study involving 15,519 science and technology undergraduate students in 192 four-year colleges and universities. Sax attempted to determine factors that influenced students' participation and persistence in the science and technology fields. The findings in this study supported the application of social cognitive theory to career choice and the earlier work of Astin and Astin (1993) strong self-ratings of science and math preparation and an early commitment to the study of science and technology determined students' persistence in science and technology majors (Sax, 1994).

Disaggregating the data by gender revealed that men, who outnumbered women in the sample nearly three to one, were influenced by the likelihood of monetary rewards in their career choice; while women reported to aspire to careers that contributed to the betterment of society (Sax, 1994). In this study, men in science and technology majors did not persist if they wished to be self-employed,

came from a high-income family, or felt under-prepared in social skills and writing ability (Sax, 1994).

Davis (1963) surveyed nearly 34,000 recent graduates from volunteer four-year institutions to shed light on the career decisions students made during their undergraduate years. Davis reported that although vocational choice is a continuous process that spans across decades, college has an effect. Half of the graduates in the sample changed their minds about career choice during college (Davis, 1963). Graduates who declared engineering as a major during freshman year have three traits in common. First, 99% of the students were men; second, the students reported that they wanted to make a lot of money; and third, the students came from low SES families (Davis, 1963). The latter trait did not keep 40% of the freshman engineering students from switching to other majors by the end of the senior year, thus making it difficult to discern if the indicated desire for wealth aligned with engineering or the field into which the students changed. Taken at face value, the results supported Wolfle's findings that engineering students, at the time of the studies, had less educated fathers than students in law, medicine, and social sciences fields.

Astin and Astin (1993) conducted a longitudinal study of 27,065 freshmen at 388 four-year colleges to find the background factors and undergraduate experiences that shape students' decisions to pursue science-related professions. The science-related professions in the study included research scientist, engineer, and scientist/practitioner (Astin & Astin, 1993). Pertinent to this review of literature, the

researchers found that 75% of students who earned a bachelor's degree in engineering chose the engineering field as freshmen. The remaining 25% of engineering graduates initially chose a different major and defected into engineering. These figures show that pre-college career choices and events during the undergraduate years affect engineering persistence.

Astin and Astin (1993) found that engineering graduates pursued careers similar to that of their fathers. Other background factors common in engineering graduates were high self-rating in math skills, strong scientific orientation, high grades in high school, Asian-American ethnicity, and strong interest in high status (Astin & Astin, 1993). High mathematical competency also related to students' interest in graduate school enrollment in science and engineering. Institutional variables such as financial aid grants, low number of general education requirement courses, and large engineering department contributed to persistence in engineering (Astin & Astin, 1993).

The Astin and Astin (1993) study included an additional layer of analysis: degree aspirations four years after entering college. The most salient characteristics that predicted graduate degree aspiration in the freshmen were high intellectual self-esteem, high SAT verbal scores, and attending college to prepare for graduate school (Astin & Astin, 1993). Upon completion of the baccalaureate degree in engineering, 53% of students indicated an interest in earning a master's degree. Thirty-seven percent of engineering graduates enrolled in a graduate program immediately following baccalaureate degree completion. Astin and Astin (1993) posited that the

low percentage of graduate school enrollment reflected the practice-oriented nature of engineering, in which graduate programs look for students to have practical experience in the field prior to graduate degree training.

Grandy (1992) surveyed examinees of the Graduate Record Examination who were U.S. citizens; earned a bachelor's degree in science, mathematics, or engineering (SME) fields; and planned to apply to graduate school within five years. Survey data from 2,484 was used for the study (Grandy, 1992). Grandy identified, in addition to background characteristics and undergraduate experiences, the personal and professional experiences after college graduation that led SME majors to attend graduate school. Grandy also compared the responses of respondents who planned to continue in SME to respondents who planned change their careers.

Grandy (1992) identified common threads among the respondents: half of the respondents indicated that their fathers worked in a technical, mechanical or scientific field. This finding supports the relation of parental socialization and the vocational choices in their children. Approximately 80% of male and female respondents stated that their parents approved of their SME career choice and field of study (Grandy, 1992). Parents, according to the respondents, were less supportive of career changes away from SME (Grandy, 1992). The vast majority of the respondents reported that they personally knew at least one professional in the field in which they planned to do their graduate work.

In addition to the importance of role models, Grandy (1992) found that respondents who planned to stay in SME reported that courses were easier than

respondents who planned to change fields. Additionally, students who planned to stay in SME also felt that had a lot in common with students in their major (Grandy, 1992). Students who planned to stay in SME gave higher scores of quality to the competence of professors, their teaching methods, and research opportunities.

Sax (2001) conducted a follow-up of study participants from her earlier research to find the variables that predict graduate school enrollment in science and engineering. The sample included 990 baccalaureate degree graduates in engineering. Seven years after the initial study, which targeted students who persisted in S&E, Sax found that approximately 56% of engineering alums enrolled in engineering graduate programs. Consistent with prior research, Sax reported that the under-representation of women in graduate engineering programs was due to their interest in contributing to social change, which steered them to pursue non-engineering graduate degrees and careers they perceived brought them closer to humanity's needs.

Regression analyses of the data revealed that, for both genders, three factors predicted S&E graduate enrollment. The best predictor was freshman-year S&E career aspirations (Sax, 2001). This finding emphasized the importance of early career aspirations on a student's final vocational choice. College grades also predicted graduate school enrollment in S&E (Sax, 2001). Although Sax did not discuss the role of academic performance in post-baccalaureate enrollment, one may suspect that students who earned high grades while completing a bachelor's degree felt capable of succeeding in a graduate program. One final predictor of enrollment

in graduate school in science and engineering enrollment was interactions with faculty in and out of the classroom (Sax, 2001). It is likely that spending time with faculty creates the opportunities for students to explore the life of S&E researchers, learn the importance of graduate education for career purposes, and receive encouragement to attend graduate school.

Financial Aid Availability

The decreases in federal and state support for higher education institutions since the 1970s have shifted the tuition cost burden from the taxpayer to the students, pricing out those who lack the resources to pay (Johnstone, 1999; Paulsen, 2001; St. John, 2003). The recent decreases in financial aid and simultaneous tuition increases restrict access college enrollment for low parental resources families (Ballinger, 2007; Gladieux, 2004; McPherson and Shapiro, 1991). As a result, less low income students can afford their undergraduate college education, or must rely on loans to finance it. Will students with large undergraduate debt continue in school to earn a graduate degree?

Ekstrom, Goertz, Pollack, Rock (1986), examined the relationship of undergraduate debt to educational aspirations and enrollment in graduate education in further detail. Using the National Longitudinal Study of 1972 (NLS-72) and the High School and Beyond 1980 (HS&B-80) cohorts, 22,652 and 10,583 participants, respectively, the researchers determined that in 1976, 38% of the NLS-72 college graduates held educational loans compared to 59% of the HS&B-80 group (Ekstrom et. al, 1986).

Ekstrom et. al, (1986) noted that minority students from low SES families were most likely to have educational debt by their senior year. However, the researchers also reported that more students with debt aspired to attend graduate school than students without debt. Moreover, low SES moderately predicted graduate school enrollment (Ekstrom et. al, 1986). In addition, high college grades predicted high educational aspirations in the cohorts studied (Ekstrom et. al, 1986).

From this study it seems that neither high educational loan debt nor low SES predicted low in graduate school aspiration and enrollment. Several possibilities exist for these findings. For the students in the sample it is possible that the desire to obtain more education, or educational aspiration, suppressed concerns about debt accumulation resulting from additional years of education. High grades, in turn, may have influenced the students' educational aspirations. The possibility of landing higher paying jobs with a graduate degree may have also encouraged graduate school enrollment.

Other financial factors that can influence the graduate school enrollment decision emerged from subsequent studies. Stoecker (1991) conducted a survey of physical therapists to find the factors that motivated their decision to attend graduate school after entering the workforce. Student background characteristics, as first listed by Ethington and Smart (1986), influenced undergraduate institution choice and academic and social experiences (Stoecker, 1991). The researcher also found that occupational opportunities intervened in the graduate school enrollment decision. Stoecker listed the following occupational opportunities variables: level of

specialization required in an employment field, compensation offered to a bachelor's degree holder, and satisfaction the individual finds in a job. In this study, the participants identified the improvement of job-related skills as the most important factor in the decision-making process (Stoecker, 1991). The exclusive use of employed physical therapists who attend graduate school in the sample limits the generalizability of the findings and may not apply to other graduate students. As with the previous study, Stoecker did not report separately the results for master's level students.

Gender and Engineering Careers

Historically, women have had low rates of participation in engineering programs at the undergraduate and graduate levels (National Science Board, 2002). The lack of recruitment efforts for women in engineering programs up until the 1970s may explain part of the problem (Frehill, 1997). Current figures show that women have not achieved parity in engineering: women account for 55% undergraduate of enrollment in four-year institutions (Choy, 2002), but only for 26% of master's degree programs in science, math, and engineering. Women's perception of a career's potential to contribute to the betterment of society may also steer them away from engineering (Sax, 2001). It is also possible that the lack of role models in engineering professions deter capable, young women from seeing engineering as a career opportunity (Eccles, 1996). A number of studies have addressed the under-representation of women in engineering, exploring issues such as: Why do girls have lower interest in science than boys? What factors discourage women from taking

engineering preparatory courses in high school? What factors encourage women to choose engineering as a major and as a career?

Dick and Rallis (1991) surveyed 2,213 high school seniors in Rhode Island to find out about the impact of their academic and social experiences on career choice. The researchers focused on the differences in perceptions of the factors and influences on career choice between students who chose careers in science and engineering and students who chose other careers. Dick and Rallis hypothesized that students make career choices based on their self-efficacy and on their beliefs of the values of different careers. Two similarly prepared students should choose the same career, unless cultural experiences or key individuals exert an influence on the students' self-efficacy and career values.

Dick and Rallis (1991) found that even among well-prepared students, three times as many men chose engineering in relation to women, therefore course taking patterns do not predict engineering career choice for women. Several women outperformed the men in physics and calculus and had the qualifications to enter engineering; yet more than half of the women chose careers in medicine, business and law (Dick & Rallis, 1991). Dick and Rallis posited that by the 12th grade, students have already chosen their career, and that the women in the study merely viewed math and science coursework as preparatory for college, rather than for a specific career.

The researchers concluded that equal participation in the math and science curriculum will not increase the representation of women in engineering (Dick &

Rallis, 1991). The survey showed that men and women who chose engineering careers had encouragement from parents and teachers to do so. Dick and Rallis stated that the influences of others on engineering career choice are very powerful and begin very early in school.

Using data from the NELS, the same dataset used by Choy (2002), Huang, Taddese, and Walter (2000) followed a nationally representative sample of 1988 eighth-graders through high school and into college or the workforce. The 24,599 students, their parents, and school administrators were surveyed in 1988 and in 1992 to determine the role of student attitudes and aspirations, family environment and support, and school factors such as curriculum and instruction in the decision to enroll in engineering undergraduate programs.

Huang, Taddese, and Walter (2000) found that the lower participation in engineering programs for women is due to a selection mechanism caused by institutional climate in the middle and high school settings as well as psychological factors, such as lower interest and motivation in math and science courses. Like Dick and Rallis (1991), Huang, Taddese, and Walter found that the selection mechanism results in a small, motivated group of women well-prepared in math and science who pursue engineering majors. Huang, Taddese, and Walter defined well-prepared women as those having strong family support to obtain a college education, high parental and self expectations, high self-confidence, and strong academic background.

Huang, Taddese, and Walter (2000) admitted that the low numbers of women of well-prepared women in the study limits the generalizability of the findings. The factors that the previous studies in this literature review found to contribute to college major and the engineering career choice may not apply adequately to women in the MS BME program because of the field's close interaction connection to medicine, which, according to Dick and Rallis (1991), is a popular career among well-prepared women.

Grandy (1994) surveyed college seniors who took the Graduate Record Examination in 1990 to determine if gender and ethnic differences existed among students in SME majors who planned to enroll in graduate school. The sample included only seniors who were U.S. citizens and planned to pursue a graduate degree in SME. Grandy reported that the statistically significant differences by gender emerged among engineering students. Women in engineering programs assigned a higher degree of difficulty to undergraduate course work, reported lower quality of instruction, and indicated lower levels of academic self-efficacy (Grandy, 1994).

The two studies reviewed in this section highlight the importance supportive, encouraging relationships in engineering career choice for young women. At the graduate level, academic climate, faculty interaction, mentoring, financial support, and self-efficacy are associated with persistence (Maton & Hrabowsi III, 2004). Yet, the studies of women in engineering have focused on plans and completion of the undergraduate degree or the doctorate degree. This investigation will add to the

educational literature base by analyzing how women in the MS BME program chose their engineering specialization.

