WOMEN AND ENGINEERING: A CASE STUDY

OF A BIOLOGICAL AND ENVIRONMENTAL ENGINEERING PROGRAM

by

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A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Philosophy

Capella University

November 2006

UMI Number: 3243588

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Abstract

This case study focused on the lack of sufficient female participation in the engineering disciplines and the reasons for the apparent gender balance that has occurred in a biological and environmental department at a major engineering university. Other universities, in their engineering programs still enroll only an average of 20% women. Scientific technologies are vital for global and economic sustainability, yet the number of emerging engineers does not maintain parity with the need. Engineering technologies are not attracting the female portion of the population. The country's deteriorating infrastructure, degraded environment, and the threats to the nation's security have provoked a national concern. Three research questions are addressed in this case study: Why has the biological and environmental engineering program at a major engineering university attracted a greater percentage of female participants than the other engineering disciplines? What are the attributes of a biological and environmental engineering program that are attractive to women? and How can these attributes be used to inform other areas of engineering in all universities in moving toward gender balance? A questionnaire, live interviews, and the examination of relevant university documents provided the sources of evidence toward the understanding of this issue.

Dedication

This dissertation is dedicated in memory of my father, Arthur D. Ruggiero

Acknowledgments

This work could not have been completed successfully without the expertise, encouragement, and support of my mentor, Dr. Kate Emmons and the additional support of the committee members Drs. Kate Green, and James Onderdonk. Without the support and participation of Cornell University, Dr. Michael Walters, Department Chair of the Department of Biological and Environmental Engineering (BEE) and BEE professor, Dr. Michel B. Timmons, this project would not have been possible. Additionally, Brenda Marchewka, coordinator of undergraduate and graduate studies needs to be thanked for her willingness to provide all sorts of administrative and departmental support. I would like to thank Claire Stancarone, my daughter and Eddie Gomez, my dear friend who supported me throughout this project with their encouragement and faith that I could really do this. And lastly, I give my heartfelt thanks to the wonderful BEE women who offered their time in the interest of equity in engineering.

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CHAPTER 1. INTRODUCTION TO THE STUDY

It is hard to imagine a time when women, as a group, were denied the right to vote, own property, and yes, had restricted access to many colleges and universities, strictly on the basis of their gender. Many universities maintained quotas, wherein girls were denied access to vocational courses and females, both schoolteachers and students, had to resign when married or leave school when pregnant. All of this changed with the passing of Title IX, the 1972 Education Amendment. Title IX is the amendment to the Civil Right Act of 1964 that required that any educational facility that received federal funds must take steps to eliminate, prevent and address sex discrimination.

The Title IX education amendment made it illegal to discriminate in the educational domain based on gender. The amendment stated that "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance" (20 U.S. Const. Amend. IX, 1972). Since the passing of this landmark legislation, women have made major gains in fulfilling dreams of higher education. Women earn more degrees than men in some science fields (Burton & Wang, 1999). Title IX has had a profound impact on helping to change attitudes, assumptions and behavior toward women in higher education and consequently, our understanding about how sexual stereotypes can limit educational opportunities (U.S. Department of Education, 1997).

The enactment of Title IX, the publication of "A Nation At Risk" (1983), and the National Science Education Standards (National Research Council [NRC], 1996), Goals 2000, and the 2001 No Child Left Behind legislation all have added further commitment to resolving issues of gender equity in education.

More than 30 years later, however, women are still grossly underrepresented in certain male dominated fields, such as engineering. Eighty-one percent of students surveyed have experienced sexual harassment, girls and women still cluster in training programs traditionally set for females, 21% of all full professors at colleges and universities are women, women receive only 20 % of computer science and engineering related technology bachelor's degrees, and females receive less attention, less praise, less constructive criticism and less encouragement from teachers than male students receive (Sadker, Sadker, & Klein, 1986). Despite changes in the law, additional reform efforts are required to move toward gender balance and provide equity in the areas of science and math. Physical science and engineering are still areas in which the number of females significantly lags behind the number of males in enrollment, in degrees awarded and those employed in the industry.

In 1992, the American Association of University Women (AAUW) Educational Foundation issued an executive report titled *How Schools Shortchange Girls*. This executive report provided evidence that females are often ignored in classrooms and neglected in the curriculum. Shortly before the start of the millennium, a new look at gender gaps examined how far our country had come in overcoming inequity. By 1998, females had made strides and most likely had received a fairer education than in 1992 (AAUW, 1998). The goal of equitable education is still elusive, but closer. "A competitive nation cannot allow girls to write off technology as an exclusively male domain. Teachers will need to be prepared for this issue" (Ford, 1998, p. iii). AAUW highlighted new areas of concern: teacher education, transition from school to work issues and educational reform; including professional development needed to address this issue on all levels of education. Some engineering schools have already begun to address these issues.

Despite the problems in gender balance, there are cases where certain engineering departments have achieved gender balance (approximately 50-50 male-to-female ratio), in particular, the Department of Biological and Environmental Engineering at Cornell University (Cornell University, 2006a).

This study examined a biological and environmental engineering program as a new kind of engineering program, one that has a greater appeal to females' decision to enter the field of engineering. It will identify the characteristics of biological and environmental engineering that enhance its appeal to women. It will discuss how these characteristics might be used to inform and promote change in the traditional engineering educational model. These changes might then encourage and support a more gender-balanced population in the other areas of engineering. This chapter includes an introductory statement, problem statement, background, purpose, rationale, research question, significance of the study, definitions of terms, limitations and assumptions, nature of the study, and organization of the study.

Statement of the Problem

There is a growing need for engineers during this time of extreme shortage of skilled technical U.S. workers. It is estimated that by 2008, the United States will need 1.9 million engineers and workers in the sciences (National Science Board [NSB], 2002). "Years of declining investment and fresh competition from abroad threaten to end US supremacy in scientific innovation" (Hart & Rudman, 2002, p. 26). In the report *America—Still Unprepared, Still in Danger*, issued after the September 11th attack on the United States, former senators Gary Hart and Warren Rudman stated that "the inadequacies of our system of research and education" posed a threat to U. S. national security greater than any potential conventional war that we might imagine (p. 26).

In civil engineering alone, there is already a crisis. The American Society of Civil Engineers has assigned a grade of D to the nation's infrastructure in their 2005 report card. "The condition of our nation's roads, bridges, drinking water systems and other public works has shown little to no improvement since they were graded an overall D+ in 2001, with some areas sliding toward failing grades" (American Society of Civil Engineers, 2005, p. 1). Furthermore, Americans are painfully aware of the limitations facing the nation's long-term oil supply, but may not be aware of the dwindling supply of petroleum engineers (Richards, 2004).

Gender Balance

Despite the fact that by the year 2008, many engineers will be needed to solve a multitude of global, economic and national security problems, engineering continues to be a career choice that few females make. Kessler reported that "the number of undergraduates (males and females) signing up for computer degrees is falling fast, making IBM and other tech companies worry that there soon will not be enough skilled U. S. workers to meet the demand" (2005, p. 1). This lack of skilled workers can easily be remedied by encouraging more females into traditional engineering programs, like computer engineering.

Although efforts have been made to encourage a more balanced gender environment, the pool hovers at the 20% mark in some of the traditional engineering disciplines such as electrical, mechanical, and computer engineering. Munshi (1999) noted that environmental, chemical and civil engineering continue to attract most females. The percentage of females is 48.9%, 44.1%, and 21% respectively in those disciplines. “Women’s failure to choose, and attrition, or failure to persist, in engineering and other nontraditional curricula, results in their continuing plight with occupational segregation and wage discrimination” (Graham, 1997, p. 3).

Women represent about 46% of the total workforce, but only 12% of the math, science, and technology (Janowski, 2004). The female student population would provide a viable and abundant source of candidates for these technologies. Presently, females are not encouraged to enter these fields. The fact that there is a low participation of females in the engineering professions represents an inequitable societal concern. As long as institutional and societal discouragement exists, then the value of equity has not been served and the pool of potential engineers has not increased.

Women are still heavily clustered into a narrow range of careers considered gender suitable by this society, and therefore, earn less than men (U.S. Department of Labor, 2005). Major strides have been made to achieve gender equity in previously male dominated careers, like medicine and social science. Since the enactment of Title IX legislation, many previously male dominated fields, such as law, medicine, dentistry, and veterinary medicine have already approached gender-balance. The areas of engineering, however, are still predominantly male.

In the past 30 years, many scientific careers have achieved gender balance. According to the NSF (1999), women represent more than half of all sociologists and psychologists. Yet, engineering is still considered a nontraditional career for women. Nontraditional is defined as any career where women's participation is less than 25%.

The participation of women in engineering programs appears to have improved since 1991. The National Science Foundation (2001) stated that compared to 1991, female graduate students in engineering have climbed from 12% in 1991 to 20% in 2001. While the number of women entering engineering programs has increased, those entering the engineering workforce (9%) are still extremely low.

The movement toward gender balance in engineering emerged as a priority in the 1970s. In 1975, 2% of Bachelor's degrees, 2% of Master's degrees, and 2% of the Doctorates in engineering were awarded to women (Society of Women Engineers [SWE], 2001). An examination of enrollment and degree statistics showed significant gains from 1980 to 2000. However, it appears that enrollments and degrees granted have stalled at approximately 20% (Leventman, 2001).

Salaries/Enrollment

Careers in science and engineering are lucrative. Salaries for engineers are among the highest. Beginning salaries for entry-level engineers with a Bachelor's degree are in the $67,000 to $93,000 range. This means that the largest portion (two thirds) of the workforce, which includes women, minorities and the disabled, continue to be isolated from these lucrative careers (IMDiversity, 2002). Table 1 illustrates participation in the sciences by gender, as noted by NSF (2001).

Table 1. Participation in the Sciences by Gender

Sciences	Women	Men
Agricultural sciences	8,491	8,976
Biological sciences	37,084	25,005
Computer sciences	11,900	31,284
Mathematics	5,497	5,958
Physical sciences	7,533	10,598
Psychology	57,467	16,701
Social sciences	62,697	51,757
Engineering	11,914	47,344
Other non-science and -engineering fields	519,042	338,400

By the next decade, there will be a shortage of women in some of these fields (computer science, physical science, and engineering). At present, there are not enough Americans to fill all of the engineering and technology positions available. All nations are facing shortages as well. If the workforce that consists of women, minority and persons with disabilities were to become engineers, then all of the jobs might be filled.

Despite the fact that there is a low rate of participation of females in traditional engineering technologies, biological and environmental engineering technologies are attracting women worldwide, from many cultures and from many socioeconomic groups. Lessons learned from biological and environmental engineering may provide the insight into how more female participation can be cultivated toward the traditional engineering technologies.

What types of strategies can the educational environment employ in order to encourage more females into these creative, satisfying and lucrative careers? What is needed is a greater understanding of what attracts more females into these careers and how to retain them in the engineering pipeline.

Background of the Problem

The reason for the low rate of participation of women in male dominated science careers has been the discussion of sociologists, psychologists and educators for decades (Caplan, Crawford, Hyde, & Richardson, 1997). This lower rate of participation can be attributed to the following influences: biology (differences in cognitive functioning), culture, religion, bias and stereotyping, societal concerns, a view of engineering as unattractive, and other attrition issues. Examining attrition is one way toward finding a solution to the problem.

Attrition

Attrition in engineering is a serious problem nationwide (Kline, 1991). Attrition, in this context means the gradual reduction of a population from the engineering academic environment. Many engineering students (males and females) do not make it through their freshmen year. Approximately 50% of the students entering an engineering program leave before graduation with a large part of this attrition occurring during freshman year (Felder, 1998).

Students leave for various reasons. These include: poor grades, rigorous math and physics courses for which they are not prepared, many prerequisites that are necessary before any engineering courses begin and the lack of relevant and hands-on experiences (real world) for which they came into engineering in the first place (Kline, 1991). Kline continued that real-world training appeals to both students and industry. Scalise, Besterfield-Sacre, Shuman, and Wolfe (2000) cited reasons for attrition including:

Loss of interest in engineering and an increased interest in other majors.

1. Poor teaching by engineering faculty
2. Overwhelming pace and load of engineering programs
3. Discouraging engineering grading systems

The attrition of women from science is well documented ("Women In Science and Engineering," 2005). Although both men and women leave the pipeline along the way, studies have repeatedly shown that a higher percentage of women leave the science and engineering fields, especially during the undergraduate years in what is known as the "weeding-out" period.