Foreign Students in Engineering

The rapid growth of foreign students in graduate programs in American colleges and universities has changed the higher education system (Borjas, 2006). In 2001, foreign students accounted for 63% of the total enrollment in U.S. IHE engineering programs (NSF, 2008). The high number of foreign students in U.S. IHE has resulted in a controversy among members of the scientific community: some worry that IHEs currently train tomorrow's U.S. engineering industry's competition; others believe that foreign students can, if permitted, become part of the American industry engineering talent pool and strengthen it (Congressional Research Reports, 2007). While research resources have been allocated to the identification of preferred majors by foreign students, scholarly research in the area of BME as a major or career choice for such a population does not exist.

The studies reviewed in this chapter looked for characteristics of students who enrolled in undergraduate engineering programs, a professional degree program, or in a graduate engineering degree. The studies, and the models that grew from those studies, did not take into account the large number of foreign students in U.S. colleges and universities. Foreign students may have different reasons for pursuing a graduate education than domestic students and different influences. The reasons for enrolling in a graduate engineering program for foreign students may include the influences of SES and parental socialization, the structure and rigor of the high

school and undergraduate education in the native country, the educational experiences a student undergoes, financial support from sponsors, job market demands in the native country, the availability of space in graduate programs in other countries, the desire to find employment in the U.S. to work in industry-leader BME firms, and the graduate's marketability after earning a master's degree from a brand name U.S. institution.

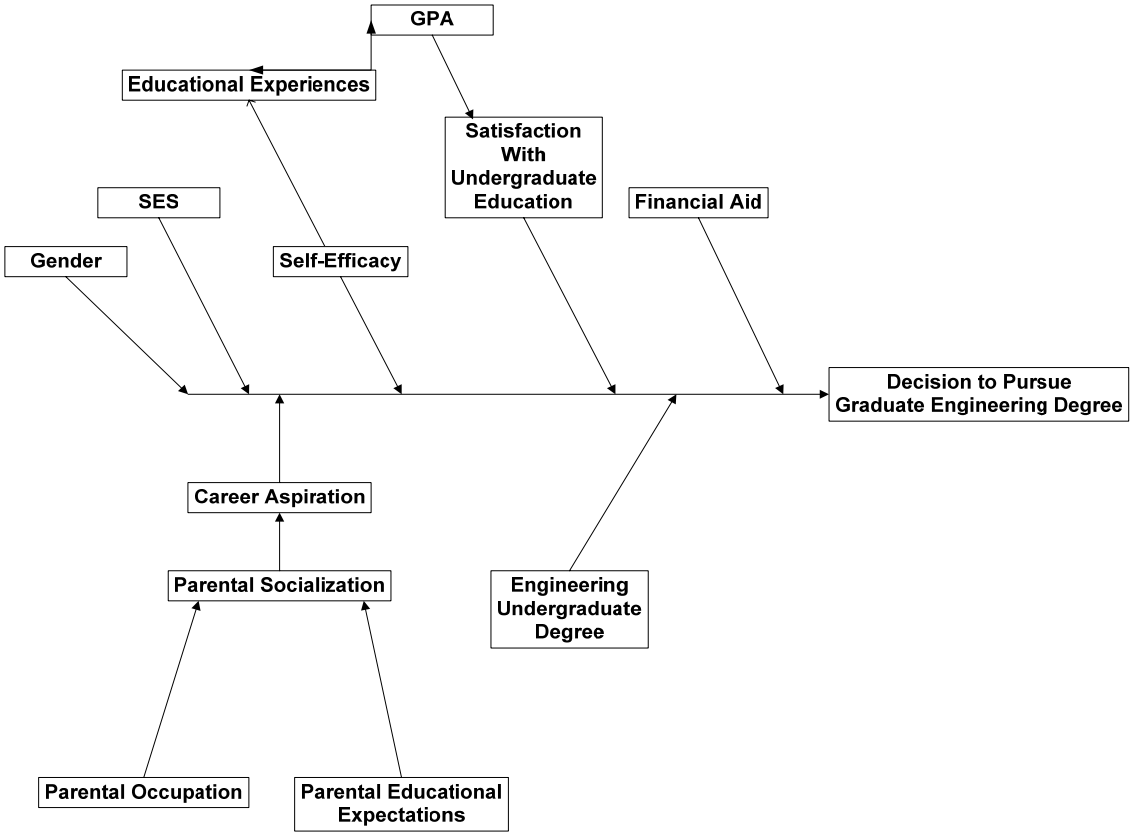
In sum, the models developed to explain the factors that affect the decision to attend graduate school may not accurately represent master's students or even graduate students in programs with a high foreign student concentration such as certain engineering disciplines. The U.S. BME industry will benefit from knowing the path of foreign students after graduation, either seek employment in the U.S. or practice their professions in their home countries.

Summary

Common themes became apparent across the studies in this review of literature. First, SES and parental socialization predicted enrollment in most studies of graduate school enrollment and in engineering programs. Secondly, educational experiences related directly to graduate school enrollment. Thirdly, self-efficacy, developed across educational experiences, contributed to major choice. Fourthly, the early choice of engineering as a college major and career aspiration successfully predicted engineering degree completion. Fifthly, the cost and the availability of financial assistance for graduate education affected enrollment in graduate programs. Lastly, gender predicted enrollment in undergraduate engineering programs, which

are a gateway into graduate engineering degrees. Figure 2.1 shows the important factors identified by the literature in the area of enrollment in graduate school and in engineering programs. The factors distilled from the literature will serve as the variables to measure in this study.

Figure 2.1. *Factors Identified in the Literature as Contributors to the Decision to Enroll in Graduate School and Engineering Programs.*



While the studies reviewed made meaningful contributions to our understanding of how individuals choose their college major, the studies did not explore the factors that led students in engineering programs to their master's degree choice. Similarly, the studies did not disaggregate their results by nationality, thus it is not possible to determine if the factors identified apply equally or differently to

domestic and foreign students. Consequently, our understanding of the factors that master's students in engineering programs consider prior to enrollment remains incomplete. The studies have added to the body of education research by illustrating the questions to ask MS BME students. The questions have not been asked of such a sample to obtain detailed information regarding why they enrolled in the program.

BME differs from other disciplines in that it marries the previously separate fields of medicine and engineering (BMES, 2007). Students, particularly women (Sax, 2001), who have viewed engineering as removed from the ideal of service to society may contemplate a career in BME with renewed interest. Additionally, the U.S. Bureau of Labor Statistics (2008) forecasted a high demand for graduates of biomedical engineering programs until 2018. The novelty of BME, the field's potential for improving the quality of human life, and the optimistic job market for master's degree graduates make for conditions previously not seen in education research.

CHAPTER 3

METHODOLOGY

The study attempted to identify the student background variables that related to enrollment in the master's degree program in biomedical engineering at a large, private university. In addition, the study aimed to identify the factors that students in a master's degree program in biomedical engineering considered in their decision to attend graduate school. As Hilton and Schrader (1987) argued, understanding the factors that students weigh when thinking about pursuing a master's degree in BME may allow the early prediction, and perhaps improvement, in enrollments in such programs. Thus, from an enrollment management perspective, the study attempted to extrapolate, from the characteristics of currently enrolled master's students, common characteristics of undergraduates who practitioners might recruit for the MS BME program. Additionally as contributors to students' experiences during the college years, BME faculty and advisors can benefit from the study by considering and improving upon their understandings of the undergraduate-to-graduate education decision for biomedical engineering students.

Research Design

Based on the gaps revealed in the literature, this study addressed the following research questions:

1. What are the gender, citizenship, age, plans after graduation, parental occupation, parental educational attainment, and SES characteristics of students in the MS BME and CE programs?

2. What are the undergraduate institution types, undergraduate majors, and levels of satisfaction with undergraduate education of students enrolled in the MS BME and MS CE programs?
3. What factors influenced their decision to enroll in the MS BME and CE programs?
4. Are factors that influenced the decision to enroll in an MS program different for CE and BME students?
5. How do domestic students' reasons for enrolling in a master's degree program compare to those given by foreign students?

In education research, investigators may utilize quantitative, qualitative, or mixed research methods to collect and analyze data. For certain research questions, quantitative methods are best (NRC, 2002). The quantitative paradigm rests on the position that all phenomena are reducible to indicators that represent the truth. These studies assume that only one truth exists and that this truth exists independent of human perception (Sale, Lohfeld, & Brazil, 2002). Guba and Lincoln (1994) added that the researcher can study a phenomenon without influencing or being influenced by it. Therefore, quantitative studies aim to minimize subjectivity in their measurements and analyses.

This quantitative study used a non-experimental design to examine the degree to which independent variables such as age, gender, ethnicity, parental occupation, SES, parental educational expectation, and undergraduate institution, and undergraduate major correlate with enrollment in the master's degree program in

Biomedical Engineering, the dependent variable. Quantitative methods also provide the best means of differentiating the reasons domestic and international students cite for enrolling in the MS BME program.

Population and Sample

The master's degree students in the BME program enrolled at a large private research university in the United States in the fall of 2007 will serve as the population in this study. The population includes first and second-year master's students. For comparison purposes the researcher also studied students in the MS CE program. The registrar database identified 136 students in the MS BME and 147 students in the MS CE program. The researcher attempted to incorporate all students in programs in the sample.

Recruitment

The researcher worked with the university's institutional researcher (IR) in the Registrar's Office to identify the students in the MS biomedical engineering and civil engineering programs. The IR furnished population demographics, including the email addresses of all students in the university's information system who pursued the MS BME and MS CE degrees. The researcher provided the email addresses to the academic advisors of the MS BME and CE programs. The researcher asked the advisors to send all their students an email (Appendix A), composed by the researcher, that briefly described the study, requested the students' participation, and provided the URL to the researcher's on-line survey instrument.

The email stated that participation was voluntary and provided the researcher's contact information in case the students had questions.

Instrumentation

Survey instruments are commonly utilized in quantitative research (Best & Kahn, 2003). To collect data from the study participants, the researcher utilized a web-based survey instrument (Appendix B) hosted by SurveyMonkey. Its ability to cover factual and subjective topics, economical implementation and fast data collection make the survey a popular instrument in higher education (Kuh & Hsu, 2001). On-line surveys can reach large and distant populations, allow easy access to participants, have verifiable delivery means, and typically have native, easy-to-use analysis tools (Gonyea, 2005).

The researcher created the survey instrument to gather information from the study participants. The researcher utilized several items from a survey piloted by Hagedorn, Maxwell, and Moon (2001) to measure participant background variables, including one item that measured parental occupation. As described by Hauser, Warren, Huang, and Carter (1996), the responses to the parental occupation and the parental educational items can be used to construct an SES composite variable, In addition, items from a survey specifically designed for bachelor's and master's BME alumni and students by Sundt, Schmolze, and Chang (2007) measured engineering-specific variables. In the development phase, five doctoral educational researchers analyzed the instrument in order to determine whether or not the content of the questions was valid. The survey consisted of 30 questions divided into five separate

sections. The instrument aimed to collect demographic information, educational experiences, and the reasons why students enrolled in MS BME and MS CE programs.

Data Collection

The academic advisors of the MS BME and MS CE programs emailed all students the URL to the researcher's survey. The survey remained open for students to access 24 hours a day, 7 days a week for a period of one month. The email informed participants of the approximate time it may take to complete the survey, that participants may quit the survey at any time, that the survey did not require personal identifiers (to maintain participant confidentiality), and that answering the survey questions implied voluntary consent to participate in the study. The responses from the surveys were entered into Statistical Package for Social Scientists (SPSS), a statistical analysis program.

Analysis of the Data

The researcher's desire to identify the student background characteristics and the factors that influenced students' decision to enroll in the MS BME or MS CE programs guided the data analysis in the study. The identification of the background variables and deciding factors for the participants required the analyses of raw data from the student surveys. The researcher analyzed the respondents' answers to all questions. First, the data were grouped by program of study, either MS BME or MS CE. The researcher computed the t-test for independent samples for all variables

with continuous answers in the survey. To compare proportions of dichotomous variables the Chi-square test was used.

With the results from the t-test and Chi-square computation, descriptive statistics, including the frequencies, means, and standard deviations of all variables, the samples were described to answer questions one, two and three. Subsequently, the data from the survey were grouped by the citizenship variable, in which the students chose citizenship in the U.S. or in another country. Based on the respondents' answer to the citizenship question, they were coded as domestic or foreign students. The researcher conducted Chi-square analyses to compare categorical variable frequencies to address questions four and five. The Chi-square test allowed the examination of frequency distribution for the categorical variables.

Ethical Considerations

To protect participants from harm the researcher obtained permission from the Institutional Review Board before the advisors contacting them and collecting data. The researcher did not directly contact any of the participants. Moreover, the researcher informed all respondents that participation was voluntarily. Lastly, the researcher did not require participants to provide personally identifiable information on the survey to respect their right to anonymity in the study.

CHAPTER 4

ANALYSIS OF THE DATA

This chapter presents the findings of the study in response to the five research questions. The study seeks describe the background and educational characteristics of students in the master's degree programs in biomedical engineering (MS BME) and civil engineering (MS CE) at a research institution in the United States. This study also aims to identify the factors that students considered in their decision to enroll in the programs. Finally, the study compares the factors considered by foreign students to those considered by domestic students.

Data were analyzed using the SPSS v16.0 statistical program. To report the findings the researcher used descriptive and inferential statistics. The first section of the chapter describes the survey response rate and the process of selecting usable responses. The second section of the chapter presents the findings to the research questions.

Description of the Sample

The participants in this study were first or second-year master's students in the MS BME and MS CE programs. To answer research questions one, two, three and four the researcher isolated the respondents from the MS BME program from those of the MS CE program. The MS BME program participants who completed the survey formed one sample. The students in the MS CE program who completed the survey comprised the comparison group. The samples came from two mutually-exclusive populations.

The researcher isolated the MS BME participants from the MS CE comparison group by reviewing how each respondent answered the survey item in which they indicated enrollment in the MS BME or MS CE programs. Table 4.1 shows the distribution of survey responders in the two master's programs. The MS BME population was smaller (N=136) than the MS CE population (N=147). Despite comprising the smaller population in the study, more MS BME students completed the survey.

Table 4.1. *Respondents by Master's Program*

Master's Program	Frequency	Percentage
Biomedical Engineering	64	58%
Civil Engineering	46	42%
Total	110	100%

The survey was published on SurveyMonkey in mid-January. At the completion of the 4-week survey period, 158 responses were collected from students in the MS BME and MS CE programs. The responses comprised 56% of the MS BME and MS CE populations. The researcher omitted data from incomplete responders, or individuals who did not complete enough survey items to yield usable data. After distilling the list of responders, 110 observations remained viable for analysis. In spite of the deleted responses, the survey's response rate (39%) was high for a Web-only research survey (Fricker and Schonlau, 2002).

Findings Related to Research Question One: What are the Gender, Citizenship, Age, Plans after Graduation, Parental Occupation, Parental Educational Attainment, and SES Characteristics of Students in the MS BME and CE Programs?

Gender

The gender for the participants was collected through a binary-response item on the survey. Respondents chose either the male or female options for gender. For the BME sample, 59% of the responses came from males (*N*=38), compared to 80% of the MS CE sample. The gender breakdown for the MS BME and CE samples parallels that of the populations they represent. Table 4.2 compares the gender distribution of the MS BME and MS CE samples and populations.

Table 4.2. *Sample Comparison of Gender and Citizenship*

	Gender		Citizenship	
Sample	Male	Female	U.S.	Other Country
BME Sample	59%	41%	38%	62%
BME Population	65%	35%	43%	57%
CE Sample	80%	20%	63%	37%
CE Population	83%	17%	81%	19%
Engineering Population	81%	19%	44%	56%

The Chi-square statistic was calculated for gender between each sample and its population. In the MS BME gender comparison, $\chi^2(2, N=136) = 1.50$, $p > .05$, while in the MS CE gender comparison $\chi^2(2, N=146) = 0.28$, $p > .05$. The results indicate that the observed values for gender in the samples were not significantly different from the two populations. In the MS BME and MS CE samples, $\chi^2(1, N = 110) = 5.47$, $p<.05$. The test results reject the null hypothesis and suggest that there is an effect for gender between the samples, with a significantly higher number of women in the MS BME sample relative to the number of women in the MS CE sample.

Citizenship

Table 4.2 also portrays the citizenship of students in the MS BME and MS CE samples and populations. In the citizenship survey item, the participants chose either the U.S. or Other Country citizenship option. In the BME sample, 38% of the respondents (N=24) were U.S. citizens and 62% (N=40) indicated citizenship in another country.

The Chi-square statistic was calculated for the citizenship variable between each sample and its population. In the MS BME citizenship comparison, the Chi-square statistic showed that sample was not statistically different from the population, $\chi^2(2, N=136) = 1.70$, $p > .05$. The citizenship comparison in MS CE showed that the sample was not statistically different from the population [$\chi^2(2, N=146) = 1.50$, $p > .05$] in citizenship composition.

In the MS BME sample, foreign students enrolled nearly in a 3:2 ratio in relation to domestic students. These enrollment distributions are consistent with NSB (2008) figures, which estimated foreign student enrollment in engineering programs at 63%. U.S.-born MS CE participants outnumbered foreign students 63% to 37%, respectively.

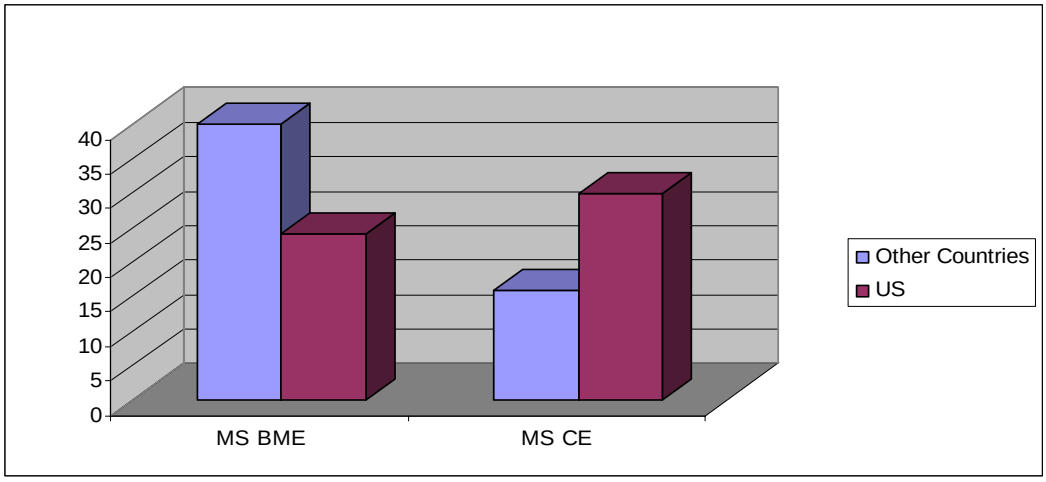
The proportions of domestic and foreign students in the MS BME and MS CE samples were compared using Chi-square. For the citizenship and master's program enrollment variables, $\chi^2(1, n = 110) = 6.99$, $p<.05$. The results reject the null hypothesis. The Chi-square results indicate that a significant relationship exists between major and citizenship in the samples, with more domestic students than foreign students enrolling in the MS CE program as compared to MS BME.

The participants also provided the country in which they completed their bachelor's degree (BS). Survey responses indicated that the citizenship and BS country variables are related for both samples. As shown on Figure 4.1, the MS BME respondents (N=64) reported that 62% completed their bachelor's degree in another country and 38% earned their undergraduate degree in the U.S. In the CE sample (N=46), approximately 35% respondents indicated that they earned their bachelor's degree in another country. U.S. bachelor's degree recipients accounted for 65% of the sample.

A Chi-square test was conducted to determine if a relationship existed between the two categorical variables, namely master's program sample and country of BS completion. The Chi-square analysis revealed that MS programs are

significantly related to the country in which participants earned their baccalaureate degree. $\chi^2(2, N=110) = 8.57, p < .05$. The null hypothesis was rejected, as χ^2 exceeded the critical value. In other words, the proportion of participants with bachelor's degrees from the U.S. or Other Countries differs for the two samples. More MS BME participants completed their BS degree in other countries, as compared to MS CE participants. This was likely due to the larger concentration of foreign students in the MS BME program.

Figure 4.1. *Comparisons of Countries where Samples Earned the BS*

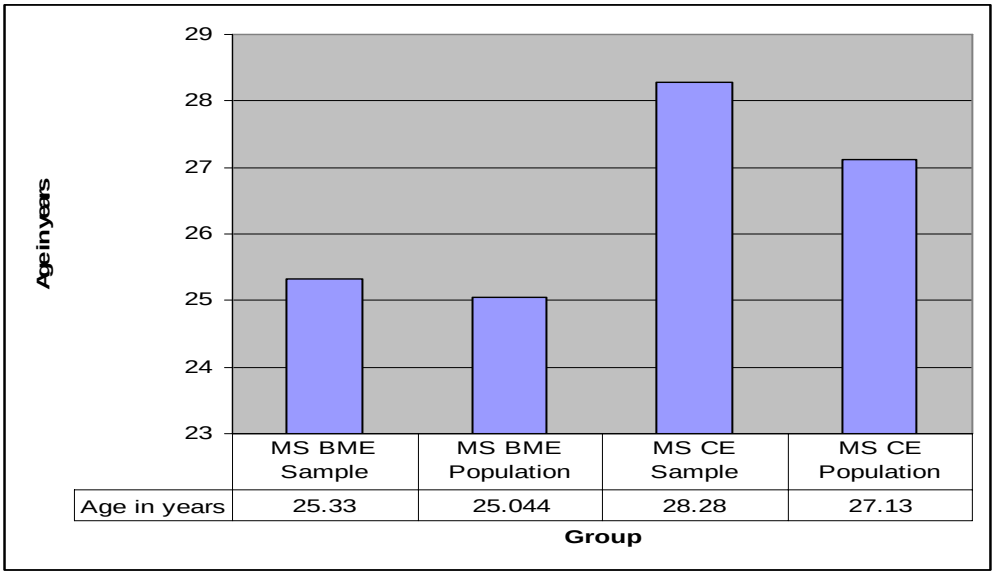


Age

The respondents provided their age in the survey. To compare the MS BME and MS CE samples to their respective populations, the researcher calculated the independent-samples t-test. There was no significant difference in age for the MS BME sample (M =25.33, SD =4.03) and the MS BME population [(M =25.04, SD =4.33); $t(102) = .55$, p = .430]. The t-test revealed similar results for the MS CE sample (M =28.28, SD =7.98) and the MS CE population [(M =27.13, SD =6.50);

$t(101) = .42$, $p = .651$]. The researcher explored differences in age between the MS BME and MS CE samples using the t-test. The t-test revealed a significant difference in ages between the MS BME (M=25.3, SD=4.01) and the MS CE (M=28.3, SD=8.2); $t(110)$=2.53, p<.05). Figure 4.2 shows the age comparison for the samples and populations in the MS BME and MS CE programs. In summary, the samples do not differ statistically from the populations they represent, but they differ from each other on every demographic dimension tested.

Figure 4.2. *Age Comparison for Samples and Populations*

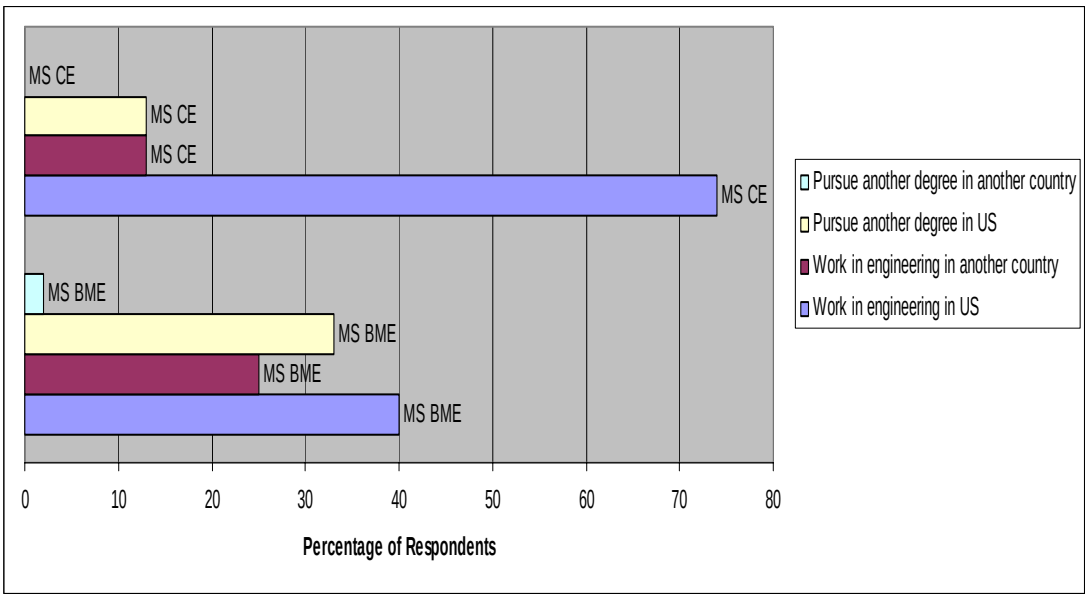


Plans after Graduation

One survey item assessed the participants' professional plans after completing their respective master's program. Participants had five options: "Work in engineering in the US", "Work in engineering in another country", "Pursue another degree in the US", "Pursue another degree in another country", and an open-ended "Other" choice. Figure 4.3 shows the percentages of respondents that selected

each choice. The majority of the study participants plan to remain in the U.S. after graduation. The two most common responses in the MS BME group were "Work in engineering in the U.S." (40 %) and "Pursue another degree in the US" (33%). In the MS CE sample, approximately 74% of the respondents plan to "Work in engineering in the U.S." and 13% plan to "Pursue another degree in the U.S."

Figure 4.3. *Comparison of Participants' Plans after Graduation*



Parental Occupation

As stated in Chapter 3, a survey item collected the participants' parental occupation as a string variable. The item asked respondents chose the job that best described their parents' occupation. Respondents chose one option from among eleven job categories for each parent. The researcher analyzed the frequencies of the parent occupation for each sample. In the MS BME sample (*N*=64), less than half (47 %) of the respondents reported that the parents worked as professionals, 28%

stated that the parents owned businesses, 10% selected the manager or supervision option, and 5% of the indicated that the parents worked in trades.