The reasons for analyzing engineering student retention include:

1. Increased demand for engineers by industry
2. Decreasing engineering enrollments
3. Large attrition rates in engineering programs
4. Recruiting costs are often greater than retention costs
5. Retention rates may be used for benchmarking
6. Required for accreditation purposes. (Scalise et al., 2000, p. 1)

Is it Biology?

Some proponents of the cognitive functioning differences theory believe that the higher percentage of female attrition in engineering programs is a matter of biology, although a wide body of knowledge no longer supports this theory (Caplan et al., 1997). Are females just not smart enough to handle the cognitive demands of engineering? Is there "not enough talent at the high-end" (Summers, 2005, p.1)? For more than 100 years, psychologists and the general public have been fascinated with the notion that there are gender [biological] differences in cognitive abilities (Hyde & McKinley, 1997). The central argument that underlies much of the research is the belief that there is a substantial difference in the cognitive functioning of men and women that translates into degree choices that females make in science and engineering.

The psychological differences in cognition between the sexes have been debated and analyzed for decades. The real or perceived differences in cognition are thought to support the reason for academic success and career choices, especially in engineering, that both males and females make regarding math, science and engineering.

The *Dictionary of Psychology* states that *cognition* is "a general term covering all the various modes of knowing; perceiving, imagining, conceiving, judging, reasoning" (Drever, 1952, p. 42). The domains of cognitive functioning receiving the most focus in this context are mathematical, spatial and verbal abilities. The specific aspects of this discussion in regard to cognitive functioning are that men outperform women in the domains of mathematical and spatial abilities and that women outperform men in the area of verbal abilities.

Since contemporary scientists understood that intellect originated from the brain, the brain was the first place that scientists looked for evidence to support these assumptions and expectations. There are visible differences in the brain structure of men and women. The male brain is indeed both larger and heavier than that of the female brain. Despite these findings, research has determined that the physiological differences between the brains of men and women do not support the underrepresentation of women in engineering (Caplan et al., 1997). Investigation, therefore, of other possible reasons for this low participation need to take place.

The general perception is that females do not belong in these occupations; it is for males. Boys are taught to tinker and girls to nurture (Leventman, 2001). The notion that males excel in mathematics, science and technology, and that females excel in the arts and humanities are two of the many beliefs and cultural influences that have been passed down through generations (Sanders, 1997). There are no significant differences between boys' and girls' math achievement in elementary school, and few differences at any age (Feingold, 1988). These between-gender differences are generally quite small compared to variability within each gender and compared to the stereotypes that many people hold (Gutbezahl, 1995).

As small as the differences are however, parents and teachers persist in believing that these differences are quite significant and are a result of biology or a "math gene." These attitudes become even more exacerbated in that the adults do not realize that they begin acting upon them and making decisions based on them. Because of these prevailing attitudes, as students move throughout the K-12 and higher educational environments, female students tend to drop out; they switch majors, which promoted the coining of the phrase "leaky pipeline." The term *leaky pipeline* is a concept that has been used to refer to the steady attrition of girls, women and minorities throughout the formal science and technology system, from primary education to science and technology decision making (Gender, Science and Technology [GST] Gateway, n.d.).

Research consistently shows that girls start out on an equal footing with boys in their interests and abilities in scientific and mathematical fields. Girls begin school looking like the “favored sex.” Female test scores begin to descend in middle school, when the girls are overtaken by the boys (Sadker & Sadker, 1994, p. 138). As their SAT scores begin to reflect a discrepancy with the scores of boys, 31 points lower in biology, 53 points lower in physics (NSF, 2001), their perceptions and the perceptions of society begin to alter. “It is thought that these score discrepancies significantly influence girls' perceptions and choices of college majors and thus future careers” (InGEAR, 1999, p. 12).

The prevailing attitude persists that women do not possess the necessary mathematical skills and thinking that are necessary to become a scientist or engineer, or that women are only interested in those professions that are of a social concern. Dr. April Brown challenged this theory by suggesting that these arguments miss the mark in relation to attainment and success in engineering and science (2000). “Engineering is a social process. Our success as engineers rests not only on our competencies, but also, in all probability, more firmly on our capability to participate in this social process” (A. Brown, p. 1).

Before women can fully utilize the available resources, they must remove barriers that prevent them pursuing careers in engineering and the sciences, including their own self-doubt. Sanders (1997) wrote that gender bias attitudes become a self-fulfilling prophecy. The self-fulfilling prophecy is further strengthened by the fact that many girls attribute their success as due to luck, an external factor, which is fickle (Dweck, 1986). Many boys attribute their success to ability, an internal factor (biology) that is reliable.

Carol Dweck (1986) suggested that girls may believe that intelligence in a given domain is something a person either has or doesn’t have. This is called the entity theory, while boys appear to base success on a theory of increments, which is a result of hard work. Anxiety, perception, self-fulfilling prophesy, stereotyped vulnerability, lower persistence and self-handicapping variables, as in the entity and increments theories, all contribute to the sustainability of these attitudes and ultimately in the low participation of females in these fields. Gender based attitudes become a self-fulfilling prophesy as girls see themselves as being inferior to boys.

Institutionalized Discouragement

Although education is noted to be a great equalizer in a democratic society, it can also be the great discourager, sorting students into educational choices by gender, race and ethnicity. “Classrooms play a major role in determining what an individual learns” (Fennema, 2000, ¶ 4). Additionally, Fennema stated that the influences in the classroom are a strong factor in the discouragement of women into certain fields. This is known as institutionalized discouragement, and can be witnessed in the suppression of female involvement in engineering and the sciences.

The problem of institutionalized discouragement, as is experienced by females, has really occurred well before high school. It is believed that it starts in elementary school. Classroom studies have indicated that the “belief of the inferiority of girls is already understood by the third grade” (Gutbezahl, 1995, p. 2). There is ample evidence that the way in which these science and math classes are taught and practiced may well reflect masculine approaches to the world, approaches that tend to marginalize women (Damarin, 1990, 1995; Harding, 1986; Keller, 1985). Teachers interact with boys more frequently, ask them better questions, and give them more precise and helpful feedback (Sadker & Sadker, 1994).

> Thus the window through which educators have access to our students in terms of developing a scientifically or even technological literate public is fairly narrow. In this short time, between K-8, the necessary foundations must be established that relate science in meaningful ways to students. (Shamos, 1982, p. 8)

If educators are committed to teaching the next generation of adults with the commitment toward gender equity, then teachers must reform the organization, examine the content of their instruction (including materials and curriculum), reflect on their pedagogy and look deep into themselves for bias. Science and technology are not as good as they could be when other perspectives are missing. If women and other groups and cultures are excluded, other viewpoints of the world are being lost (Malcom, 1996).

Societal Expectations

In some cultures, technology and engineering are not considered appropriate careers for women. "In all cultures of the world, women have clearly defined roles and responsibilities according to a socially defined gender division of labour" (Malcom, 1996, p. 2).

Expectations and limitations regarding behavior and academic choice are imposed by society. These influences are paramount to a female's or male's sense of identity. Traditionally, there are both assumptions and expectations concerning roles for men and women. Caplan et al. (1997) asserted that the origins in contemporary research lie in the traditional concerns that support or refute the various assumptions. The assumptions and expectations are that men are of the superior intellect. This serves as an explanation for the subordinate social position of women and their consequent restriction to the roles of wife and mother (Caplan et al.).

Gender differences are distinct from sex or biological differences, as they are socially determined and change according to social, environmental, economic and technological trends. Social factors affecting these gender roles and gender-differentiated interests include

1. Institutional arrangements that create and reinforce gender-based constraints.

2. Sociocultural attitudes, ethnic and class obligations that determine men's and women's roles, responsibilities, and decision making functions.

3. Religious beliefs and practices that limit women's mobility, social contact, access to resources, and the types of activities they can pursue.

4. The formal legal system that reinforces customs and practices giving women inferior legal status in many countries (GST Gateway, n.d.).

As gender differences are socially constructed, they can and do change.

The Image of Engineers as Unattractive

The traditional image of engineers is coldly analytic. Young girls and women are often discouraged by what they perceive engineers do. The message that females receive that engineers are cold and analytical may hinder their approach to these professions.

A poll of the American Association of Engineering Societies (2003-2004) revealed that engineering is thought of as the "stealth profession" because so few know what it is. When adults were asked to identify what engineers do, a response was, "they drive trains." This narrow view of engineering as an unattractive profession might be part of the problem. "With so little known about engineering, students, parents, teachers, counselors, and role models all base their choices on this incorrect information" (Wulf, 1999, p.1).

But what do engineers do? Engineers solve human problems, but not any solution will do. Wulf liked to define engineering as "design under constraint" (1999, ¶ 17). Solving problems means taking into consideration, size, weight, power consumption, heat dissipation, manufacturability, reparability, reliability, safety, environmental impact, ergonomics, and so on. Wulf believes that engineering is one of the most creative careers he knows and often likens it to composing, hardly the cold analytical stereotype that is so prevailing. Engineers not only solve problems related to the environment, energy and social issues, but also the design and manufacture of toys and games, from roller coaster rides to robots to special effects in movies (Gray, 2001). Both men and women alike are great consumers of engineering.

Women, teachers and parents must overcome the stereotype of engineering and engineers as being boring. But there are other, more dangerous and entrenched stereotypes that perpetuate engineering as being an exclusive club. The dangerous, entrenched stereotype is that engineering is for smart white males.

Traditionally, women and girls have not been encouraged to pursue these careers. Ingrained social attitudes of what is an acceptable career choice restrict women's participation in these lucrative fields (Malcom, 1996). This may contribute to the unattractiveness of these careers. These sociocultural and educational attitudes play a pivotal role in the lack of female participation in science and engineering.

Most recently, the President of Harvard and his remarks regarding the low participation of women in certain careers revealed that many of the same perceptions are still active, even at the highest levels of the educational community.

Much of the discussion regarding the low participation of females in traditionally male dominated careers, like engineering, is wedded to the perception that females are not capable of achievement in these careers. Three reasons for the low participation of females in engineering professions were addressed in Dr. Summers's remarks.

1. High-powered job hypothesis. "People in leadership positions are expected to give a continuity of effort throughout their lifecycle. Dr. Summers continued, there is a level of commitment that a much higher fraction of married men have been historically prepared to make than of married women (2005, p. 1).

2. Different availability of aptitude at the high end. Overall IQ, mathematical ability, scientific ability-there is relatively clear evidence that whatever the difference in means-which can be debated-there is a difference in the standard deviation, and variability of a male and a female population (p. 1).

3. Different socializations and patterns of discrimination. Somehow little girls are all socialized towards nursing and little boys are socialized towards building bridges. No doubt there is some truth in that. (p. 2).

Dr. Summers's comments have recharged the debate concerning women and certain careers. What is clear is that in 2005, the belief systems that have denied women access to certain scientific careers are still operating and powerful.

Higher Educational Environment

Attrition rates in engineering can also be attributed to the poor match between teaching style and learning style of instructor and student. There is significant evidence that the traditional teaching style of most engineering programs is limited to a lecture format with little student to student or student to teacher interaction as well as little relevance or application through a problem solving format. What needs to be examined is an understanding of the value of student differences, making engineering more relevant to real-world issues, and altering instructional style to include active learning, induction, team approaches, and more problem solving activities (Felder & Solomon, 2003).

Purpose of the Study

The purpose of this study is to understand the reasons for a movement toward gender balance that is occurring in some engineering disciplines as opposed to others. Given the background of this introductory chapter, the question remains as to why women are currently choosing one engineering discipline (such as biological and environmental engineering) over another, despite social, cultural, and educational considerations still viable in our society.

As an example, enrollment statistics for the Biological and Environmental Engineering Department (BEE) at Cornell University indicate that gender balance has been achieved in this discipline in the last 2 years (Cornell University, 2006a). What are the experiences and perceptions that have attracted females into this engineering discipline? The descriptions of female engineering students in this program or others might reveal the reasons why this department has affected their degree choice. This case study will then attempt to identify the variables that have made this discipline appealing to women.

Sought here is an understanding of the components of an engineering program to determine which of these components might influence females' decision toward specific types of engineering degrees. These components may include: curricular issues, course outlines, and ABET (Accreditation Board for Engineering and Technology) information. These components might then be used to provide the environment necessary to encourage female participation in other engineering fields. The experiences of female students in this case study provided descriptive information about their degree choice and their educational experiences.