The MS CE participants reported that approximately 43% of the parents worked in professional-type occupations. Nearly 23% indicated that the parents owned a business. Small percentages of the participants' parents worked as managers or supervisors (9%), in the trades category (6.8%), and as laborers (4.5%).

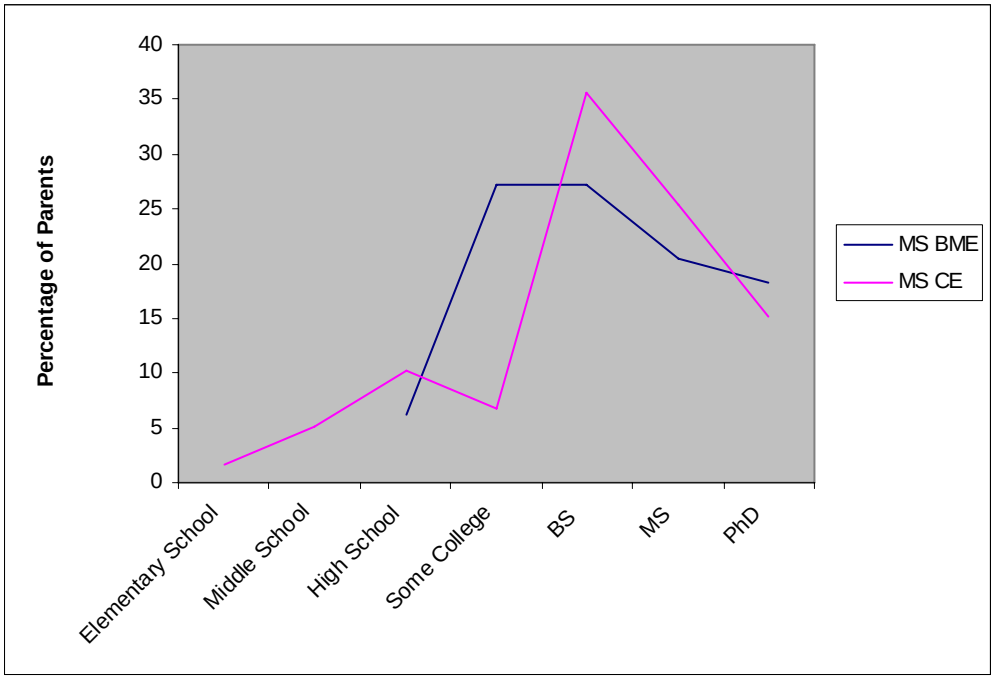
Across both samples, the over-representation of participants with high-paying parental occupations becomes clear. In the MS BME sample, 85% of the parents worked as professionals, business owners, or managers. The MS CE group reported that 75% of their parents worked as professionals, business owners, or managers. From these results it seems that a relationship exists between parental occupation and educational attainment for MS BME and MS CE sample participants. The researcher used the Chi-square to find differences in the proportions of parental occupations in the two samples. The Chi-square test showed that the observed differences in the proportion of parental occupation in the samples could be attributed to chance and was not statistically significant, $\chi^2(2, N=100) = 3.29$, $p = .314$.

Parental Educational Attainment

Respondents also provided the educational attainment of their parents. For the purposes of this study, the researcher used the highest degree achieved by either parent as the indicator of parental educational achievement. As shown on Figure 4.4, the biomedical engineering participants stated that approximately 83% of their

parents attended college. Only 10% of the participants' parents completed high school or less.

Figure 4.4. *Comparison of Parental Educational Attainment*



The MS CE sample reported higher parental educational attainment. Parental college attendance accounted for approximately 93% of the responses. None of the respondents indicated less than a high school education for their parents. The researcher computed the Chi-square to determine if a relationship existed between parental educational attainment and master's program. The Chi-square analysis showed that parental educational attainment does not significantly differ for the two samples, $\chi^2(3, N=107) = 2.86$, $p = .414$.

Socioeconomic Status

Determining the participants' SES presented a unique challenge. Educational researchers typically triangulate SES from father's education, father's occupation, mother's education, mother's occupation and family income (Hauser, Warren, Huang, & Carter, 1996; NCES, 2006). However, Terenzini, Cabrera, and Bernal (2001) found evidence in the literature of the unreliability of self-reported family income. To avert the problems associated with inaccurate income reporting, family income was intentionally omitted from the survey. The researcher assigned equal weights to the father's occupation, mother's education, and mother's occupation variables to derive the participants' SES.

The researcher recoded the levels of educational attainment on a scale from 1 to 7, with doctorate degree recipients on the high end of the range. The parental occupation categories were also recoded to a 1 to 7 scale, in which the higher-paying jobs had the higher values. In line with NCES (2006) coding practices, scores in the low quartile of the 28-point scale indicated low SES, while scores in the middle quartiles signified middle lowest and middle highest socioeconomic status, and scores in the top quartile resulted in high socioeconomic status classification.

As Table 4.3 shows, only 2 respondents, or less than 2%, came from low socioeconomic status families. Fourteen respondents, or nearly 13% of the valid cases, scored in the middle lowest SES quartile. The largest group (50%) of participants scored in the middle highest SES quartile. Nearly 28% of the respondents scored in the high SES quartile.

Table 4.3. *SES Scores for Survey Respondents*

SES Score	Frequency	Percent
5	1	.9%
6	1	.9%
8	3	2.7%
10	1	.9%
11	3	2.7%
12	3	2.7%
13	1	.9%
14	3	2.7%
15	5	4.5%
16	9	8.2%
17	4	3.6%
18	20	18.2%
19	9	8.2%
20	4	3.6%
21	4	3.6%
22	8	7.3%
23	4	3.6%
24	8	7.3%
25	8	7.3%
26	2	1.8%
27	1	.9%
Missing	8	7.3%
Total	110	100.0%

To explore differences in the SES scores in the MS BME and MS CE samples the researcher conducted an independent-samples t-test. There was no significant difference in SES scores between the MS BME (M = 18.60, SD = 4.854) and the MS CE sample [(M = 18.43, SD = 4.459); $t(102)$ = .180, p = .952]. The mean SES scores for both samples suggest that the participants come from high SES families, which lends support to the parental resources framework.

Findings Related to Research Question Two: What are the Undergraduate Institution Types, Undergraduate Majors, and Levels of Satisfaction with Undergraduate Education of Students Enrolled in the MS BME and MS CE Programs?

To answer this research question, the participants were asked to provide the name of the institution where they earned their undergraduate degree. Based on the responses, the undergraduate institutions were classified according to the 2005 Carnegie Foundation system for institutions of higher education to provide a descriptive picture of the types of IHEs from which MS BME and MS CE participants earned their undergraduate degrees. Because the Carnegie Foundation classifies only accredited, degree-granting institutions in the US represented in the NCES' Integrated Postsecondary Education Data System, the researcher excluded foreign institutions.

Approximately 45% (*N*=49) of the participants attended US institutions. In the MS BME sample, of the 21 students used in the analysis, nearly 85% attended an institution with very high research activity, highly-selective admissions, full-time student enrollment and high transfer-in rates. Approximately 15% of the participants earned their degrees from a college or university, selective admissions, medium-time student enrollment, and high-transfer-in rates. Nearly 71% of the MS BME respondents attended private institutions.

In the MS CE sample, 28 students attended US institutions. The majority (57%) of the students attended private institutions. Nearly 75% of the participants attended an institution with very high research activity, highly-selective admissions,

full-time student enrollment and high transfer-in rates. Approximately 25% of the respondents in the sample graduated from non-research, selective, high-transfer in institutions.

To compare the proportion of participants in both samples that attended research and non-research undergraduate institutions, the researcher used the Fisher's Exact Test because of the small number of observations in one cell of the contingency table. The proportion of MS BME students who attended research-based institutions did not differ significantly from the proportion of MS CE students, Fisher's Exact Test = .29, p = .000.

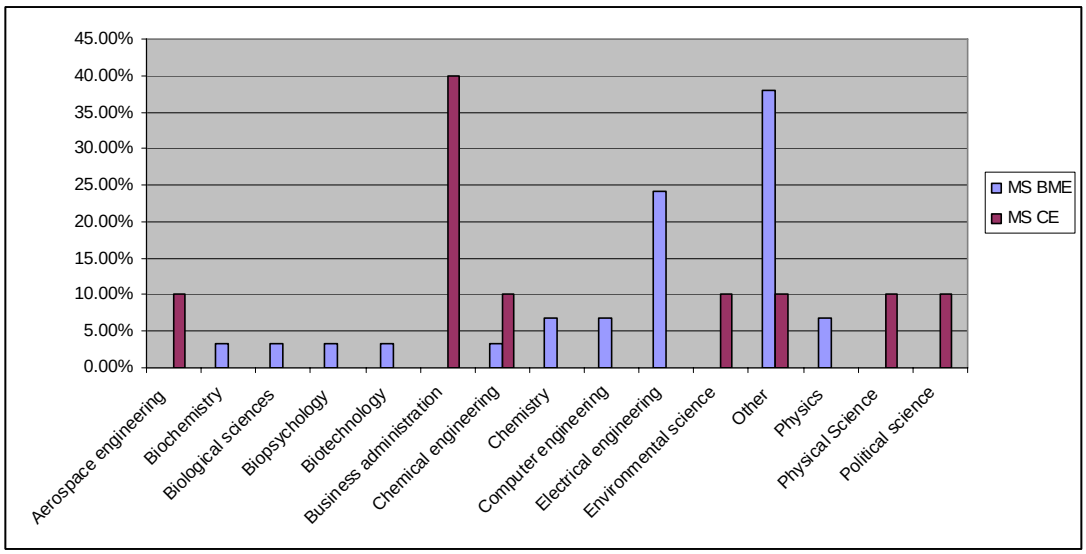
Undergraduate majors

The participants self-reported the undergraduate majors they pursued. The survey first asked respondents to indicate if they earned a BS in engineering. If the respondents answered yes, the survey presented a list of engineering fields and an "Other" category for the participants to specify their BS engineering major. Respondents who did not earn a BS in engineering entered their undergraduate major in a subsequent survey item.

Overall, 86% of the participants had earned their BS in engineering. As expected, in the MS BME sample 47% of participants earned their BS in BME. Nearly 18% of the respondents in the sample chose the "Other" category, which means that the sample majored in one or more engineering disciplines not listed on the survey. Approximately 11% of the MS BME participants majored in electrical engineering. Undergraduate science majors accounted for nearly 13% of the

respondents, with natural sciences and physical sciences equally represented. Figure 4.5 presents the undergraduate major distribution in the MS BME and MS CE samples, with BS BME and BS CE degrees coded as "Missing" to highlight the presence of majors in the samples.

Figure 4.5. *Comparison of BS Majors of MS BME and MS CE Participants*



Civil engineering is also a popular major for MS CE students, as 78% of the respondents earned a BS in CE. After coding civil engineering as "Missing," the results showed that 50% of the students who did not major in CE earned the bachelor's degrees in non-engineering, non-science disciplines. In addition, 30% of the respondents majored in engineering disciplines that included aerospace engineering and chemical engineering. Finally, 20% of the non-civil engineering BS graduates majored in the sciences.

Since some undergraduate majors had small representation in the survey results, the researcher used Fisher's Exact Test to compare the proportion of the

majors present in the MS BME and MS CE samples. The results indicated that the proportion of undergraduate majors in the MS BME sample differs significantly from the proportion of undergraduate majors of participants in MS CE, p=.000, Fisher's Exact Test = 27.24.

Satisfaction with Undergraduate Education

In the survey, participants chose the level of satisfaction with their undergraduate institution. Respondents had five choices: very satisfied, satisfied, unsatisfied, very unsatisfied and not sure. In the BME sample, more than half (53%) of the respondents stated that they were satisfied with their undergraduate institution. Almost 36% of the MS BME participants selected the "Very satisfied" option. Nearly 6% of the respondents reported that they were dissatisfied with the school where they earned their bachelor's degree. One student in the sample, comprising 1.6% of the respondents, was very dissatisfied with the undergraduate institution.

The MS CE sample was more homogeneous in its satisfaction with the undergraduate institution. The most MS CE participants (65%) indicated that they felt satisfied with their undergraduate institution. Nearly 35% of the respondents stated they felt "Very satisfied."

To compare the undergraduate institution satisfaction levels between the samples, the researcher recoded the string variable into a numeric scale. The independent-samples t-test showed no statistically significant difference in satisfaction levels between the MS BME participants (M=1.16, SD=.877) and the MS CE respondents (M = 1.35, SD =.482); $t(108)$ = -.342, p = .182. While the two

samples were not statistically different in their levels of satisfaction, both groups indicated that they felt at least satisfied with their undergraduate institution. This finding buttresses the conclusion of other researchers that undergraduate experiences, including satisfaction with the undergraduate institution, contribute to graduate school enrollment.