Rationale

The low participation of females in the engineering professions and the importance of increasing the number of available engineers to solve global and national security problems, would be of critical importance to equity. Additionally, knowledge and understanding of why fewer females than males enter these fields would potentially increase the total pool of engineers, as well as providing females with access to these careers. This would satisfy issues of both equity and national security. With this said knowledge and understanding, areas that have achieved gender balance potentially hold knowledge that may apply to other engineering categories seeking gender balance.

What are the factors that are relevant to a degree choice in biological and environmental engineering? The rationale is to understand the characteristics that are present in a biological and environmental engineering program as a way to learn how and why they appeal to women. Then, their importance may be generalized so as to draw women into the other fields of engineering. This study provided a foundational understanding of why biological and environmental engineering was the degree choice for females in this context toward the engineering professions.

Research Questions

The purpose of this study is to determine why a biological and environmental engineering program achieved gender balance while other engineering disciplines attract (on average—nationwide) only a 20% female population. The research questions that this study seeks to answer are

1. Why has the biological and environmental engineering program at a major engineering university attracted a greater percentage of female participants than other engineering disciplines?

2. What are the attributes of this biological and environmental engineering program that are attractive to women?

3. How can these attributes be used to inform other areas of engineering in moving toward gender balance?

These questions will be answered through an explanatory case study, using both interviews and questionnaires of female engineering students, as well as through a thorough exploration of the curriculum components of biological and environmental engineering and learning outcome information (ABET, n.d.). Descriptive conclusions were drawn from these interviews and from the investigation of the curriculum and pedagogic components. The conclusions drawn from this study provided the insight into how engineering education can encourage more women into the degree choices of engineering.

Significance of the Study

For many years, the reasons for the low participation of females in the engineering professions have received much attention with the focus on the biological or cognitive differences between males and females. The engineering discipline known as biological and environmental engineering at Cornell has achieved gender balance during the last two academic years, while other engineering disciplines at the same university, have remained at a 28% female population on average (Cornell University, 2006a).

Contribution to Knowledge and Educational Reform

With the low participation of women in engineering, and the problems that the planet faces, increasing the number of engineers by tapping into the female population as a source of potential engineers is of significant importance. Understanding why women have chosen a biological and environmental engineering program as their degree choice will provide a greater understanding of the degree choices of women in engineering in general.

Discovering the attributes of biological and environmental engineering and then generalizing those attributes to other engineering fields has the potential to increase the female population in engineering in general.

Understanding the educational needs of all learners will support education and the needs of society. Understanding the various needs of learners will add to the educational literature regarding an environment that creates a comfort zone necessary to have an impact upon attrition rates, retention rates and enrollment figures. This may support the creation of a more comfortable learning environment for all learners in all engineering disciplines.

Definition of Terms

Aquaculture. The propagation and rearing of aquacultural species, including, but not limited to, any species of finfish, mollusk, or crustacean (or other aquatic invertebrate), amphibian, reptile, ornamental fish, or aquatic plant, in controlled or selected environments.

Biological and environmental engineering. The biology-based engineering discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems from molecular to ecosystem level.

Case study. The qualitative method as an empirical inquiry that investigates a contemporary phenomenon within the real-life context.

Chilly climate. The hostile environment that women sometimes experience in the workplace, the classroom or in society.

Cognition. "A general term covering all the various modes of knowing--perceiving, imagining, conceiving, judging, reasoning" (Drever, 1952, p. 42).

Comfortable learning environment. The quality of the educational environment, including the curriculum design, classroom constructs and management, lessons, teaching and learning approaches, learning styles, pedagogy, etc that would appeal to a wide range of learners.

Comfort zone. A place or situation where one feels safe and at ease and without stress. Usually used in conjunction with educational settings.

Gender. The state of being male or female (typically used with reference to social and cultural differences rather than biological ones).

Gender balance. The enrollment figures that are approximately 50% male and 50 % female.

Infrastructure. The basic physical and organizational structures and facilities (e.g., buildings, roads, and power supply) needed for the operation of a society or enterprise.

Leaky pipeline. The steady attrition of girls and women throughout the formal science and technology system, from primary education to science and career decision-making in technology (GST Gateway, n.d.).

Marginalization. The attempt to diminish individual value or intellect, based on gender.

Microinequities. The subtle expression of hostility that over time has a negative cumulative effect on learning for females in school.

Sex. The physical differences males and females.

STEM. The acronym referring to Science Technology Engineering and Math.

Switcher and nonswitcher. The change of educational focus resulting in change of major concentration of a particular discipline.

Weeding out. The removal of something inferior or unwanted from a group or collection. Used in education and courses in science and engineering technology to refer to the removal of students perceived to be unsuitable for the discipline in question.

Assumptions and Limitations

There are several assumptions and limitations inherent in this study.

Assumptions

The assumptions underlying this study are

1. There are obstacles in the educational environment that create barriers to females pursuing an engineering degree.

2. Women, as a population, are equally talented in engineering as men and in the same proportion.

3. There is not just one type of learner or learning style that can be successful in engineering.

4. Understanding the value of student differences and learning styles can contribute to a more comfortable learning environment for all learners.

5. Each participant may or may not understand the power of the educational community in either supporting or discouraging engineering as an acceptable career choice for females.

6. Designing courses to include a new paradigm and alternative instructional strategies will have a positive impact on attrition and retention rates for females in many engineering disciplines.

Limitations

1. The relatively small sample of university students at one institution may make it difficult to generalize to a wider university audience.

2. Since the researcher has had some positive experience with aquaculture, a subcategory of biological and environmental engineering, the researcher may exhibit bias in the interview questions and procedures.

3. The high degree of subjectivity concerning how each participant perceives her academic environment may be a limitation to this research study.

4. Self-esteem issues, cultural backgrounds and educational experiences that each participant brings to the study may contribute to the limitations of the study.

5. This author views certain aspects of bias and marginalization through the lens of the 1950s and 1960s. This may present a limitation, as socially constructed aspects of gender roles in society change over time.

6. Issues in the learning environment that affect girls' and women's self-esteem and discouragement, can be extremely emotional and subjective, thus creating limitations in this study that may be difficult to quantify.

Nature of the Study

This case study investigated the reasons why a biological and environmental engineering program at Cornell University has reached gender balance, while other, more traditional engineering disciplines remain male dominated. The case study content will be limited to Cornell University Biological and Environmental Engineering Department in Ithaca, New York.

Female biological and environmental engineering students from Cornell University comprised the participants in this case study. The intent of this study was to gather evidence and data pursuant to the participant's choice regarding biological and environmental engineering. Interviews, questionnaires, class observations and other artifacts were used to gather the information used in this case study. This methodology was suitable for this study because what was sought here was a rendering of the experiences, observations interpretations and relationships of the participants.

Organization of the Study

Chapter 1 presents an introduction to the problem, including problem statement, background, purpose, rationale, research questions, significance, assumptions, and limitations of the study, nature, and the definition of pertinent terms.

Chapter 2 provides an overview and review of both present and historical literature related to the reasons (biological as well as psychological) as to why certain fields, especially in the areas of science, engineering and technology, do not attract a significant number of females.

Chapter 3 introduces the case study methodology: its design, procedures protocols, and its application in this context as a research method. It provides a sequence of events for a study that explores the issue of the gender balance in biological and environmental engineering through qualitative research.

Chapter 4 presents the data and information collected in the interviews and questionnaires.

Chapter 5 presents an analysis and discussion of the findings and implications of the study. Conclusions and recommendations for future studies and for practical improvements are also described.

CHAPTER 2. LITERATURE REVIEW

Introduction

What makes one engineering discipline more attractive to women than another? The purpose of this chapter is to examine the related literature that pertains to the central question and related questions:

1. Why has the biological and environmental engineering program at a major engineering university attracted a greater percentage of female participants than the other engineering disciplines?

2. What are the attributes of this biological and environmental engineering program that are attractive to women?

3. How can these attributes be used to inform other areas of engineering in moving toward gender balance?

The related literature will examine themes or common denominators related to reasons for the apparent move toward gender balance in biological and environmental engineering, while female participation in other engineering fields is still low compared to male participation.

This chapter will examine the following:

1. Encouragements and Discouragements in Engineering for Women

2. Self-Esteem

3. Teacher Expectations

4. Self-Efficacy Theory

5. Self-Efficacy and Motivation

6. Chilly Climate

7. Factors that Influence Choice of Career in the STEM Fields.

8. Sex and Gender Differences in Achievement

9. External Influences and Gender Role Socialization:

10. Attrition

11. Diversity Among Students

12. Learning Styles and Engineering Education

13. Accreditation Board for Engineering and Technology (ABET)

14. Aquaculture; Women's Work?

15. The "New Engineering" for the 21st Century: Biological and Environmental Engineering

Discouragements/Encouragements

Females, in engineering degree choices, can either be discouraged or encouraged by many factors or variables. Females can be discouraged by bias and stereotyped images of what is appropriate for females. They can be discouraged by a hostile and unfriendly climate in the classroom, by parental and teacher expectations based on old and outdated models and observations, by social and cultural influences, by media images, by reinforced feelings of self-doubt and lowered feelings of self-confidence. The curriculum, approaches and teaching styles might be outdated and appeal to a narrow range of student audience. Enlightened parents and teachers, however, a change in society, and educational reform efforts that promote educational equity on every level of the educational environment can also encourage them (National Science Teachers Association [NSTA], 2006).

Self-Esteem

One factor that influences women's entry into the Science Technology Engineering and Math (STEM) fields is that some women experience a lack of self-confidence (self-efficacy). Rayman and Brett (1995) found that women have lower self-confidence, perceived ability, and self-reliance than men in spite of higher or equal grade point averages. Crawford and MacLeod (1990) reported that low self-esteem inhibits the performance of women in all fields of higher education.

Girls show less confidence in their ability to learn than boys do (Betz & Hackett, 1983; Fox, Brody, & Tobin, 1985; Matsui, Matsui, & Ohnishi, 1990) and are less willing to approach new material (Reyes, 1984). Meyer and Koehler (1990) found that successful female students in high school continued to demonstrate less confidence in themselves in math related activities. Similarly, Leedy, Lalonde, and Runk (2003) found that the traditional gender-based differences in the beliefs regarding mathematics persist even in mathematically talented students.

Because girls may assume that math is going to be difficult, they may have trouble distinguishing between work that will yield results and work that will not (Gutbezahl, 1995). The effect of lower self-confidence is that should females believe that they cannot perform well in math class, they feel a sense of helplessness in the classroom (Covington & Beery, 1976; Dweck & Repucci, 1973; Kloosterman, 1988). Women seem to have perceptions of competition and difficulty with majoring in the sciences that are paired with low self-ratings of ability in analytical fields that have traditionally been male-dominated (Chang, 2002).

Females also expect less of themselves (Gutbezahl, 1995). The educational choices that women make are not a true reflection of their intellectual capacity. As women enter college, their assessment of how well they perform in math is unrelated to their actual ability (Singer & Stake, 1986). Aspirations and choices of females are usually far below that of men with equal levels of intelligence (Fitzgerald & Crites, 1980). This causes women to seek the more traditional careers for women, such as psychology, social work, social science and teaching.

Teacher Expectations

The expectations of teachers can have a significant effect on students' self-confidence and grades. Gutbezahl (1995) noted that teachers (female and male) have lower expectations of girls than boys. Gutbezahl continued that teachers adjust many behaviors; questioning strategies, choice of activities, and difficulty levels on the basis of their perceptions of student achievement. "Learning is therefore directly affected by teacher perceptions of their students' subject matter proficiencies" (Helwig, Anderson, & Tindal, 2001, p. 1). Instructors' lowered expectations along with students' math anxiety have also been shown to hinder women from participating in the sciences (Seymour & Hewitt, 2000).

Self-Efficacy Theory

Self-Efficacy theory is one variable that seeks to explain a female's decision to decline entry, enter and drop out or enter and remain in the fields of math, science, and technology. Self-efficacy, similar to self-confidence, is the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations (Bandura, 1986, 1994, 2003). It is a belief in one's self that pertains to the ability to perform and accomplish certain tasks. The strength of an individual's belief in one's abilities is influenced by complex environmental factors, and learning experiences. Bandura (1994) noted that self-efficacy has four main sources of influence: experiences, social models, social persuasion and the emotional effects on judgment.