Grade Point Average (GPA)

The participants self-reported their undergraduate grade point average (GPA). In line with Ethington and Smart (1986) and Baird (1985), who found that undergraduate GPA predicted enrollment in graduate programs, the participants in the samples, on average, earned high grades in their undergraduate studies. There was, however, no statistical difference in the GPA of the MS BME participants (M=3.40, SD=.413) and the MS CE participants (M=3.27, SD=.409); $t(97) = 1.56$, $p = .122$.

The survey also included a free-response item that asked participants to state what skills they wished they had learned in their undergraduate years that might help them in the MS program. Nearly one-third of the MS BME sample chose not to answer the question. Analysis of the participants' responses to the question revealed the following patterns: 14% of the respondents stated that they wished they have learned more computer programming skills. Another 14% stated that they would have liked to have learned how to use the MATLAB statistical software. Approximately 11% of the participants cited the application of theoretical knowledge, or more practical knowledge, as the skill they wished they had learned.

A different group of participants, 11%, reported that they would have liked more training in electronics.

More than half (54%) of the MS CE participants answered the free-response item. Twenty percent of the respondents indicated that their undergraduate education prepared them sufficiently for MS CE. Sixteen percent of the participants who answered the question expressed that they would have benefited from more foundational engineering courses. A different group of respondents (16%) stated that more courses in structural dynamics would have helped them in MS CE.

Findings Related to Research Questions Three and Four: What Factors Influenced their Decision to Enroll in the MS BME and CE Programs? Are the Factors Different for MS BME and MS CE Students?

Research questions three and four attempted to find the importance of internal and external influences on the students in the two samples and when said influences acted upon the participants. Survey items 12, 13, 14 and 15 aimed to collect data to answer research questions three and four. Question 12 on the survey listed seven sources that may have started the participants' interest in engineering. The first option was exposure through news, other forms of mass media, science magazines, engineering journals, engineering program brochures or course flyers. The other influences listed in question 12 included undergraduate experiences, exposure through an internship, exposure during a conference, exposure during a career event or college day, advice from people in the field, and advice from others.

The participants indicated, on a scale of one to ten, the importance of each source. Table 4.4 shows the rank order given by the samples to the factors.

Table 4.4. *Comparison of Rank Order of Factors for MS BME and MS CE Participants*

	MS BME	MS CE
Influence	Rank	Rank
Undergraduate experiences	1st	1st
Advice from others	2nd	2nd
News	3rd	3rd
Advice from people in the field	4th	7th
Exposure during internship	5th	4th
Exposure during a conference	6th	6th
Exposure during career day	7th	5th

Based on the responses provided by the participants, the researcher computed mean scores for each of the sources. The MS BME participants (N=60) indicated that the most important influence was the exposure during their undergraduate education (M = 7.46, SD = 2.38). Advice from others was the second most important influence (M = 6.61, SD = 2.73). According to the responses, mass media sources such as television, radio, magazines, and professional publications (M = 6.32, SD = 2.50) also contributed to their interest in engineering. Advice from people in the BME field (M = 6.00, SD = 3.07) was somewhat important to the participants. Participants selected exposure during an internship (M = 5.81, SD = 3.16) as the next relevant influence. Exposure during a conference (M = 5.25, SD = 2.46) and

exposure during career day (*M* = 5.05, *SD* = 2.66) were the least important influences in their interest in engineering.

The MS CE participants (*N*=43) indicated that undergraduate experiences (*M* = 7.02, *SD* = 2.33) and advice from others (*M* = 6.93, *SD* = 2.45) had nearly the same level of influence. Mass media sources (*M* = 6.32, *SD* = 2.31) was the third most influential source. The participants cited internship exposure (*M* = 5.88, *SD* = 3.16) as somewhat influential. Exposure during a conference (*M* = 5.37, *SD* = 2.60), exposure during career day (*M* = 5.05, *SD* = 2.64), and advice from people in the field (*M* = 4.48, *SD* = 2.98) were, respectively, the least influential for the sample.

The researcher used the independent-samples t-test to test for differences in the importance of the factors provided by the participants. The results of the t-test appear on Table 4.5. The samples do not differ significantly on any of these external influences, with the exception of advice from people in the field. In summary, both samples indicated that the most influential factors in starting their interest in engineering were undergraduate experiences, advice from others and mass media sources.

When did the participants decide to pursue their MS degree?

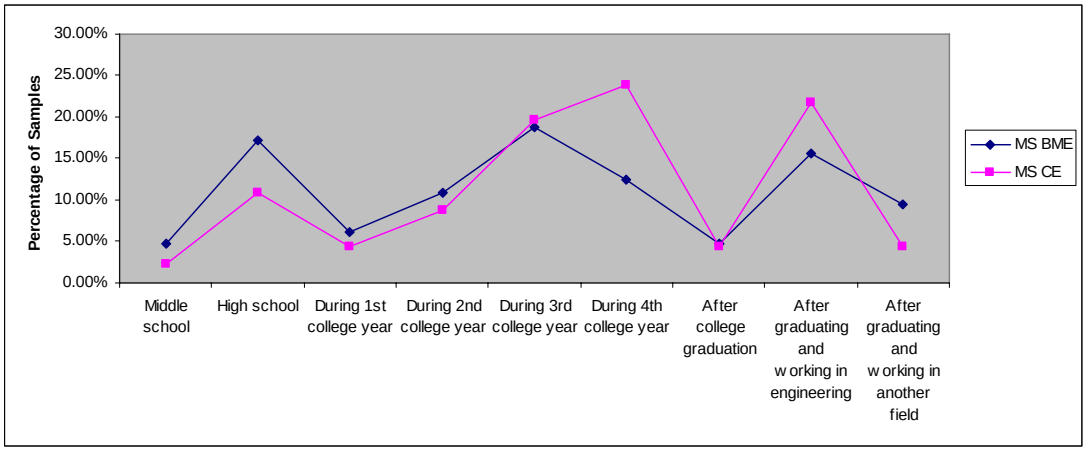
Question 13 on the survey asked the participants to state when they decided to get a master's degree in their engineering disciplines. The respondents chose one answer from nine options: in middle school, in high school, during college freshman year, during college sophomore year, during college junior year, during college senior year, after graduating from college, after graduating from college and working

Table 4.5. *T-test Scores for Sources of Interest in Engineering for MS BME and MS CE Participants*

Influence	t-test score	Significance
News	$t(101) = -.018$	$p = .985$
Undergraduate experiences	$t(101) = .939$	$p = .350$
Exposure during internship	$t(101) = -.105$	$p = .917$
Exposure during a conference	$t(101) = .401$	$p = .689$
Exposure during career day	$t(101) = -.611$	$p = .543$
Advice from people in the field	$t(101) = 2.94$	$p < .05$
Advice from others	$t(100) = -.599$	$p = .550$

in engineering, after graduating from college and working in another field. Figure 4.6 shows the percentages indicated at each educational level by the MS BME and MS CE respondents.

Figure 4.6. *Comparison of when Participants Decided to get MS BME or MS CE*



The researcher recoded the educational levels into a numeric scale to compute the means for the two samples, and subsequently to determine the

differences in the educational levels when the participants decided to pursue a MS in engineering. Statistically, no significant difference emerged in the educational level in which the decision to get a MS in engineering was made by the MS BME participants (M = 5.39, SD = 2.56) and MS CE participants [(M = 5.91, SD = 2.72); $t(108) = 1.03$, $p = .305$]. However, the means scores may hide noteworthy differences in the two samples. Upon closer evaluation of the percentages, it became clear that the majority (58%) of the MS BME participants decided to get the master's degree before they became college seniors, compared to 46% for the MS CE sample. For 44% of the MS CE participants, the 3rd and 4th years of college were critical in the decision to pursue the master's degree, compared to 31% for the MS BME sample. It seems that most of MS BME participants made their decision to get the MS degree by the end of the sophomore year in college. The majority of MS CE participants made the decision during their junior year or later.

The importance of key individuals on the decision

Participants also provided, in question 14, the level of influence eight individuals made in the decision to pursue a MS BME or MS CE. The participants rated the influence of their father, mother, school teacher, school counselor, university professor, college advisor, friend and other individual. The participants indicated the level of influence of each individual by selecting the Very influential, Somewhat influential or Not influential options.

Collectively, the majority of the respondents indicated that their fathers (51%) and their mothers (51%) were very influential in their decision to enroll in the

MS program. The majority of participants (53%) also rated their school teachers not influential. School counselors were not influential on the participants' decision for 61% of the respondents. The approximately 40% of the respondents considered university professors very influential. Yet college advisors (51%) received the Not influential mark. The participants considered their friends (44%) somewhat influential. Lastly, the "Other" individual earned received the mark of not influential by most respondents (42%). Table 4.6 shows the rank order and the means for the eight individuals rated by the two samples after the responses were recoded into a numerical scale.

Table 4.6. *Rank Order and Means of Influential People on Participants' Decision to Pursue MS*

	Sample	
Individual	MS BME	MS CE
Father	*M* = 2.29, *SD* = .792	*M* = 2.30, *SD* = .813
Mother	*M* = 2.29, *SD* = .792	*M* = 2.30, *SD* = .813
University professor	*M* = 2.05, *SD* = .805	*M* = 2.14, *SD* = .824
Friend	*M* = 2.03, *SD* = .782	*M* = 2.09, *SD* = .701
Other	*M* = 1.80, *SD* = .816	*M* = 1.95, *SD* = .848
University advisor	*M* = 1.73, *SD* = .784	*M* = 1.66, *SD* = .745
School teacher	*M* = 1.71, *SD* = .744	*M* = 1.53, *SD* = .767
School counselor	*M* = 1.58, *SD* = .724	*M* = 1.43, *SD* = .695

After computing the means for all the individuals, the researcher calculated independent-samples t-scores for each individual rated by the samples to determine if differences existed in the levels of influence. No statistically significant difference

emerged between the samples for the level of influence of the father [$t(107) = -.120$, $p = .905$], the mother [$t(107) = -.120$, $p = .905$], a school teacher [$t(100) = 1.171$, $p = .244$], a school counselor [$t(101) = 1.019$, $p = .311$], a university professor [$t(103) = -.542$, $p = .589$], a college advisor [$t(101) = .456$, $p = .649$], a friend [$t(106) = -.391$, $p = .697$], or another individual [$t(84) = -.830$, $p = .409$].

From the analysis of influential people for the participants, it seems clear that parents had a strong influence on the participants' decision to pursue the MS degree. In Research Question 1, the participants' parental occupation and parental educational attainment were analyzed. The majority of the parents held white-collar jobs in the MS BME (85%) and MS CE (75%) samples. Most MS BME parents (83%) and nearly all MS CE parents (93%) attended college. These findings begin to suggest that parents were powerful agents in the participants' educational attainment.

The factors that influenced the participants' decision to pursue the MS degree

Item 15 on the survey explored the importance of 13 internal and external factors in the participants' decision to pursue the degree in MS BME or MS CE. The respondents indicated the importance of each factor by checking the box for Very important, Somewhat important, or Not important. The responses were recoded into a numeric scale to calculate the means for each sample. Table 4.7 lists the factors the participants rated and the respective mean scores.

Table 4.7. *Means Scores of Factors Important to Respondents in the Decision to Pursue MS*

	Sample	
Factor	MS BME	MS CE
Your educational aspirations	*M* = 2.87, *SD* = .389	*M* = 2.89, *SD* = .321
Your parents' expectations	*M* = 2.18, *SD* = .725	*M* = 1.91, *SD* = .830
Family moral support	*M* = 2.47, *SD* = .650	*M* = 2.34, *SD* = .645
The desire to deepen your knowledge of engineering	*M* = 2.78, *SD* = .415	*M* = 2.86, *SD* = .347
Self-confidence in your academic competence	*M* = 2.73, *SD* = .516	*M* = 2.75, *SD* = .534
The availability of financial aid	*M* = 1.93, *SD* = .800	*M* = 2.09, *SD* = .858
MS suggested by employer	*M* = 1.52, *SD* = .65	*M* = 1.75, *SD* = .839
MS required by employer	*M* = 1.45, *SD* = .675	*M* = 1.52, *SD* = .762
The ability to get a better job	*M* = 2.53, *SD* = .650	*M* = 2.55, *SD* = .663
The ability to earn more	*M* = 2.52, *SD* = .651	*M* = 2.48, *SD* = .664
There was nothing better to do	*M* = 1.32, *SD* = .624	*M* = 1.25, *SD* = .576
MS takes less time than PhD	*M* = 1.57, *SD* = .767	*M* = 1.75, *SD* = .781
To prepare for another degree	*M* = 1.88, *SD* = .825	*M* = 1.48, *SD* = .698

When the samples' responses were ranked, the six most important factors or reasons ranked equally. The participants' educational aspiration was the most

important reason for their enrollment in the MS program. The desire to learn more about engineering ranked second. Academic self-confidence was third in the order of importance. The hope to land a better job and to earn more followed, respectively. Family moral support ranked sixth place.