The first and most effective way of creating a strong sense of efficacy is through frequent mastery experiences. According to Bandura, successes “build a robust belief in personal efficacy” (1994, p. 2). If failure occurs before a sense of efficacy is firmly established, self-efficacy is undermined. Educational experiences that support success can modify and strengthen an individual’s self-efficacy (Bandura). Over time, these experiences positively enhance self-efficacy.

Social models or role models supply the second influence in creating and strengthening beliefs of self-efficacy. The vicarious experiences provided by these social models influence self-efficacy. “Seeing people similar to oneself succeed by sustained effort raises observers' beliefs that they too possess the capabilities to master comparable activities to succeed” (Bandura, 1994, p.1). Conversely, observing someone of similar nature fail undermines one’s efforts despite strong feelings of self-efficacy.

> Modeling influences do more than provide a social standard against which to judge one's own capabilities. People seek proficient models that possess the competencies to which they aspire. Through their behavior and expressed ways of thinking, competent models transmit knowledge and teach observers effective skills and strategies for managing environmental demands. Acquisition of better means raises perceived self-efficacy. (Bandura, 1994, p. 71)

The converse is also true. Certain behaviors and models that show educators (females in this context) lacking in science interest, recoiling in the presence of slimy things, repeating and restating old ideas that girls are not good in math and science, and demonstrating lack of persistence in these endeavors, add to the package of modeling influences.

Social persuasion can influence one's idea that they have the necessary skills to successfully participate in challenging activities. Encouragements and verbal persuasions allow learners to muster the courage and determination to persist even when they hold self-doubts. Students persuaded, however, that they lack capabilities in certain disciplines tend to avoid those challenging activities. Social persuasion alone is not enough to raise feelings of self-efficacy. It is often more difficult (Bandura, 1994) to instill higher levels of self-efficacy than to undermine it. Persuasive boosts and verbal encouragement tend to support the notion that one can try harder.

People rely on their emotional state in judging their capabilities (Bandura, 1994). Stress reactions and tension trigger feelings of vulnerability. "Positive mood enhances perceived self-efficacy, while despondent mood diminishes it" (Bandura, p. 2). Based on feelings of self-efficacy, the perception of the activity is viewed through the lens of self-efficacy. It is not the intensity of the experience that is the defining factor. Bandura continued that learners might view "their state of affective arousal as an energizing facilitator of performance, whereas those who are beset by self- doubts regard their arousal as a debilitator" (p. 2).

Since self-efficacy behaviors are learned, they therefore can be modified. Bandura (1994) specified four sources of information through which self-efficacy expectations are learned and by which they can be modified. These attributes of self-efficacy are constructed and not biological or immutable. They can be modified in the following ways:

1. Frequent experiences successfully performing the behaviors in question can lead to increased self-efficacy.
2. Frequent exposure to models that reinforce positive images of females in target career categories, like engineering can increase self-efficacy.

3. Frequent positive verbal reinforcement, encouragement and support from others can allay anxiety in connection with the behavior.

4. A lessening of anxiety through an examination of the classroom environment, satisfying the learning comfort zone of all learners through modified classroom organizational adjustments and the use of non-gender specific language also modify attributes of self-efficacy (Bandura, 1994; InGEAR, 1999).

Self-Efficacy and Motivation

In educational communities, the ability to strengthen or undermine self-efficacy can manifest itself in various ways. What happens in a classroom, through teachers' expectation, profoundly affects students' self-efficacy, motivation and female participation in the engineering careers.

> You see, really and truly, apart from the things anyone can pick up (the dressing and the proper way of speaking, and so on), the difference between a lady and a flower girl is not how she behaves, but how she's treated. (Shaw, 1916, Act V)

Girls internalize the teachers' and parents' negative expectations, which become self-fulfilling prophecies. "Because teachers believe that students cannot achieve in math, they do not achieve in math" (Gutbezahl, 1995, p. 2). Unintentional biased behaviors exhibited through verbal interactions, eye contact, and body language, all create an unfriendly classroom environment for girls and some boys (Sadker & Sadker, 1994). Because they are unintentional, they defy correction.

As reported in *Newsweek* on December 15, 1980—and subtitled "Do Males Have a Math Gene?"—Benbow and Stanley asserted that males had a higher average in their math SAT scores. Many parents believed that their sons' ability in math was due to genetics, and unfortunately this study reinforced the stereotype of girls as people who are simply unable to do math (Gutbezahl, 1995). Biology is predetermined and therefore unchangeable.

"Low self-efficacy expectations regarding a behavior or behavioral domain lead to avoidance of those behaviors, and increases in self-efficacy expectations should increase the frequency of approach versus avoidance behavior" (Betz & Hackett, 1998, p. 2).

The use of the expectancy construct emanates from a general cognitive perspective on motivation that the individual is an active and rational decision maker in contrast to earlier behavioral models of motivation (Pintrich & Schunk, 1996). Expectancy represents the key concept that most individuals will not choose to do a task or continue to engage in a task when they expect to fail. Even if they value the task or express interest, the repeated failure eventually will lead to lack of engagement.

Teacher expectations have a direct influence on students' grades (Feldman & Theiss, 1982; Good & Brophy, 1987; Rosenthal & Jacobson, 1968). It is documented that students consistently do well and outperform in those classrooms where the teacher has a high expectation. Pintrich and Schunk (1996) stated that teachers could help students maintain relatively accurate but high expectations and efficacy and help students avoid the illusion of incompetence. Research shows that those college students' attributions for success or failure (Weiner, 1986) and their beliefs about their own abilities, or self-efficacy (Bandura, 1994), influence students' motivation and goals for academic work.

The self-handicapping tragedy here is that women or others with low self-efficacy believe that because ability is a stable cause of failure that cannot be overcome, the prudent thing to do is to withhold effort. Risking failure may only confirm one's low ability (Gutbezahl, 1995). Making an effort and failing anyway is devastating to the ego (Arkin & Baumgardner, 1985; Berglas, 1985).

Chilly Climate

Another discourager for women in engineering is an unwelcoming environment or a chilly climate. A "chilly climate" in academe refers to the subtle and unwelcoming ways that women are treated differently than men (Sandler, 1999). This kind of discrimination against women, in the work place and in the classroom can be both overt as well as covert. Tonso noted that when she accepted her first job, a colleague remarked, "You must be our token woman," to which she fantasized, "You must be our token jerk" (2003, p. 2). These additional discouragements as well as a lack of encouragement in the engineering fields add to the variables that keep the numbers of women entering the field from climbing.

Sometimes called *microinequities*, a word coined by Mary Budd Rowe, past president of NSTA, these inequities, small as they are, can have a cumulative damaging effect (as cited in Sandler, 1999) on women in STEM fields. These can include

1. Behaviors that communicate lower expectations for women;
2. Yielding to the influence of internalized stereotypes;
3. Excluding women from participation in meetings and conversations;
4. Treating men and women differently when their behavior or achievements are the same;
5. Giving women less attention and intellectual encouragement;
6. Defining women by their sexuality; and
7. Overt hostile behavior toward women.

Women work in every field of endeavor. Nonetheless, in engineering, women are marginalized. Their numbers are lower, they do not do as well as expected and they experience alienation (Tonso, 2003). There are many factors that impact young women when they enter the engineering arena at the college level. These factors include academic, social and cultural factors. What happens in the classroom is considered an academic factor, while what happens on campus and in society fall under social and cultural factors, respectively.

Although Title IX, the 1972 education amendment to the Civil Rights Act of 1964, made it illegal for colleges accepting federal money to discriminate based on gender, the chilly atmosphere (Handelsman, 2005) still remains on campus as well as in the work place. There remains a masculine culture in engineering, dominated by a set of beliefs, behaviors and assumptions (McClean, Lewis, Copeland, O'Neill, & Lintern, 1997). Title IX opened the door for many female students in previously male dominated careers, but Title IX did not guarantee a welcoming environment. The overt barriers have been eliminated, but the covert, subtle hidden barriers, especially in the classroom continue to be a barrier toward equal access. A chilly climate still characterizes many college classrooms for women.

Women and minority men are not treated equally in the classroom. Men and women sitting side by side in the same classroom often have very different experiences (Sandler, 1996; Tonso, 2003). They experience behaviors that marginalize, devalue, undermine their self-confidence and ultimately lead to some of the attrition. Sandler (1999) wrote that these behaviors do not happen in every class, every time. Faculty and colleagues, both male and female, are guilty of participation. These behaviors have their origin in their own cultural biases. Sandler noted that these biased behaviors are sorted into a number of categories.

Handelsman (2005) wrote that despite gains, women still face obstacles and bias in many scientific careers. Besides a chilly campus climate, others include roadblocks of bias, and the challenge of balancing career and family.

Dr. Karen Tonso (2003) described the engineering culture as being two interlocking societal frames of reference: the preeminence of academic-science over the application of scientific thought, and of masculine prototypical way of life over feminine. In her study of engineering culture, Tonso described two types of engineering. One is called *academic engineerin*g and the other is called *actual engineering*. Academic engineering is affiliated with mathematical equations and conventional courses while actual engineering, a term coined by Tonso, is a complex combination of activities common to everyday life.

Cooper Union School of Engineering boasts of having some success in the area of equal access for women. Some of the reasons for Copper Union's success is attributable to a majority of female students (65.8%) that feel they are not treated differently than male students, their experience at Cooper is individual and has no bearing on gender issues (Cerro & Duncan, 2002). Cerro and Duncan believed that the success occurring at Cooper Union School of Engineering is due to the positive perception of the school's curriculum, programs and academic results. Thirty-five percent of the student population in engineering is female, a figure that has held for the past few years (Cerro & Duncan).

One telling statistic was the response from the question, "Would you discourage other females from entering the engineering school at Cooper?" A staggering 89% said no, and only 9.6% say yes.

Factors That Influence Career Choice

The very process of academic choice hinges on many factors. It identifies the "interactions of genetic factors, environmental conditions, learning experiences, cognitive and emotional responses and performance skills that produce movement along one career path or another" (Krumboltz, 1979, p. 19). Social learning theory is one factor that influences career choice. Social learning theory seeks to explain how educational and career preferences are acquired, and how selection of courses and fields of work are made (Graham, 1997).

There are many variables that influence a female's career choice decision or any decision that would affect a female's entrance into a science or engineering endeavor. Krumboltz (1979) suggested four areas of influence. The first is (a) genetic abilities and special talents, (b) the environmental conditions and events, (c) learning experiences, and (d) learning styles or task approach skills. Aspects of values, interests, skills and personality type can also serve as indicators toward career choice (Wagner College, 2005).

The relative genetic ability in math and science and general intelligence of both males and females are variables that support the decision to enter the math, science and technology fields. Those students entering the sciences show common experiences, including earning high SAT math and high school GPAs, and have taken courses in the sciences (Seymour, 1992). Given variability among populations, there is some indication that learning experiences as well as general intelligence can affect the choice of an engineering career or any career, for that matter.

Learning experiences can influence such choices. Observational learning experiences are often relevant to a nontraditional occupational choice and occur when an individual learns by observing real or fictitious models (Krumboltz, 1979). Observational learning occurs when an observer's behavior changes after viewing the behavior of a model (Funderstanding, 2005a). Krumboltz noted that successful performances and positive feedback form our likes and dislikes for various cognitive activities. Krumboltz continued:

> Sequential cumulative effects of numerous learning experiences affected by various environmental circumstances and the individual's cognitive and emotional reactions to these learning experiences and circumstances that cause a person to make a

> decision to enroll in a certain educational program or become employed in a particular occupation. School enrollment or employment is not a simple function of preference, choice, or interest but is influenced by complex environmental factors, many of which are beyond the control of any single individual. (p. 37)

Primary influences on the learning experience of women can include the educational system, per pupil expenditures, the administration, faculty professional development, teacher preparedness, teacher personality and behavior. Proper preservice training in education, ongoing professional development and sufficient funds to maintain quality instruction all influence the learning experiences of students.

Betz and Hackett (1998) developed a measure of general occupational self-efficacy intended to help explain the continued underrepresentation of women in traditionally male-dominated careers. The proposition was that differential sex-role socialization denies women equal access to information from which self-efficacy expectations are acquired. For example, regarding performance accomplishments, "girls are less likely than boys to gain the experiences that will enable them to develop abilities related to male-dominated occupational areas" (Graham, 1997, p. 13). Hackett and Betz (1981) also found that boys receive more encouragement for career pursuits than females. A combination of fewer or more narrow career opportunities and underutilized talents lead to fewer females than males pursuing the male dominated fields of engineering and science (Betz & Hackett; Hackett & Betz).

Sex and Gender Differences in Achievement

It was once believed that women could not pursue mathematics because of sex differences or because their nervous systems were too delicate (Campbell, 1991). The differences between the physical characteristics of men and women are indeed real. The heads of females are smaller than that of men; the brain size compared to body size is smaller. On average, the female brain is 4 ounces less that that of men (Caplan et al., 1997). Their brains, however are not unfit to tackle problems that require abstract thought. The 4-ounce difference does not explain the low representation of women in the fields of science and math.

A common belief is that the male brain is more suited for mathematical thinking and spatial relationship. Many aspects of our culture and society hold this belief (teachers, parents, boys, girls, men, women).

While males are thought to be predisposed to math, females are thought to be predisposed to areas of language. The ability to do math and use language utilize the same brain function. “The features of the brain that enable us to do mathematics are the very same features that enable us to use language, to speak to others and understand what they say” (Devlin, 2000, p. 2). Your genetic predisposition for language is precisely what you require to do mathematics (Devlin). With these differences in mind, women are indeed capable of pursuing careers in math and science and handle issues of abstraction. Small and significant differences do occur between the sexes. These between gender differences are small compared to variability within each gender (Gutbezahl, 1995). It is important to note that studies that have found a gap between men and women's abilities have also found much more overlap. A man can grasp the skills of language just as well as a female. Similarly, many women excel in spatial skills (Hyde & Linn, 2005).

Math ability and general intelligence are areas of concern for the underrepresentation of women in the engineering fields. Early studies found a difference in math achievement between males and females. Benbow and Stanley (1980) asserted through published works that supported the idea that males were genetically superior to females in areas of math. Many of these claims and studies were flawed and the analysis exaggerated (Jacklin, 1989).

In a study that examined 907 6th, 9th, 11th, and 12th graders (420 males and 487 females), students had gender specific attitudes about achievement in math and language arts. "Male students had higher self-perceived abilities and motivation in mathematics whereas females had higher self-perceived abilities and motivation in language" (Skaalvik & Skaalvik, 2004, p. 41). Similarly, Heyman and Legare (2004) found that among 60 kindergarteners and first graders and 60 fourth and fifth graders, the prevailing attitude was that girls were better at spelling with better pro-social tendencies, while boys were more aggressive. These self-perceived perceptions occurred as early as upper elementary school.

The differences between boys' and girls' math achievement in elementary school is not significant. Younger girls' proficiency in math lags slightly behind that of boys (National Center for Education Statistics, 2004). Computer related gender-gaps are disappearing, small gaps in science achievement exist, and girls tend to score higher in reading and are less prone to behavior problems. Although more males than females take AP exams in science and calculus, there are no significant differences in achievement between males and females (Institute of Education Sciences, 2004). Also, "although boys and girls differ in their physical, emotional and intellectual development, there is no evidence that these are linked. Social and cultural factors appear to be the major reasons leading to gender differences in academic performance" (Gallagher, 2001, p.1).

Girls and women tend to earn higher grades than boys and men (Kenney-Benson, Pomerantz, & Ryan, 2006) although statistically, males receive higher SAT scores on math and reading ("Math SAT Scores Reach 36-Year High," 2003). SAT scores were very high in

2003, as noted by the Associated Press ("Math SAT Scores Reach 36-Year High"). Female test-takers improved greatly during the last decade, with their average scores increasing 19 points to 503. Male math scores have gone up 13 points over the same period of time to 537. Females also averaged 503 on the 2003 verbal exam (up a point from last year), while males averaged 512, a jump of 5 points from 2002 ("Math SAT Scores Reach 36-Year High").

FairTest, the National Center for Fair and Open Testing, shows that in 2000, of the 1.3 million test takers, males scored an average of 533 as compared to females, 498. SAT scores are traditionally used to determine college success. FairTest (2005) believed that SAT averages for the high school class of 2000 deflects attention from the country's real educational problems and encourages misuse of exam scores.

The gender achievement gap has narrowed significantly in the past 30 years, supporting the idea that these differences were not an affect of biology, but a result of social and cultural constructs. Genetic change does not happen that fast. There is some evidence to support the idea that males have an advantage in their spatial abilities. Males engage more often in activities that exercise these abilities. While boys are enhancing their visual/spatial abilities, females tend to exercise their verbal abilities (Nash, 1979; Sadker, Sadker, & Klein, 1991). Both differences in math achievement and gender differences in spatial abilities are decreasing over time (Linn & Hyde, 1989).

The NRC determined that there was almost "no difference in performance among male and female students who have taken equal advantage of similar opportunities to study mathematics" (1989, p. 4). Although small differences do occur, they are not significant. A leveling effect in gender differences in achievement may occur when given equal advantage to similar opportunities and similar prior experiences.

External Influences and Gender Role Socialization

Cultural norms are the conceptions of appropriate and expected behavior that are held by most members of the society (O'Neil, 2005). When anthropologists use the term culture, they are referring to an identifiable community that shares a sense of the way the world is supposed to work (Tonso, 2003). Family and community imprint learned patterns of behavior, both conscious and unconscious, and values or culture on individuals. These patterns frame the "context" for individuals to perceive, interact and learn about the world (Ibarra, 1999).

Gender role socialization occurs early in the life cycle of both males and females. Culture is acquired through this process of socialization. Girls also learn how to be daughters, sisters, friends, wives and mothers. During this process, language is also acquired. The influence of gender role socialization determines one's sense of identify and ultimately their choice of occupation (Betz & Hackett, 1998). Gender refers to "different sets of expectations and limitations imposed by society on girls and boys simply because they are female or male" (AAUW, 1992, p. 5). The term *gender* is used in the International Communications Technology (ICT; World Bank, 2005) toolkit to refer to the socially constructed relations between women and men in a particular society. These roles that both men and women assume are both culturally and institutionally embedded. What is gender appropriate, on the other hand, changes over time both historically and geographically (World Bank). It is learned rather than innate.

In traditional gender roles, men are encouraged to be decisive and to show leadership qualities. Women, on the other hand, are encouraged to be deferential and dependent. These traditional gender roles do not benefit anyone, particularly women (Witt, 2000). Every aspect of expression and accomplishment should be available to every individual, male and female. The traditional roles, established by current society, do not offer these opportunities and in many cases discourage them. “Children should be allowed to develop a sense of self in a gender fair environment which encourages both boys and girls to feel they are a force in the society” (Witt, p. 322).

Society has different role expectations for both males and females. Gender role socialization can come from a variety of sources, from the parental influence to pop culture. Gender role socialization begins early in the home. Parents possess and transmit their attitudes and beliefs about gender through ways of interacting, selection of toys (Solomon, 1982) play, dress codes, delegation of tasks and chores. Often these influences are based on gender role stereotypes.

Girls also learn occupational roles allowed by the society. Traditionally, women and girls have not been encouraged to pursue certain careers, especially engineering, due to cultural restraints. Ingrained social attitudes restrict women's participation in these lucrative fields (Malcom, 1996). Social and cultural norms may contribute to the unattractiveness of these careers. These sociocultural and educational attitudes play a pivotal role in the lack of female participation in science and engineering. There is considerable variety in gender relations across cultures (Tonso, 2003) and considerable within-group variation as there is between cultures. Tonso wrote that cultural models for interpreting the world, and those in it, provide a better account of the variation in women and men’s circumstances in science and engineering.

Gender role socialization occurs in part through observations of the rewards and punishments that others receive (Bussey & Bandura, 1999). The experiences of boys also provide more practice in the very skills that are necessary for certain careers. Boys construct, throw balls, and build more towers than do girls. The process of socialization occurs in schools as well. In schools, their science experiences are also different. Differences in teacher behavior combined with the organization of instruction make up a pattern of classroom organization that appeared to favor males (Fennema, 2000).

As they develop their cognitive abilities, children assimilate new information and accommodate it to what they already know (Piaget, 1954). Children's ideas about how the world works come from their experiences and from the attitudes and behaviors they see around them (Witt, 2000). Among the factors that influence gender role socialization are role models. Role models have an important influence on gender specific behaviors (Bandura, 1977; Basow, 1992; Beal, 1994; Hargreaves & Colley, 1986). The media plays a significant role in the gender socialization of adolescents. Witt stated that children see, imitate and repeat these behaviors that they see on television.

Parents also have different expectations for males and females. Rosenwasser (as cited in Graham, 1997) wrote that girls are often assigned indoor chores while boys are assigned outdoor chores. Rosenwasser continued that career goals and occupations might also be influenced by parental expectations. Other outside influences reinforce, mitigate or exacerbate existing ideas and stereotypes.

Witt (2000) researched how children are influenced by gender bias behavior through media sources. Content analysis of publications viewed by females and males in science textbooks was performed by Witt. Elgar (2004) found that photographs of males were four times more numerous than that of females. There were six drawings of males for every one of females. Photographs and drawings depicted females for pregnancy, childcare, heredity, the five senses and care for the environment.

When children witness female characters on television that are passive, indecisive and subordinate to men and also witness this type of behavior confirmed and reinforced either in the home, at school or in their community, they come to believe that this is the appropriate way for all females to behave. As a final outcome, differential sex-role socialization prevents women from gaining access to the four sources of information through which self-efficacy beliefs are acquired (Hackett & Betz, 1981), thus limiting them from access to certain careers.

Attrition

Declining interest in engineering among high school students, leading to declining enrollment in engineering programs is the subject of research by Felder and Brent (2005). The annual graduation rate has declined by roughly 20% in the last decade. Increasing difficulty in attracting students into engineering and the high attrition rate of enrolled students have caused a decline in graduation rates, posing a serious threat to industry and society (Felder, Felder, & Dietz, 1998).

Approximately 50% of students entering college with an intention to major in Science, Technology, Engineering and Math (STEM) careers, change majors within the first 2 years (Felder & Brent, 2005). Lacking the basic science and math literacy needed to be successful in the STEM careers is one reason for the decline in interest (Feuers, 1990). National Science Board (2002) found that among the community colleges, a third of the students enrolled in remedial math courses, demonstrating the students' lack of preparedness for the college level courses. In addition to the lack of preparedness for college level courses, Seymour and

Hewitt (2000) wrote that lower expectations of certain student groups, in addition to math anxiety, hindered women's participation in the science and engineering fields, leading to attrition.

An early study found that of the 2276 participants who expressed initial interest in the sciences, 40% did not finally concentrate in science. More men persisted (66% to 48%) with low grades being the greatest predictor of attrition (Strenta, Elliott, Matier, Scott, & Adair, 1993).

In a 6-year longitudinal study, it was found that female undergraduates in engineering switched fields due to a combination of "losing interest in science and engineering, being attracted by another field, and being discouraged by academic difficulties and low grades" (Brainard & Carlin, 1998, p. 8).

Felder and Brent (2005) stated that it might have more to do with the way students process information combined with the teaching style of the instructor, that contributed to the decline of interest in engineering and first year attrition rates. Granted, some students drop out because of academic failure, but others drop out because of dissatisfaction with instruction and the learning environment (Seymour & Hewitt, 2000). Seymour and Hewitt wrote that there is little difference in academic achievement between students staying and student leaving the science-engineering environment.

A discouragement influencing whether or not to pursue an engineering career is the mismatch of student personality to the engineering learning environment. As engineering environments are considered endeavors with male approaches to the world, Hegg (as cited in Graham, 1997) found that many females left engineering because the environment is viewed traditionally as competitive and analytical. Competitive activities encouraged boys' learning but had a negative influence on girls' learning. Cooperative learning activities encouraged girls, but discouraged boys. Since competitive activities were much more prevalent than cooperative activities, it appeared that classrooms studied were more often favorable to boys' learning than to girls' learning (Fennema, 2000).

A 5-year study by Felder et al. (1998) compared outcomes for an experimental cohort with outcomes for students in a traditionally taught comparison group. The experimental group, which used nontraditional approaches to learning, outperformed the comparison group on a number of measures. These measures included retention and graduation in chemical engineering, while many more of the graduates in this group chose to pursue advanced study in the field (Felder et al.).