The factors that the samples ranked differently included parental educational expectations, seventh by MS BME and eighth by MS CE. The availability of financial aid scored eighth and seventh, respectively. The MS BME respondents indicated ranked the "Prepare for another degree" factor ninth while their MS CE counterparts ranked the factor 12th. The MS degree is shorter than the PhD factor ranked 10th and 9th in MS BME and MS CE, respectively. Both samples indicated that their employers suggested or required the MS degree very low in importance in their enrollment. Lastly, both samples ranked the factor "There was nothing better to do" the least important.

Independent-samples t-test scores were computed for all the factors. No statistically significant difference between the samples emerged on 12 of the factors. The single factor in which the samples differed was "Prepare for another degree." The MS BME sample (M = 1.88, SD = .825) gave more importance to the factor than the MS CE sample [M = 1.48, SD = .698; $t(102) = 2.64$, $p < .05$].

The higher level of importance given to the "Prepare for another degree" by the MS BME respondents was validated through item 9 on the survey, which asked participants to indicate the highest degree they would like to attain in their lives, if there were no obstacles. The majority of the MS CE respondents (53%) indicated

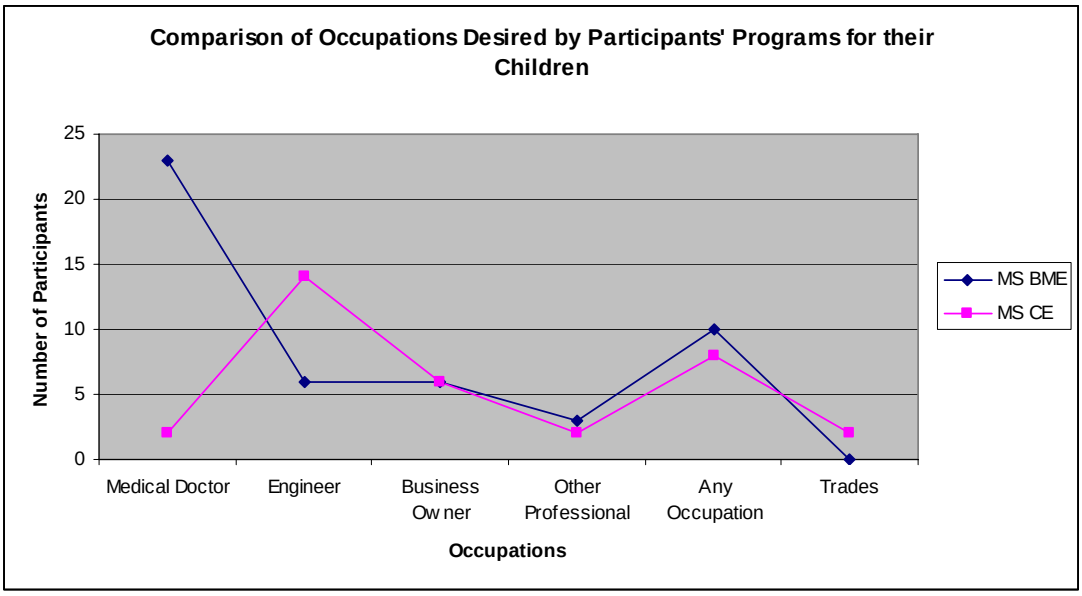
that the highest degree they desired was the MS. Approximately 47% of this sample expressed a desire to earn a PhD. In the MS BME sample, less than one-third (30%) wanted to earn a MS. The majority (70%) wanted to get a doctorate degree, with 53% of the respondents interested in the PhD and 17% in another doctorate degree. Thus, the results indicate that most of the MS BME participants viewed the MS degree as a step along the way to their ultimate degree or career objective.

Occupations parents desired for their children

The survey asked participants to state the occupation that their parents expected them to achieve. Seventy-five percent of the participants answered the question, each using naming specific occupations. The researcher classified the occupations into the categories used in the parental occupations questions. Figure 4.7 shows the frequencies and percentages of the occupations.

The strong influence of parents in the participants' decision to pursue the MS degree, the higher percentage of MS BME respondents who want to earn a doctorate degree when compared to MS CE participants, and the high percentage of MS BME respondents who indicated that their parents wanted them to be doctors suggests that the parents played a pivotal role in the educational and career choices that students made.

Figure 4.7. *Comparison of Occupations Desired by the Participants' Parents for their Children*



Findings Related to Research Question Five: How do Domestic Students' Reasons for Enrolling in a Master's Degree Program Compare to those given by Foreign Students?

In this section, a comparison was made of the responses given by foreign and domestic participants to the survey items that addressed what factors they considered in the decision to enroll in their MS programs. Survey questions 12, 13, 14 and 15 collected the data necessary to answer this research question. Based on the respondents' answer to the survey citizenship question, the researcher coded each participant as a domestic or foreign student. Overall, the sample included 57 foreign students and 53 students. The 57-participant sample comprises 41% of foreign

student population in the MS BME and MS CE programs. In the MS BME and MS CE programs, foreign students account for half (50%) of the population.

External and Internal Influences on the decision to pursue MS degree

Item 12 on the survey listed seven sources that may have started the participants' interest in engineering: exposure through news or mass media, exposure during BS, exposure through an internship, exposure during a conference, exposure during a career event or college day, advice from people in the field, and advice from others. The participants indicated, on a scale of one to ten, the importance of each source. Table 4.8 presents the rank order and mean scores for the seven sources for the samples.

Table 4.8. *Rank Order and Mean Scores of Sources of Interest in Engineering for Domestic and Foreign Participants*

	Domestic		Foreign	
Influence	Rank	Mean	Rank	Mean
Undergraduate experiences	1st	7.73, SD=1.85	2nd	6.77, SD=2.64
News	2nd	6.74, SD=2.23	3rd	5.69, SD=2.54
Exposure during internship	3rd	6.70, SD=2.88	4th	5.07, SD=3.25
Advice from others	4th	6.54, SD=2.83	1st	6.96, SD=2.29
Advice from people in the field	5th	6.20, SD=2.88	6th	4.54, SD=3.16
Exposure during career day	6th	6.17, SD=2.47	7th	4.17, SD=2.32
Exposure during a conference	7th	5.78, SD=2.32	5th	4.71, SD=2.71

The different weights the samples gave to the sources, which the rank order shows, suggests that advice from others, more than other external influences played the most important role in the foreign participants' decision to pursue the MS degree. The researcher computed the independent-samples t-test to determine if differences exist between the domestic and foreign participants. The t-test did not reveal any statistically significant differences between the samples on any of the external sources.

The importance of key individuals

Responses to question 13 on the survey provided the data to address this topic. The level of influence of eight individuals on the two samples' collective decision to pursue the MS degree was analyzed by assigning to the Very influential, Somewhat influential and Not influential options the 3, 2 and 1 values, respectively. Parents ranked as the most influential individuals for the domestic (M=2.08, SD=.805) and the foreign (M=2.50, SD=.739) samples. University professor ranked the second most influential individual for the samples, followed by friends, advisors, and other individuals. School teachers and counselors were ranked the least influential in the students' decision to pursue the MS degree.

The researcher computed means scores for the eight individuals. Subsequently, the independent-samples t-test was calculated to determine if differences exist between the means for the two samples. The two samples were statistically different in the level of influence of the parents [$t(107)=2.864$, $p<.05$], the level of influence of the college advisor [$t(101)=2.11$, $p<.05$], the influence of the

school teacher [$t(100)=2.74$, $p<.05$], and the influence of the school counselor [$t(101)=3.59$, $p<.05$]. In summary, the foreign and domestic participants ranked the order of influence of the individuals on the list very closely, but the foreign students gave higher scores to each individual than domestic students.

The factors that influenced decision to pursue the MS BME and MS CE

On survey item 14 the participants indicated the level of influence of 13 factors in their decision to enroll in the MS program. The complete list of factors appears on Table 4.9. The participants ranked each factor as Very important, Somewhat important, or Not important.

The domestic and foreign samples both ranked their own educational aspirations as the most important factor. Their desire to know improve their knowledge of engineering ranked second. Academic self-confidence ranked third and the desire to get a better job ranked fourth. Collectively, both samples indicated that financial aid was somewhat important. The participants also stated that their employers did not want or require that they obtain the MS degree.

To determine if the samples differed in the importance of each factor, the researcher computed the independent-samples t-test. The results showed that the domestic and foreign participants differed in the importance they gave to their parents' educational expectations [$t(108)=4.31$, $p<.05$], family moral support [$t(107)=4.56$, $p<.05$], the hope to get a better job [$t(108)=3.31$, $p<.05$], and the desire to earn more [$t(108)=2.85$, $p<.05$]. Briefly, the foreign students ranked the order of influence of the factors similarly to the domestic participants. The foreign students,

however, assigned a higher level of influence to each of the factors than the domestic comparison group.

Table 4.9. *Means Scores of Factors Important to Respondents in the Decision to Pursue MS*

	Sample	
Factor	Domestic	Foreign
Your educational aspirations	*M* = 2.85, *SD* = .361	*M* = 2.89, *SD* = .363
Your parents' expectations	*M* = 1.79, *SD* = .743	*M* = 2.39, *SD* = .701
Family moral support	*M* = 2.15, *SD* = .662	*M* = 2.68, *SD* = .543
The desire to deepen your knowledge of engineering	*M* = 2.75, *SD* = .434	*M* = 2.86, *SD* = .350
Self-confidence in your academic competence	*M* = 2.65, *SD* = .590	*M* = 2.82, *SD* = .428
The availability of financial aid	*M* = 1.98, *SD* = .828	*M* = 2.07, *SD* = .828
MS suggested by employer	*M* = 1.62, *SD* = .771	*M* = 1.62, *SD* = .733
MS required by employer	*M* = 1.37, *SD* = .658	*M* = 1.62, *SD* = .757
The ability to get a better job	*M* = 2.34, *SD* = .732	*M* = 2.74, *SD* = .483
The ability to earn more	*M* = 2.30, *SD* = .696	*M* = 2.65, *SD* = .582
There was nothing better to do	*M* = 1.30, *SD* = .575	*M* = 1.33, *SD* = .673
MS takes less time than PhD	*M* = 1.58, *SD* = .776	*M* = 1.70, *SD* = .768
To prepare for another degree	*M* = 1.66, *SD* = .783	*M* = 1.84, *SD* = .834

An open-response item on the survey asked the foreign participants to state why they chose to come to the U.S. for their master's degree. The participants reported that in their home countries, the biomedical field was severely under-developed at the industry and educational levels in comparison to the U.S. One respondent reported that electrical engineering faculty who lacked experience in biology taught BME. Another participant shared that in India only a few institutions offered MS BME because of the prohibitive cost of laboratory facilities. Consequently, the admission to the few BME programs was extremely selective.

Summary

The researcher collected all the completed surveys and separated them according to the participants' master program to form the MS BME and the MS CE samples. To address research questions one through four, the researcher used the MS BME and MS CE samples. The findings presented in this chapter supported some of the hypotheses formed early in the study and rejected others.

The MS BME and MS CE samples were representative of their populations in terms of gender, citizenship, and age. Significant differences existed between the two samples. The MS BME sample contained nearly twice the number of women in the MS CE sample. While foreign students made up the majority of the MS BME program, domestic students outnumbered foreign students in the MS CE sample. The MS BME participants were, on average, three years younger than the MS CE participants. Thus it appears that the MS BME participants waited less time to enroll in the master's program.

The overwhelming majority of the participants in the study had college-educated parents who worked in high-paying occupations. The combination of parental educational attainment and occupation allowed the construction of a composite SES variable. Only 15% of the respondents came from families that scored in the middle lowest quartiles of the SES scale. High score on the SES scale used in this study predicted enrollment in the MS BME and MS CE programs.

The participants attended mostly high-research activity, selective admissions institutions. The majority of the MS BME sample and one-half of the MS CE sample attended private institutions. The samples differed significantly in the undergraduate majors that participants earned. Nearly half of the participants in the MS BME sample earned a BS BME degree. Other engineering disciplines and science fields made up the rest of the MS BME sample. Most of the MS CE participants earned their BS in civil engineering. Surprisingly there were a few students in the MS CE sample who did not earn their degrees in S&E. The presence of science majors in both samples suggests that said majors may adequately prepare students for the MS BME and MS CE programs. Additionally, both samples indicated that they felt satisfied with their undergraduate institution. The participants also self-reported high undergraduate GPAs.

The MS BME and MS CE samples identically ranked the influences that sparked their interest in engineering. The three most important influences were undergraduate experiences, advice from others, and media, respectively. The

relatively-strong influence of media implies that these were effective methods of recruitment for the MS BME and MS CE programs.

Parents were the most influential individuals in the participants' decision to enroll in the MS BME and MS CE programs. University professors were the most important educational personnel in the participants' decision. University professors were an important source of recruitment for the participants in the study.

From a list of 13 factors that may have influenced the participants' decision to enroll in the MS BME and MS CE programs, intrinsic factors emerged as the most influential. Educational aspirations, the desire to become a better engineer, and academic self-confidence were the most important factors. The ability to get a better job, the hope for higher earnings, and family moral support were the most important extrinsic factors. The MS BME participants differed significantly from the MS CE group in that the former planned to use the MS degree to prepare for another degree.