The discussion concluded that:

1. Retention was higher in the experimental group.
2. The experimental offering of the introductory course served as a better gateway to the chemical engineering curriculum than did the comparison offering of the course.
3. The experimental group developed higher critical thinking skills.
4. The comparison group may have improved more in their abilities to solve computer problems and to work independently.
5. The experimental instructional approach led to better peer interactions.
6. The testing and grading policies and procedures in the experimental course sequence contributed to the improved performance and attitudes of the students in the experimental group.

Exacerbated by high school drop out rates, members of the engineering faculty community continue to view attrition positively; a natural process of weeding out poorly equipped students. Complaints about students unable to memorize and plug numbers, and an inability to think, are heard throughout faculty communities (Felder & Brent, 2005). Other faculty members are able to get many similar students to perform at high levels, showing critical and creative thinking with a variety of student types. The inference here is that an increase in academic success is related to what instructors are or are not doing (Felder & Brent).

Overcoming this problem of high attrition rates means that colleges must make attempts at improving instruction and professors must understand the various learning needs of students. No two students are alike. This means that classroom environments must embrace multiple ways of learning and teaching in order to make knowledge accessible to all. Felder and Brent (2005) continued that attempting to create a learning environment to satisfy each and every student is not practical, it is equally misguided to think that a one-size-fits-all instructional strategy is also wise.

Diversity Among Students

Diversity in educational settings has increasingly become an important consideration for the instructor in the K-12 environment as well as at the university level. Diversity usually refers to gender and ethnicity. Diversity, according to Felder and Brent (2005), means understanding the diverse learner from three perspectives:

1. Learning Styles
2. Approaches to Learning and Orientation to Studying
3. Intellectual Development.

Learning styles are "characteristic cognitive, affective, and psychological behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (Keefe, 1982, p. 241). Students preferentially focus on different types of information and tend to operate on perceived information in different ways according to individual learning styles (Corno & Snow, 1986).

Some students are more comfortable with theories and abstract reasoning. They prefer to work alone and reflect, while others prefer interaction and negotiating the learning in a cooperative atmosphere. Some students find that having a visual representation in addition to verbal instructions is preferable than just having one mode of instructional delivery. One learning style is not better than another, each having its strengths and weaknesses. A combination of skills is vital to function effectively in any profession. An instructional goal would be to equip all students with the skills needed to function professionally. There is not one learning style appropriate for engineering education (Felder, 1998).

Approaches to Learning and Orientations to Studying

According to Felder and Brent (2005), there are three ways that students can approach learning and studying.

1. Reproducing orientation; characterized by rote memorization, applying mechanical formulas which leads to shallow or a surface approach to understanding. This student makes little or no attempt to understand the materials presented.

2. Meaning orientation; learning is characterized by deep understanding. Students probe and question and explore opportunities to extend the learning with applications and new discovery. They look for meaning.

3. An achieving orientation: students who seek good grades will use either a deep meaning or shallow understanding approach as a means to good grades.

The role of the instructor is to induce students to develop a deep meaning approach to learning the material being offered.

Intellectual Development

Students progress from “belief in the certainty of knowledge, and the omniscience of authorities to an acknowledgment of the uncertainty and contextual nature of knowledge” (Felder & Brent, 2005, p. 65). Students must learn that decisions require evidence and that ideas change when confronted with new evidence. It is the responsibility of the instructor to help students move toward that direction of intellectual growth. The goal of superior instruction is therefore developed along the lines of offering instruction that meets many learning styles, supports the move toward developing deep meaning and understanding, and challenges student thinking by supporting evidence-based decision making in the sciences.

The effects of not addressing differences in learning styles can affect the learner and attrition. Barger and Hoover (as cited in Marrapodi, 2004) explored what the implications are for the mismatch of dominant learning style between learner and instructor. Barger and Hoover suggested that “Differences in psychological type between teachers and students can lead teachers to misunderstand learning styles of students. Teachers may project their personal learning styles on students, expecting that they will learn in the teacher’s way” (1984, p. 58). Felder and Silverman (1988) wrote that students affected by these mismatches demonstrate a loss of interest and motivation, leading to attrition.

One method toward a better understanding of the variety of learning styles found in a classroom is to conduct learning style inventories of the students. There are several dozen learning style models from which to choose, five of which are found in the engineering education literature.

Myers Briggs Type Indicator (MBTI) is strongly linked to Jung’s Theory of Psychological types. Felder and Brent (2005) asserted that MBTI has strong learning style implications. It is important to note that Felder and Brent stated that learning style theory is not universally embraced by the higher educational community.

According to MBTI (Myers & Briggs Foundation, n.d.), people are classified into four main categories:

1. A. Extraverts (try things out, focus on the outer world of people), or

   B. Introverts (think things through, focus on the inner world of ideas)

2. A. Sensors (practical, detail-oriented, focus on facts and procedures), or

   B. Intuitors (imaginative, concept-oriented, focus on meanings and possibilities).

3. A. Thinkers (skeptical, tend to make decisions based on logic and rules,) or

   B. Feelers (appreciative, tend to make decisions based on personal and humanistic considerations).

4. A. Judgers (set and follow agendas, seek closure even with incomplete data), or

   B. Perceivers (adapt to changing circumstances, postpone reaching closure to obtain more data).

Traditional engineering education is oriented toward the introverts, intuitors, thinkers and judgers. The traditional engineering student prefers individual assignments and lecture format rather than class interaction and cooperative learning. This student prefers emphasis on math and science fundamentals rather than on application and operations, prefers an objective approach to decision-making rather than interpersonal considerations (Felder & Brent, 2005) and prefers following the syllabus rather than creative problem solving.

Understanding student learning (learning styles) is supported by National Science Education Standards (NRC, 1996). The standards express the need for more active learning and inquiry in the sciences. The National Science Education Standards stated, “Teachers must respond to student diversity and encourage all students to participate fully in science learning (NRC, p. 36). “Inquiry and the Standards” (NRC, 2000) suggested that inquiry and experiential learning support that challenge through a change in emphasis.

Addressing students’ learning styles is yet another way for instructors to promote equal access to knowledge in the engineering classroom. Addressing student learning style theory in higher education and adult learning has not been frequently examined nor embraced (Felder & Silverman, 1988). College and university teaching, especially engineering education, is still a very traditional lecture style approach to instruction. This traditional approach has led to decreases in enrollment in engineering programs and colleges (Felder & Silverman). Understanding Learning style theory is one way toward improving the engineering classroom environment.

Brent and Felder (2000) wrote that teaching methods more effective than the traditional “chalk-and-talk” will be needed to equip engineering graduates with the technical, communication, and interpersonal skills specified in the new “Engineering Criteria 2000.” Professional development will be required to equip engineering instructors to use new methods of instruction. Felder, Woods, Stice, and Rugarcia (2000) continued that, unfortunately, participation in faculty development programs has never been part of the prevalent culture of engineering education. Adding additional dimensions to one’s instructional style benefits everyone, including the industry.

Richard M. Felder, an instructor of chemical engineering, has written extensively on instructional changes (related to learning style theories) necessary in achieving equity in the engineering classroom. The need to examine these approaches to teaching and learning in the engineering classroom is vital if the educational community is to stem declining interest in engineering occurring in high schools and make engineering education more equitable. Felder and Brent (2003) suggested the use of cooperative learning, active learning and induction.

Learning Styles and Engineering Education

Students have many ways of processing information. They preferentially take in and process the information based on input of information. Some see and hear, reflect and act reasonably and logically and intuitively, analyze and visualize steadily or in spurts. Teachers also have different styles of making the learning accessible to students. Some lecture, some provide demonstrations; still others work in environments where students construct knowledge through hands on activities. Other instructors focus on principles and still others on applications; some emphasize memory and others, understanding. Felder and Silverman (1988) outlined learning styles within four categories. Each style represents a dichotomy within the category and was influenced by Myers-Briggs Type Inventory.

Felder and Silverman (1988) stated that most engineering students learning types and the teaching styles of their professors are not compatible. This leads to discouragement and drop out. For years, the traditional thought (Seymour & Hewitt, 2000) stated that this dropping out really represented a healthy “weeding out” of poor engineering candidates. Felder and Brent (2005) stated that this is no longer the prevailing attitude. This process eliminates both poor engineering candidates and good engineering candidates.

Instructors have varying teaching styles too. With classrooms full of learners with varying learning styles and the various teaching styles of professors, meeting the needs of learners presents a challenge in the 21st-century engineering classroom. Felder and Silverman

(1988) said that learning style match up with engineering professors is vital toward keeping all students in the pipeline.

When mismatches exist between learning styles of most students in a class and the teaching style of the professor, the students may become bored and inattentive in class, do poorly on tests, get discouraged about the courses, the curriculum, and themselves, and in some cases change to other curricula or drop out of school (Felder & Silverman, 1988).

Studies indicate that the educational climate of the traditional engineering classroom may indeed be a poor match for female students and contribute to poor success in these fields (Felder, 1998). Dislike of the highly competitive approach found in science, math and technology classes was a factor in 14.8 % of switching decisions and a source of complaint of 28.4 % of switchers overall (Seymour & Hewitt, 2000). Many students felt that the competitive atmosphere was a "set-up" engineered by professors to fight the curriculum, the professors and each other (Seymour & Hewitt) in an attempt to create what is known in the field as the "weeding out" process.

ABET: Accreditation Board for Engineering and Technology

ABET is making demands on higher education in the area of engineering and technology. Similarly, the 2001 No Child Left Behind legislation is making demands on the lower schools. There is a need to convince ABET that schools are meeting ABET demands and instructors are teaching what they say they teach. In the past, accreditation was based on course work. Universities needed only to spell out the course requirements. In 2001, "Engineering Criteria 2000" took effect and represented a new standard for all of the U.S. engineering schools (ABET, n.d.). Engineering schools will now have to demonstrate that engineering students can function in interdisciplinary teams, communicate effectively, engage in lifelong learning, understand contemporary issues and understand how engineering fits into the context of global/societal issues (Felder, 1998).

The challenge of "Engineering Criteria 2000" is that learning will need to become outcomes-based and universities will need to demonstrate just how well the students are learning. Outcomes-based learning is defined as "where instructional efforts are designed to have produced specific, lasting results in students by the time they leave school" (Funderstanding, 2005b, p. 1). Outcomes-based education assumes that learning can be measured and assessed. Outcomes-based education has the following components:

1. Is a learner-centered process
2. Is developmental: it encompasses both what learners learn and are able to do at the end of the learning process
3. Is an activity-based approach to education designed to promote problem-solving and critical thinking
4. Through its outcomes, at the end of the learning process shapes the learning process itself, the process of learning is considered as important as what is learned.
5. Emphasizes high expectations of what all learners can achieve (Heinemann South Africa, 2005).

Engineering instructors will have to demonstrate what students will be able to do at the end of the instructional sequence, how students will demonstrate this and how instructors will assess that the desired learning has taken place. Learning, therefore, becomes a shared responsibility between the learner and the instructor.

Accreditation success will be judged on how well universities are meeting those challenges. Teaching and learning will move from an open-looped process to a close-looped process, which requires constant feedback on how much learning is actually taking place. Assessment informs instructional practice.

Aquaculture: Women's Work

Aquaculture is a biological and environmental engineering discipline that appeals to women. In some cultures, it is the women who are the biological engineers. For many years, aquaculture, that is, the culturing of fish or other aquatic products, either in recirculating tubs or flooded fields, has historically attracted women worldwide. From subsistence production levels to viable food production industries, aquaculture has generated a host of new professional specialties (C. Brown, 1987). Aquaculture is a biological and environmental engineering technology. Women play a major role in aquaculture (Engle, 1987).

Women's role in aquaculture has been historically used as a means of livelihood and subsistence (Brugere & Lingard, 2001). In Thailand and China, women often bear the sole responsibility of farm and aquaculture production (Brugere & Lingard) In Cambodia, higher yields are obtained from fishponds managed mainly by women. Aquaculture meets a practical goal with an eye toward efficiency. It benefits women through an increase in income and improvement in nutrition (Brugere & Lingard). Aquaculture meets strategic needs of empowerment. With more control over aquaculture activities, women gain control over their own lives and improve their status both within the household and the community.

Aquatt (Aqualet, Centro Technologico del Mar, and the Association of Scottish Shellfish Growers), in their 2004 workshop in France, listed three objectives of their conference:

1. Promote the role of women in the sector and enhance their participation in decision-making roles and gender diversity in aquaculture.
2. Clearly identify, and bring to the forefront of discussion, gender diversification issues specific to the aquaculture industry in the European Community.
3. Promote and support the fisheries sector through connecting and networking women in aquaculture. (as cited in Pisces TT, 2004, ¶ 1)

In Indonesia, 856 fisheries graduates have included 197 women (23%). Of the 405 students currently enrolled at the University of Hasanuddin in South Sulawesi, 117 (29%) are women. Almost half of the current enrollment of 86 students at the University of Pattimura in Moluccas is comprised of women.

The College of Fisheries of the University of the Philippines has awarded Diplomas in fisheries since 1948. Since then, 66 (38%) of students receiving diplomas, 238 (60%) of those receiving B.S. degrees, and 11 (50%) of those receiving M.S. degrees in fisheries, have been women.

A degree is necessary in order to get a professional position in aquaculture. A Bachelor's degree is considered minimal for jobs in commercial production, and an advanced degree is frequently required for positions in research, education, or extension management (C. Brown, 1987).

Currently, many United States universities as well as overseas universities offer degrees in aquaculture or aquacultural engineering.

1. Auburn University offers B.S., M.S., M.Aq., and Ph.D. degrees in Fisheries and Allied Aquaculture. Since 1969, 735 Master's degrees have been awarded in aquaculture. Of these, 35 (5%) have been awarded to women.

2. Oklahoma State University has had 1 woman seeking a B.S. degree in fish culture, and Louisiana State University has graduated 3 women at the M.S. level.

3. Texas A&M University has graduated 12 women at the B.S. level in aquaculture, including 1 Honduran and 1 Mexican.

4. The University of Rhode Island has 4 foreign female students in aquaculture-related programs, including 2 from Ecuador, 1 from Costa Rica, and a Peace Corps worker in the Philippines.

C. Brown (1987) concluded that there is a realization that women are on parity with men in terms of their ability to contribute professionally in aquaculture. Equal opportunities in education, training, and employment in aquaculture are available.

Some of the reasons that C. Brown (1987) concluded that women may be attracted to aquacultural engineering are that aquaculture professional opportunities are more technically and less physically demanding than most professional opportunities in fisheries or agriculture.

As aquaculture is a comparatively new industry in most of the developing world and as such has few social or political biases. It is important to maintain a distinction between aquaculture and agriculture to avoid the transference of traditional stereotypes.

In 1987, interviews with 17 women in the United States who selected aquaculture as a career revealed that the majority believed aquaculture would remain a male-dominated profession (C. Brown). That may be changing, as the need for aquaculture technologies and large-scale food production need to meet the demand of the world's 6 billion people.

The relevance of this information is that aquaculture, a biological and environmental engineering endeavor, appeals to women, regardless of culture or ethnicity. Clearly, there is historical evidence and precedent for women's role in aquacultural technologies. Aquaculture serves the practical need for food, a creative need for design, a social need that meets the protein requirements of the world community and the empowering need for independence.

Aquaculture is biologically based, multidisciplinary and inextricably connected to aspects of chemistry and physics. As a relatively new technology, it may be that aquaculture does not suffer the traditional gender biases that other engineering technologies have suffered. Clearly, women have marked a place in aquaculture, whether in the small villages of South East Asia or large-scale production in the Gulf of Mexico. Women continue to meet the social and nutritional requirements of the world.

The New Engineering

Engineering is changing. It must change. The implications of those changes (accreditation demands, and the needs of the industry) will impact both curriculum and instruction. Wulf and Fisher (2002) cite reasons for a makeover in engineering education to include the changing nature of international trade and the subsequent restructuring of industry, the shift from defense to civilian applications, the use of new materials, and biological processes. The emergence of new technologies, the computer age, sophisticated hardware and software programs have created design activities that have changed the way engineering is taught and depicted (Goldstein, 2004). This new engineering has reduced the need for the traditional engineer with the current education. At present, engineering education appears to be out of touch with the practice of engineering (Wulf & Fisher). "Traditional methods will not be adequate to equip engineering graduates with the knowledge, skills, and attitudes they will need to meet the demands likely to be placed on them in the coming decades" (Felder et al., 2000, p. 14).

The problem in engineering education is twofold, as described by Goldstein (2004). The current picture in the minds of the public of the engineer as a mechanic that fixes things needs to be replaced by the newly educated engineer who will provide technical leadership for the future (Goldstein). This requires changes in thinking, changes in engineering education, as well as changes in curriculum and instruction. An increased focus on the paradigm of problem solving in mathematics and a movement away from the traditional curriculum of drill and practice (Rayman & Brett, 1995) benefits all learners.

Reformers of engineering design courses focus on the interaction between the students and the real world of work. These course designs extend the book learning of other courses and provide opportunities to work closely with practicing engineers. They gather information from their clients, apply specific engineering principles to real world specific situations, work in teams and provide opportunities to collaborate and communicate (Tonso, 2003). These approaches tend to support women in engineering (Tonso).

Characteristics of the new engineer include:

1. Becoming more interactive with people
2. Understanding the multicultural environment
3. Understanding the global environment
4. Have direct experiences working in a team environment on a technically oriented problem
5. Learn more about the economics of the design process.
6. Pay more attention to problem solving skills

Goldstein (2004) described the *new engineer* has having a greater background in various cultures, languages, history, business, and sociology, than the current engineering education allows. It will be much more interdisciplinary, along with the technical training necessary in engineering education, than current traditional engineering education provides.

Degree changes, such as the first professional degree will be at the Master's level. The Bachelor's degree will feature the concept of engineers serving people. These changes will provide a friendlier environment to minorities and women (Goldstein, 2004).

Biological and Environmental Engineering, the New Engineering

A biological and environmental engineering program may well represent a new image of engineering. The name itself contains the female friendliness of the biological sciences. Biological and environmental engineering creates the picture of an interdisciplinary learning environment that meets the needs of society. The mission statement of this biological and environmental engineering program is described in the following manner:

1. Educate the next generation of professionals and discover new knowledge in Biological and Environmental Engineering;

2. Disseminate cutting edge research-based engineering information through the scientific media and outreach programs;

3. Conduct all programs in the context of a world-class university and deliver the highest value knowledge to our students, citizens and global society (Cornell University, 2006a).

Cornell University Biological and Environmental Engineering Background Information

Cornell University's Department of Biological and Environmental Engineering represents the context of this study. Cornell University is located in New York State in Ithaca, New York. Rich in history, Cornell was founded by Ezra Cornell in 1865. Cornell University is a Land Grant College or University. A Land Grant College is an institution that has been designated by its state legislature or Congress to receive the benefits of the Morrill Acts of 1862 and 1890. The original mission of these institutions was to teach agriculture, military tactics, and the mechanic arts as well as classical studies so that members of the working classes could obtain a liberal, practical education ("About the Land Grant System," 2005).

Some 3,000 undergraduates choose from 12 engineering majors (schools), with the additional option of developing an individual interdisciplinary curriculum through the Independent Major (Cornell University, 2006c). Biological and Environmental Engineering (BEE) is one of the 12 schools of engineering.

BEE history began in 1900, when the first course in agricultural mechanics was taught. Over the years the department has revised it name, adjusting to changing societal needs.

1910: The Department of Farm Mechanics

1913: The Department of Rural Engineering

1930: Agricultural Engineering

1988: Agricultural and Biological Engineering (ABEN)

2002 to present: Biological and Environmental Engineering

Originally named Agricultural and Biological Engineering, the department is described as examining:

> Current and future needs for engineering in agricultural and biological systems have brought about a change in name to meet the demands of a changing world. Recent years have brought a renewed vigor and resurgence of activity dealing with solutions to environmental problems. (Cornell University, 2006a)
>
> BEE is at the focus of three great challenges facing humanity in the 21st century:
>
> 1. Protecting or remediating the world's natural resources, including water, soil, air, energy, and biodiversity.

2. Developing engineering systems that monitor, replace, or intervene in the function and operation of living organisms.

3. Ensuring an adequate and safe food supply in an era of expanding world population (Cornell University, 2006a).

It is these three challenges that drive curriculum and instruction.

Summary

This related literature review provided a historical and contemporary perspective of the issue of the underrepresentation of women in the engineering technologies. The path toward understanding comes from many aspects of culture and biology. Many of these are not within the control of the instructor. What was learned through this exploration is that what happens in the classroom is the one major variable over which engineering education, both instructors and universities, have ultimate power and control. Instructors have no control over issues of background and prior knowledge in engineering. The real power for learning and equity is in the hands of the instructor. It is where it has always been. Ultimately, the educator is and must be accountable for equal access to knowledge, attrition and retention. Unless engineering is accessible to everyone: men, women, minorities, and the disabled, the world is deprived of solutions to environmental problems and two thirds of the population is deprived of potentially lucrative professions.

CHAPTER 3. METHODOLOGY

Introduction

The low rate of participation of women in male dominated science and engineering technologies is a concern in both the academic as well as the business community (Phillips, n.d.). The number of females who enter engineering fields is still substantially lower when compared to other science-related careers (Burton & Wang, 1999; NSF, 2001).

Although the discouragements that cause many females from losing interest have been discussed and examined in the literature, the enrollment statistics (Cornell University, 2006a) in a particular biological and environmental engineering program appear to have achieved gender balance.

The purpose of this case study was to understand the reasons for a movement toward gender balance that has occurred in a biological and environmental engineering program at an engineering university, despite social, cultural, and educational considerations that are still part of the fabric of society. Approximately 20% of students enrolled in engineering programs nation-wide are female (IMDiversity, 2002). Additionally, the other engineering disciplines at this university have (on average) a 28% female population. The enrollment figures in this case, have demonstrated gender (52% female) balance for the past 2 years (Cornell University, 2006a).

To investigate the issue of gender balance in engineering, this case study explored the Biological and Environmental Engineering (BEE) program at Cornell University. Providing questionnaires and conducting interviews of those females who have chosen this degree path might shed light on what constitutes an environment that supports females in all engineering disciplines.

Understanding why talented women do not readily chose an engineering degree is complex. It might be related to a variety of perspectives, including individual differences; differences in developmental or cognitive related personality, or interpersonal interaction of a particular subject. It might be related to organizational constructs of bureaucracies like schools and organizations, or it might be related to social and cultural constructs (Bickman & Rog, 1998). The highly contextual and complex nature of this issue supports the use of case study as a research method of choice. Case study research is used when examining complex, contemporary issues in real-life situations.

An explanatory case study of women in a biological and environmental engineering program would focus on explanation and understanding through the production of the detailed descriptions (Gall, Gall, & Borg, 2003). In explanatory case study, the researcher looks for connections or patterns of causal relationship, those factors and variables that might affect this population of female engineering students. In this case, exploratory or descriptive case study would not have been appropriate. In exploratory case study, the field work and data collection would occur before the composing of the research questions and in descriptive case study, based on a theory, a more in depth study of the person or persons in question would be necessary.

The ratio of women to men enrolled in BEE represents a particular phenomenon. It is this phenomenon of interest that is the focus of the research. This chapter details the research design, sampling procedures, sources of evidence, data collection, data processing and rationale for the case study research plan.

The Research Design

There are a series of six steps that describe what should be considered, in advance, in order to prepare the case study. It is these six elements that provided the direction and sequence of events that helped to secure a valid study. Stake (1995) and Yin (2003) have written extensively about case study and have provided the direction and techniques for organizing and conducting the work for this case study. A synthesis of both their findings is as follows:

1. Develop the case study's questions
2. Consider theoretical propositions
3. Select samples or cases
4. Choose data gathering instruments
5. Collect and analyze the findings
6. Prepare the report

The Study's Questions

A study of a complex phenomenon requires focus. Establishing a firm research focus to which the researcher can constantly refer is the first step in the research design. The researcher forms questions about the situation or problem to be studied and determines a purpose for the study. The questions established for this study include:

1. Why has the biological and environmental engineering program at a major engineering university attracted a greater percentage of female participants than other engineering disciplines?