To answer research question five the researcher sorted the surveys according to citizenship. Participants born in the U.S. comprised the domestic sample while participants born in other countries made up the foreign sample. The foreign students indicated that advice from people sparked their interest in engineering, followed by undergraduate experiences, and mass media. The domestic students, on the other hand, indicated that the undergraduate experience started their curiosity in the engineering field.

The foreign and domestic participants ranked the individuals that influenced their decision to enroll in the engineering programs identically. However, each

individual was given a higher score of importance by the foreign participants. The three intrinsic factors listed in the survey were the most important in the foreign and domestic participants' decision to enroll in the engineering programs. For the foreign students, the ability to get a better job and the family moral support factors were the most important external influences.

The next chapter, I discuss the findings in depth in the context of the literature on graduate engineering students and foreign students in engineering programs. I also make recommendations for how biomedical engineering programs might more effectively recruit and support their students. Finally, I suggest directions for future research.

CHAPTER 5

DISCUSSION

The participants in this study were amazing individuals – bright, ambitious, and enthusiastic about their fields of study. After reading the alarming reports of the poor condition of the engineering talent pipeline (NSB, 2002, 2008), it was comforting to see that many of these talented students hope to join the U.S. BME industry in the near future. Due to the relative novelty of biomedical engineering (BMES, 2007), limited research has been conducted specific to the master's degree in the field. The purpose of this study was to describe the MS BME and MS CE populations at a research institution in the U.S., to identify the factors that the students considered as they decided whether to enroll in their respective MS program, and to determine if foreign students differ from domestic students in their reasons for choosing to enroll in the MS program. The findings of this study provide information which can help engineering program administrators recruit more students to avert a shortage of such professionals in the U.S. industry.

The hypotheses to the five research questions reflected the findings of previous studies. The findings in this study affirmed or questioned themes that emerged from the literature. The next section reviews and addresses the hypotheses tested in the study at hand.

Hypothesis One: The Gender Make-up of the MS BME and MS CE Programs will Differ. The Parents of the Participants are College-educated, have High-paying Occupations, and Provide a High SES Environment for their Children.

The gender make-up of the two samples was different. While the National Science Board (2002) reported that women have low rates of participation in engineering programs at the graduate level, women account for 35% of the MS BME program enrollment. To put the figure in the context of the institution, MS BME attracted nearly twice the number of women as the other engineering disciplines (19%). Biomedical engineering program administrators should find this result encouraging as it suggests that women, collectively a minority population in other programs, have an interest in BME as a career.

The survey's citizenship question also revealed interesting findings. The MS BME attracted a larger proportion of foreign students than MS CE. According to the MS BME participants, the saturation of foreign students in the MS BME program may be the result of BME's under-development in many countries, extremely selective admissions at universities in the students' home countries due to a lack of BME programs, or inadequate industry-university collaboration in certain nations. As expected, nearly all of the foreign students completed their bachelor's degree outside of the U.S. This finding reflects positively on the quality of preparation provided by the foreign institutions represented in the samples for U.S. MS BME and MS CE programs.

Some researchers previously found that the influence of parental resources and parental socialization attenuated by the time individuals reached graduate school (Blossfeld & Shavit, 1993; Grusky, 2000; Mare, 1981; Stolzenberg, 1994). The over-representation of students with college-educated, white-collar job parents in the samples confirms that both sociological frameworks likely contributed to MS BME and MS CE program enrollment.

Hypothesis Two: Undergraduate Majors will be Different for the Two Studied Populations. GPA and Level of Satisfaction with Undergraduate Education will be high for both Groups.

The overwhelming majority of the participants who earned their BS degree in the U.S. attended research-based institutions. A comparison of the types of institutions attended by foreign students was not possible due to the lack of a world-wide system of institutional classification. Because foreign students accounted for the majority of the MS BME study participants and for the MS BME population, the types of institutions attended by the majority of this sample remains unanswered. This point will be explored further in the section of recommendations for future research.

As Dawson-Threat and Huba (1996) and Hearn (1980) found, the undergraduate major was a good predictor of career choice for the participants. The overwhelming majority (81%) of the MS BME participants earned a bachelor's degree in engineering. The remaining participants (19%) majored in the sciences. The homogeneity of undergraduate majors in S&E of the MS BME participants

suggests that students have only a few majors from which to choose to prepare for a career in biomedical engineering. This was contrary to the MS CE sample, in which several participants earned non-S&E BS degrees.

Ethington and Smart (1986) found that overall satisfaction with the undergraduate institution had a strong direct influence on graduate school attendance. The current study concurs with those findings. Overall, both samples indicated that they felt satisfied with their undergraduate institution. The clear pattern of satisfaction across the samples should prompt institutions to provide quality student services at the institutional level. Good student services may, after all, stimulate the students to pursue a graduate degree at the same institution.

Hypotheses Three and Four: Family Support, Self-confidence, Degree Requirements by Employers, Financial Aid Availability, the Amount of Time Required to Complete the Degree, the Prospect of Getting a Better Job are Significant Considerations for Students when they make the Decision to Enroll in MS BME and MS CE Programs. The Reasons provided by the Students in the MS BME Program are Significantly Different to those stated by the MS CE Students.

Internal sources-such as educational aspirations, the desire to know more about engineering, and self-confidence in academic competency-influenced the students to enroll in the MS BME and MS CE programs more than external sources like family, educational personnel, financial aid and employment-related factors. Ethington and Smart (1986) found that educational aspirations contributed to graduate school enrollment. The participants in the current study stated that their

own educational aspiration influenced their decision to pursue the MS degree more than any other factor. However, it remained unclear from the results whether parental socialization indirectly or directly contributed to the participants' educational aspirations. The desire to learn more about engineering, another internal factor, was the second most important factor. Similar to the findings of Einarson and Santiago (1996), the participants had high self-confidence in their academic competence.

For the participants, the influence of parents outweighed that of university professors and advisors in the decision to pursue the MS degree. School teachers and counselors were the least influential for the participants. The magnitude of parental influence suggests that parents should be informed of the benefits of a graduate degree in BME and CE and of the master's programs available at the institution.

The undergraduate experiences were the most influential source of interest in the engineering field for the participants. MS BME sample decided to pursue the master's degree during the freshman and sophomore years, while the junior and senior years were critical for the MS CE group. Engineering recruitment officers may want to re-think whether a one-key-fits-all approach is the best approach for the two populations.

Financial aid, contrary to the findings of Ethington and Smart (1986), did not play a major role in the students' decision to enroll in MS BME or MS CE. Consistent with McMahon and Wagner (1981), the participants cited the hope to get

a better job and earn more money as important factors. In the current study, no evidence supported the claim that employers required or suggested that the participants get a master's degree. This finding must be taken with caution because the participants did not indicate whether they currently work in industry. The participants' response may reflect a perception rather than factual knowledge.

The results showed that the MS BME and MS CE samples have more similarities than differences in the reasons they provided for pursuing the MS degree. The participants were identical in the internal sources dimension. In the comparison of the influence of key individuals, the samples ranked the individuals identically. The participants ranked the external sources of influence on their decision similarly.

The MS BME and MS CE samples differed only in one of 12 external factors. Considerably more MS BME participants reported that they planned to use the MS to prepare for another degree. This finding causes concern as some of the participants did not plan to join the biomedical engineering industry and others plan to do research, rather than development, in BME.

Hypothesis five: There are Significant Differences in the Reasons provided by the Domestic Students and the Foreign Students.

In the comparison of domestic and foreign students, both samples reported that educational aspirations, the desire to learn more about engineering and self-confidence played a larger role in their decision to pursue the MS degree than external influences. The undergraduate experiences factor was chosen as the most important in starting the foreign students' interest in engineering. This finding

makes sense since the majority of the foreign students reported that they decided to get a master's degree in engineering during the undergraduate years. Although college was an important period for the domestic students, many reported that they decided to get the MS degree after their college graduation. The employment-related factors were the most important external influences for both samples.

For the two samples, parents emerged as the most influential individuals in the decision to enroll in the MS degree. Parents had a higher degree of influence for the foreign than for the domestic participants. University professors were also influential figures for the participants. Other educational personnel exerted a smaller influence on the participants than peers, although the foreign participants indicated a higher degree of influence from teachers and counselors than the domestic comparison group.

As suspected, many foreign students indicated that they came to the U.S. to study engineering because they wanted to further their knowledge of engineering and their home countries lacked in quality and quantity of programs and industry, particularly in biomedical engineering. The foreign students acknowledged that the United States' world-leader status in biomedical engineering technology and devices lured them to leave their home countries. Many of the foreign students also wanted to work in the U.S. biomedical engineering industry after completing the MS degree. The NSF (2008) confirms this finding. The intention of many foreign students to work in the U.S. has far-reaching implications, as they broaden the talent pool available to the U.S. biomedical engineering industry.

Summary

Several noteworthy points emerged from the current study. The study determined that the MS BME program attracted a significantly higher proportion of women than MS CE. Many more foreign students enrolled in the MS BME program than domestic students because many foreign institutions lack the professional talent and facilities to adequately train engineers for the BME industry. The majority of the MS BME participants plan to work in biomedical engineering in the U.S. after graduating from the master's program. Overall, the participants have parents who attended college and hold high-paying jobs. On the composite SES variable constructed from four indicators, the majority of the participants scored in the high SES quartile.

The participants' graduate degree specialization somewhat accurately predicted their undergraduate major. Enrollment in the two master's programs predicted satisfaction with the undergraduate institution. Several participants expressed that their undergraduate training was less than perfect and made recommendations for undergraduate program improvement.

Internal factors such as educational aspirations, the desire to learn more about engineering and academic self-confidence were the most influential in the participants' decision to enroll in the MS programs. Parents, followed by university professors, were the most influential people in the participants' decision. Undergraduate experiences were the most important factor in sparking an interest in engineering for the participants. Broadly speaking, the MS BME sample did not

differ much from the MS CE comparison group. One salient difference was the view of the MS BME participants of the master's degree as a springboard to their ultimate degree objective. Several MS BME participants aspired to doctor-level careers.

Foreign students, for the most part, resembled domestic students in the strength of internal and external influences. Specific differences included the higher importance given by the foreign students to key individuals, parental educational expectations, family moral support and economic advantages from earning a master's degree.

Implications

The findings of the current study produce several important recommendations for action by university and engineering program administrators, as well as implications for future research. This research study acknowledges the importance of the MS BME students and programs to the labor needs of the U.S. biomedical engineering industry. The study is also a first attempt at understanding how the MS BME students learn about educational and career opportunities in biomedical engineering to develop effective recruitment and outreach efforts. To sustain the rate of growth expected in the BME field, engineering program administrators must actively recruit highly-qualified students who show commitment to engineering.

Clear gender and citizenship patterns emerged from the results of the study. These findings have profound implications for the currently-shorthanded biomedical industry. Previous research has indicated that many women do not major in engineering because they do not see how engineering betters society (Sax, 2001).

BME program administrators should investigate the reasons why women in MS BME chose their undergraduate and graduate major.

From the findings of this study, it is impossible to pinpoint the reasons why women chose biomedical engineering. One explanation is that the women in the program believed that biomedical engineering contributes to society more than other engineering disciplines. The presence of women in the program may have also occurred because the biomedical engineering program culture is warm to them. Umbach and Porter (2002) and Clark (1987) argued that academic departments have their own cultures. The academic discipline-created cultures reflect the technologies, work patterns and philosophies of their respective occupations (Clark, 1987). Engineering program administrators may want to study the BME department cultures and compare it across engineering departments to find similarities and differences.

The undergraduate experience, which participants in the study cited as a principal contributor to the decision to go into the MS program, can influence a student's educational aspirations (Pascarella, 1984). Since most of the participants earned the BS degree in the same major as their MS, it is possible that the participants had high educational aspirations and pursued the master's degree in a familiar field. The women in the program have made observations and lived experiences that might offer insight to practitioners.

The demand for industry-ready biomedical engineers in the U.S., the supply of foreign students who want MS BME training and the desire of many foreign students to work in the U.S. have implications for the U.S. BME industry and IHEs.

U.S. policymakers must weigh the advantages and disadvantages of training high proportions of foreign students in field such as BME. This study found that the majority of the foreign students of the MS BME program intended to work in the biomedical engineering industry. If the U.S.-trained foreign students work in the U.S. BME industry, they become a resource to our economy. At the same time, policymakers must determine if the over-representation of foreign students in engineering programs is due to a lack of interest in the part of domestic students or if U.S. students lose the admissions competition to foreign students.

For IHEs, the presence of foreign students in the MS BME program brings cultural diversity and financial resources to the institution. However, does the institution have to invest disproportionate financial and personnel resources to recruit and provide services to the foreign students? Engineering administrators should conduct a cost-analysis study to determine the cost of training domestic and foreign students.

According to the NSF (2008), graduate engineering enrollment has decreased in the last two years due to foreign student enrollment. IHEs should view domestic ethnic minority populations as potential clients. Blacks and Hispanics collectively account for only 10% of MS degrees in science and engineering (NSB, 2008). Because a significant portion of these populations begin their college journey in community colleges (Bailey, 2004), universities should make efforts to reach out to minority students by improving the transition to four-year institutions for community college students.

The early start of recruitment efforts is particularly important for the MS BME program. This study found that nearly 40% of the master's students in biomedical engineering decided to pursue a MS degree before the start of the junior year in college. For 75% of the civil engineering students, the decision to get a master's degree was made during the junior year of college and later. Thus, it appears that the optimal recruitment time for engineering students is a moving target and a one-key-fits-all approach may not work across all engineering disciplines.

Engineering program administrators should also look at students who earn undergraduate degrees other engineering disciplines and in the sciences with renewed fervor, as many of such students have the skills but lack the knowledge that they can go on to a career in engineering. Advisors in the sciences should begin to see a degree in science as a pathway to engineering. Awareness by both groups of practitioners may result in a larger interest in biomedical engineering and bring cross-discipline, gender, and ethnic diversity into graduate engineering programs.

The pivotal role parents played in the participants' decision to enroll in the master's programs suggests that engineering program administrators should reach out to parents during their children's undergraduate years. With minimal expense to engineering departments, parents can become recruitment assets. If departments wish to launch a robust parent marketing plan, departments may need to learn a set of skills that student services personnel currently lack. It may be necessary for practitioners to enlist the help of personnel who work with parents on a regular basis, possibly staff from the institution's alumni association or the development office.

Given the small percentage of under-represented minorities that earn master's degrees in engineering, the marketing plan should target these parents. To effectively reach the intended audience, the marketing effort may need to extend to a variety of advertising media and languages.

Professors are influential in BME and CE students' decisions to go into a master's program. Engineering departments should establish faculty teaching workshops, in which education researchers can present information regarding effective teaching practices. The goal of these cross-discipline workshops is to help engineering faculty continue to make more of their students good engineers in a challenging, yet rewarding way. Institutions should create as many opportunities as possible for students to interact with faculty. Such interactions increase students' satisfaction with the undergraduate institution (Astin & Astin, 1993; Kuh & Hu, 2001). Engineering faculty members should also impress upon students the importance of a graduate degree in engineering to meet industry's employment requirements.

Biomedical and civil engineering master's students reported that their undergraduate degree did not build all the skills necessary for the MS degree. Several participants expressed that they wished that their undergraduate program had prepared them better in the use of the MATLAB statistical software and applied theory. Since most of the students in the MS BME and MS CE programs came from research-based institutions, the undergraduate curriculum should align with the master's program skills requirements. Students should receive exposure to all the

skills necessary for the master's program during the undergraduate years. The knowledge that their undergraduate education prepared them for the master's program may improve the students' self-confidence in their academic competence.

The biomedical and civil engineering students reported that the events that least contributed to their interest in engineering were conferences and career day. Engineering program administrators may want to double their efforts in hosting events, such as one-day conferences or assemblies, and invite high school, community college and undergraduate students to raise their awareness of engineering programs at the institution. The conference will require a partnership with high school and community college administrators to yield a high student turn-out. Engineering faculty and students should participate in the events to present their research and testimonials, respectively.

Suggestions for Further Research

As stated previously, this study marks the first step toward understanding the biomedical engineering population. The current study focused on students pursuing the master's degree. Future research studies should examine the same variables with undergraduate and doctorate-level biomedical engineering students, paying particular attention to women and foreign students in the programs. The understanding the entire biomedical engineering talent pool may enhance the ability to guide committed students through the BME educational pipeline.

Another available research opportunity is the use of qualitative methods to explore in greater detail the factors that brought the student to pursue a master's

degree in BME. This study collected the information through a survey. The natural flow of conversation may yield further information of the variables measured in the current study. To cite an example of a limitation of the survey in this study, the respondents chose from a list of factors and rated the level of importance of each. It is possible that some participants did not find the list of factors exhaustive. A more in-depth analysis may provide greater insight into the factors that mattered for the MS BME population.

The current study measured the variables of students enrolled in MS BME and MS CE. Future studies may want to compare the variables measured in this study for undergraduate students who choose not to go on to a graduate program in biomedical engineering. Said information will inform engineering program administrators of the factors that contribute to the decision not to pursue a graduate degree in BME and possibly design intervention programs to prevent this loss of potential graduate students.

The current study asked students to state their level of satisfaction with their undergraduate institution. Gwinner and Beltramini (1995) defined satisfaction as the difference between a student's expected institutional and departmental services and the actual services received by the student. Institutional services may include basic services such as housing, dining, recreational and classroom facilities as well as granular services like music download privileges. Departmental services may include faculty-student interactions, quality of advisement services and quality of the curriculum. This study only measured overall satisfaction. Future studies should

measure the students' level of satisfaction with the various components and determine the relationship of each satisfaction unit to the whole.

In this study, the participants indicated that the most influential educational figure was the university professor. Professors interact with students during orientation, advisement sessions, class time, laboratory, office hours, directed research, student organizations and others. It is unclear from this study which type of interaction contributed to the formation of the influence of professors on students. Future studies should explore each of these interactions in depth.

Future studies should also investigate the stay rates of foreign students who graduate from MS BME programs. This study asked students to state their professional plans after graduation. Many students indicated that they wished to stay and work in the U.S. However, the students' plans may change as they approach graduation. While the NSF (2008) monitors the stay rate of doctorate-level foreign students, no such effort has been made for the master's level population.

Conclusion

Overall, the current study adds to the literature that addresses the recruitment of engineering students, specifically for the relatively-new biomedical engineering field. This study described the MS BME population and identified the factors that the students considered in the decision to pursue the master's degree. The study also compared the MS BME participants to those in the MS CE program. Additionally, the study compared the factors identified by foreign students and compared them with the factors cited by domestic students. It is the hope of the researcher that the

study provided valuable information that can improve the recruitment efforts of master's level biomedical engineering students.

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APPENDICES

Appendix A

Recruitment Email Message from Academic Advisors

Dear Student,

I hope you are on your way to an academically challenging and rewarding semester. I would like to request your assistance with an important Civil Engineering program evaluation study. Please take a few minutes (about 15-20 minutes) to share your input about your educational experiences and your next professional steps using the SurveyMonkey link below.

http://www.surveymonkey.com/s.aspx?sm=uW0BJ6aZ0NRViWL2Jwux_2fQ_3d_3d

Please note that your participation is voluntary. You may quit the survey at any time, although I would prefer that you answer all questions. Your answers will not be identified individually in the findings and will be helpful in informing program practice for future students at USC.

If you have any questions about this survey, please contact the researcher directly at fjc@usc.edu. Again, thank you very much for your helpful input.

Appendix B

Survey of Master of Science Students in Biomedical Engineering (MS BME) and Civil Engineering (MS CE) Programs

Thank you for taking a few minutes to complete this survey. Your responses will be helpful in strengthening university practice for future students at the university. All answers will remain anonymous and any reporting of our findings will be provided only in the aggregate, so please be candid in your responses.

1. Did you earn your bachelor's undergraduate degree in engineering?

- ☐ Yes
- ☐ No

2. In which engineering field below did you earn your bachelor's or undergraduate degree?

- ☐ Aerospace engineering
- ☐ Biomedical engineering
- ☐ Chemical engineering
- ☐ Civil engineering
- ☐ Computer engineering
- ☐ Electrical engineering
- ☐ Manufacturing engineering
- ☐ Systems engineering
- ☐ Other

3. If you did not earn you bachelor's degree in engineering, in what field or discipline did you get your bachelor's or undergraduate degree?

- ☐ Biology
- ☐ Chemistry
- ☐ Physics
- ☐ Mathematics
- ☐ Other (please specify _____)

4. Please type the year you completed your bachelor's or undergraduate degree.

_____

5. Where did you complete the educational levels listed below? (Please select one option for each educational level).

	United States	Another country
High School		
Bachelor's degree		

6. Please provide the name of the institution where you earned your bachelor's degree.

7. Please rate your satisfaction with the college from which you earned your undergraduate degree.

- ☐ Very satisfied
- ☐ Satisfied
- ☐ Unsatisfied
- ☐ Very unsatisfied
- ☐ Not sure

8. What was your undergraduate GPA?

9. If there were no obstacles, what is the highest degree you would like to attain in your lifetime? (Mark one)

- ☐ Master's degree in engineering
- ☐ Other master's degree
- ☐ PhD in engineering
- ☐ PhD in another field
- ☐ Another doctorate degree

10. What specialization in engineering are you pursuing at this time? (Mark one)

- ☐ Civil engineering
- ☐ Biomedical engineering

11. Please rate your satisfaction with your education at your current institution so far. (Mark one)

- ☐ Very satisfied
- ☐ Satisfied
- ☐ Unsatisfied
- ☐ Very unsatisfied
- ☐ Not sure

12. Below are some sources that might have started your interest in the engineering field. On a 10-point scale, please indicate the importance of each source. (Mark one answer for each source)

News (television, radio, internet, magazines, professional publications, job bulletins)
Exposure during undergraduate education
Exposure during an internship
Exposure during a conference
Exposure during college day or career event
Advice from people in the field
Advice from others
Do not recall

13. When did you decide that you would get a master's degree in engineering? (Mark one)

In middle school
In high school
In my 1st year of undergraduate studies
In my 2nd year of undergraduate studies
In my 3rd year of undergraduate studies
In my 4th year of undergraduate studies
After graduating from college
After graduating from college and working in the engineering field
After graduating from college and working in another field

14. How influential were the individuals below in your decision to pursue a master's degree in engineering?

	Very influential	Somewhat influential	Not influential
Father			
Mother			
School teacher			
School counselor			
University professor			
College advisor			
Friend			
Other			

15. In deciding to pursue a master's degree, how important was each of the following reasons. (Mark one answer for each possible reason)

	Very important	Somewhat important	Not important
Your educational aspirations			
Your parents' expectations			
Family moral support			
Your desire to improve your engineering knowledge			
Self confidence in your academic competence			
The availability of financial aid			
Master's degree suggested by current employer			
Master's degree required by current employer			
The ability to get a better job			
The ability to make more money			
There was nothing better to do			
Master's degree takes less time than a doctorate degree			
To prepare for another degree.			

16. Did you attend your current institution before enrolling in the master's program?

- ☐ Yes
- ☐ No

17. How important were factors below in your decision to attend USC for the master's degree program in engineering? (Mark one answer for each factor listed)

	Very important	Somewhat important	Not important
Reputation of the institution			
Engineering department reputation			
Engineering faculty research areas			
Specialization areas offered by the department			
Financial aid quality from the university			
Financial aid from your engineering department			
Financial support from employer			
Proximity to your home			
Proximity to your job			
Distance education course offerings			

18. Please mark which types of financial assistance, if any, you are currently receiving. (Mark all that apply)

- ☐ University scholarship or grant
- ☐ Viterbi School of Engineering scholarship or grant
- ☐ Engineering department scholarship or grant
- ☐ Employer sponsorship
- ☐ US federal government loan
- ☐ Other

19. Now that you are in a master's program, what else do you wish you had learned or mastered as an undergraduate that would help you in this master's program?

20. What is the highest level of education reached by your parents either in the U.S. or in another country? (Mark only one per column)

	Father	Mother
Elementary school (up to 5th grade)		
Middle school (up to 8th grade)		
High school (up to 12th grade)		
Some college		
Earned bachelor's degree		
Earned master's degree		
Earned doctorate degree		

21. While you were growing up, mark the job that best describes your parents' main occupation. (Mark only one in each column)

	Father	Mother
a. Retired		
b. Day laborer (cleaning, construction, farm, factory)		
c. Worker or hourly employee (service, hotel, hospital, truck driver, sales, maintenance)		
d. Factory worker (manufacturing, ware-housing, shipping, operations)		
e. Skilled tradesman (machinist, plumber, electrician, auto mechanic, secretary, nurse, technician)		

f. Supervisor or manager (professional)
   Professional (doctor, lawyer, engineer, accountant, teacher)
g. Business owner
h. Housework (taking care of children at home)
i. Unemployed
j. Do not know

22. Please indicate the educational level you think each parent expected you to achieve (Mark only one in each column)

	Father	Mother
Elementary school (up to 5th grade)		
Middle school (up to 8th grade)		
High school (up to 12th grade)		
Some college		
Bachelor's degree		
Master's degree		
Doctorate degree		

23. What type of occupation did your mother express as a goal for you, if any? (Example: doctor in medicine, lawyer, banker)

24. What type of occupation did your father express as a goal for you, if any? (Example: doctor in medicine, lawyer, banker)

25. Please indicate your gender.

26. What year were you born?

27. Are you a U.S. citizen?

- ☐ Yes
- ☐ No

28. After completing your current degree program, what is your next professional step? (Mark one)

- ☐ Work in engineering in the U.S.
- ☐ Work in engineering in another country
- ☐ Pursue another degree in the U.S.
- ☐ Pursue another degree in another country

29. Are there any other factors that influenced your enrollment in the master's program in engineering?

30. If you have questions regarding the study, or if you would like to receive the results of this investigation, please provide your email address below.