2. What are the attributes of this biological and environmental engineering program that are attractive to women?

3. How can these attributes be used to inform the other areas of engineering in moving toward gender balance?

The Question's Propositions

The next step is to establish propositions. Propositions direct attention to something that should be examined within the scope of the study (Yin, 2003). There are theoretical propositions that relate to the study's questions and support the questionnaire and interview questions. Yin suggested identifying theoretical propositions early in the process as a vehicle for maintaining focus. The overarching theme is that engineering is changing and that these changes will require a different kind of engineer. The new engineer will need a different array of skills, and support a different kind of image. This paradigm shift will necessitate a change in engineering education that may well appeal to a broader audience. These propositions include

1. Engineering is a societal endeavor which may appeal to females

2. The image or view of engineers and engineering is changing

3. The change in engineering education through outcomes-based learning objectives

Types of Samples or Cases

In the Department of Biological and Environmental Engineering, there are 173 female students enrolled for the spring semester of 2006. It is from this population that the samples were drawn. The samples necessary to conduct this research are

1. For the questionnaire: the female population in the Biological and Environmental Engineering Department at Cornell University of which there are 173.
2. For the interview: a sample of 10 women of those who participated in the questionnaire.
3. Observation of six engineering classroom

Questionnaire

Seeking students willing to take the questionnaire and thus participate in the interview process was necessary in order to collect data and answer the study's questions. Currently, as of fall of 2005, BEE has a total of 340 students, of which 173 are female. All female BEE students were invited to participate in the questionnaire phase of the study. With permission from the Chair of the BEE department, Dr. Michael Walter, via the Administrator for Graduate and Undergraduate Instruction, the questionnaire was electronically delivered to all 173 female students. Forty-eight responded.

Interviews

For the interview, participants were chosen based on availability. Initially, a purposive sampling of females without a parent as an engineer was suggested. Research has determined that children of engineers have a much higher likelihood of becoming engineers than those students without any personal connection to the field (Orsak, 2003). It would allow the researcher to identify other variables that contributed to their degree decision. The lack of available students with a parent as an engineer did not permit a purposive sampling. Ten women volunteered to be interviewed. All that volunteered were chosen.

Data Collecting Instruments

The data collecting instruments (sources of evidence) were a questionnaire, live interviews, observations and ancillary documents. The strength of case study lies in using multiple methods and techniques in the data gathering process (Bickman & Rog, 1998). The use of more than one technique compensates for any inherent weakness that may be present if only one type of research method is used. Multiple sources of evidence strengthen the project through the process of the triangulation of evidence. Traditional tools used in gathering data for case study include surveys, questionnaires, interviews, documentation, observations, and even the collection of artifacts. Table 2 illustrates the Sources of Evidence or types of data gathering instruments, and the strengths and the weaknesses of each source of evidence.

A questionnaire, individual live interviews, classroom observations, course information, accreditation information, engineering sequences, and enrollment records were among the tools used in connecting the data to the theoretical propositions of this case study. Questionnaires provided the experiential history of the students, live interviews provided a means for the in-depth stories and "rich descriptions" of each of the young women in engineering, and classroom observations supported an understanding of the climate of the engineering environment. The questionnaires, live interview, and classroom visits were helpful in understanding the changes that may be going on in the instructional environment.

Table 2. Sources of Evidence

Sources of evidence	Strengths	Weaknesses
Documentation	Documentation is a stable form of evidence. It existed prior to the case study. It uses exact names and may have existed over a long period of time. The tradeoff is that retrievability may be difficult. Both selectivity and reporting may reflect author bias and access may be blocked.	Retrievability may be difficult. The selectivity and reporting of the evidence may reflect author bias.
Archival records	Archival records exhibit the same strengths as documentation, but additionally are both precise and quantitative.	Archival records hold the same weaknesses as documentation. Additionally, privacy issues may emerge.
Interviews	Interviews cover events in real time. It is contextual and covers events in context.	Interviews are time- consuming and costly. The selectivity of the project might miss facts. Additionally, the observer's presence might cause change in response.
Direct observation	Focuses on the case study topic. It is insightful and provides perceived causal inferences.	Bias may be exhibited due to poor questions. There may be bias in participants' responses. Recollections may be incomplete and interviewee expresses what interviewer wants to hear.

Information concerning learning styles added another dimension to the instructional needs of the community. As teaching becomes outcomes-based, changes in instructional strategies become necessary. This information illuminated the propositions that a new kind of engineering along with the development of new skills in engineering might be driving the instructional environment.

Questionnaire

The purpose of the questionnaire was to understand the relevant experiences and attitudes related to STEM careers that might be viewed as explanation for the rise in the female participation in BEE. Questions were generated from the literature review chapter of this proposal regarding the low participation of females in engineering technologies. They included the lack of adequate encouragement and preparedness in the sciences, marginalization in the science and engineering fields, role models, and the reasons for BEE as a degree choice.

The questionnaire (Appendix A) contained 17 items consisting of both short and extended response questions, and a Likert scale. The questionnaire was constructed using the forms feature of Microsoft Word.

Interviews

The purpose of the interview was to further explore the experiences of these women in engineering, thus providing narratives. The interview (Appendix B) consisted of six core questions. The interview questions were altered as a result of reading the extended responses in the questionnaire. Interview questions were open-ended and included

1. Why did you agree to be interviewed?
2. Have you experienced any marginalization on or off campus?
3. Is BEE considered fake engineering?
4. Do you think that it is true?
5. How do you learn best?

6. What is your favorite class and why?

7. Why did you decide on Biological and Environmental Engineering?

Observations

Included in this study were informal observations of various engineering classrooms. According to Cornell University, a simple request was all that was needed to observe a class. Having access to the classroom experiences of the women in BEE provided an additional dimension to the engineering educational picture. Classroom observations were chosen based on availability.

The purpose of informal observations was to provide an additional tool to gather data. Danielson and McGreal wrote, "The live classroom observation allows an observer to note the 'feel' of the class, the climate that is not always communicated through video camera" (2000, p. 47).

For the classroom observations (Appendix C), a checklist of relevant information provided the researcher with an additional tool: a snapshot of what engineering education is really like. The researcher was treated as one of the students and given all of the appropriate handouts available to the class.

Data Collection Procedures

The processes used to collect and gather the data was as follows:

Questionnaire

An invitation regarding the questionnaire was e-mailed from the BEE office to the 173 females students. An introduction by Dr. Timmons, BEE professor, alerted them to the incoming questionnaire. Dr. Timmons provided a brief introduction of the rationale for the project and the researcher. Forty-eight participants returned the questionnaire to the researcher through e-mail. At the end of the survey, participants were invited to participate in the interview process. Based on their responses to the questionnaire, 10 young women volunteered to participate in the audio taped interviews.

Interviews

The interviews provided what short-answer, black-and-white, two-dimensional questionnaires could not. The open-ended questions focused on deeper meaning of this study's theoretical propositions. The list of interview questions was purposively short to allow for questions to develop or evolve as a result of the questionnaire. A conference room on campus at Cornell University was the setting for the interviews. Interviews took place during the day, at the convenience of the participants. All interviews were recorded using a digital tape recorder.

The interview process began with short introductions used to create a trusting and relaxed environment. During the interview, Morgan (1988) suggested paying careful attention to the nonverbal aspects of the interaction, including, pauses and patterns of speech, and analysis of conversations. In addition, the researcher kept an ongoing diary to record any additional information that might not be picked up by the taped interviews. At the conclusion of the interview, refreshments were offered and the young women were graciously thanked for their participation and helpfulness in examining this issue. All participants were given the opportunity to view the results of the project.

The quality of the data collected hinges on the quality of the questions, and the rapport that is established between the interviewer and the person interviewed. Most importantly, the "respondent has to be convinced that the interviewer is not an adversary but is at the very least impartial" (Partington, 2001, p.2).

Using a variety of skills, the interviewer worked toward developing a positive relationship with the respondent in order to obtain quality information. The quality of the data are diminished when interviewers do not attend to basic principles of interviewing. Most importantly, interviewers should avoid a lot of interviewer talk and little respondent talk (Partington, 2001).

Interviewers should maintain good eye contact, clarifying information, and paraphrasing or summarizing when necessary. If an interview works well, the respondent should be doing around 70% of the talking, and the interviewer should be spending most of the time listening.

As in all interviews, spontaneous questions emerged, leading the interviewer down alternate paths and thus uncovering additional themes. The opportunity to develop additional questions resulted from the data processing of the questionnaires.

Observations

Observations of several classrooms provided additional information about the engineering environment. Engineering classrooms, traditionally have been focused on the lecture format. A variety of courses were observed.

Other Documents

Other relevant documents reviewed included course information, accreditation information, course alignment to the ABET learning outcomes 3a-3m (Appendix D), engineering sequences, and enrollment records. Enrollment records substantiated the movement toward gender balance in Biological and Environmental Engineering, course information helped to understand the requirements necessary to become a biological or environmental engineer, and accreditation information sought to understand how engineering schools are meeting required learning outcomes, through outcomes-based learning.

Rationale for Field Testing

The questionnaire required a field test. Six female engineering students at Cornell were used in the field test. The rationale for field-testing the questions was to increase the validity of the case study project. Field-testing the questionnaires became an important consideration toward validity and credibility of the research. The case study's questions were vital in extracting the necessary information to answer the three research questions that either supported or refuted the theoretical propositions. The use of a field test identified problems. This encouraged a reframing of the questions, an elimination of questions or creating new questions. In addition to field-testing by students, suggestions were also considered from members of the engineering faculty. A brief discussion followed the completion of the field test questionnaire. Based on input from the six students and engineering faculty, adjustments were made.

The field test assisted the researcher in identifying problems in any area of the design. It took advantage of the flexibility, by addressing necessary changes as the project evolved and unfolded. Flexibility can modify the design with each and every step. Those participating in the field test are not part of this study. Additionally, Yin (2003) wrote that a field test could also (a) help the researcher refine the open-ended questions put to interview participants; (b) improve methods for selecting participants; (c) help the researcher refine data collecting plans, with respect to content and data; (d) provide conceptual clarification of the propositions; and (e) provide further insight into the questions being investigated.

The field test is strongly suggested as a tool for insuring that the case study follows some kind of logic and theory. All relevant data collection issues were encountered and resolved as a result of the field test.

During a field test of the questionnaire and interviews, participants were asked to provide feedback on both the wording and content of the questions. All necessary changes were made before the next phase of the case study continued. Rewording questions and the addition of other items was in response to the field-testing process. As in any scientific inquiry of social concern, there is always an unknown factor that can redirect and drive the inquiry. Based on the examination of the questionnaires, the interview questions were revised.

Recapitulation

In summary, a linear, chronological approach to the data collecting process was as follows:

1. Questionnaire was generated based on relevant information on women and engineering.
2. Questionnaire was field-tested with six women.
3. Questionnaire was revised based on student input and researcher reflection.
4. Revised questionnaire was then distributed to all female BEE students.
5. Information from the questionnaire was collected and analyzed for themes.

Interview questions were processed in the same manner.

1. Interview questions were generated based on relevant information on women and engineering.
2. Interview questions were then revised based on student responses to the questionnaire, researcher reflection and other preliminary findings.

3. Revised interview questions were used in the final interview process.

4. Information from the questionnaire was collected and analyzed for themes.

Timeline

This case study took place on the University campus, in the classes, meeting and talking with students. There were many steps necessary before the research could commence. The study was conducted over a 3-month period, beginning in April of 2006 and ending in the spring of 2006. The mentor, the dissertation committee, Internal Review Board, the School of Education at Capella University, as well as the University, accepted the proposal. The questionnaire was field-tested at Cornell and will not be part of the study. The rationale for field-testing was to sharpened the focus of study and add reliability and validity to the case study. The revised questionnaire was then made available to those participating in the first phase of the case study. After the data was collected, sorted and analyzed, 10 participants volunteered for in-depth audio interviews. After the interviews, the data was processed and analyzed.

Monthly Projected Timeline

February-April 2006:

1. Set up an appointment with the Engineering Department for a field test of the questionnaire and interview questions.

2. Make contact with Brenda Marchewka, coordinator of Graduate and Undergraduate Instruction and BEE Student Groups and Activities.

3. Obtain approval from the Internal Review Board and the School of Education.

4. Field-test the questionnaires on campus.

5. Field-test the interview questions on campus.

6. Revise questionnaire and interviews as appropriate.

7. The questionnaire was delivered to students from the department.

8. Analyze revised questionnaires.

9. Prepare for the interviews based on information gathered during the pilot process.

10. Visit the University to conduct interviews with BEE students.

11. Observe classrooms.

12. Compile questionnaire and interview data.

Data Processing

Questionnaires

For background information, several systems of organization were used, including raw percentages, and histograms. More lengthy responses to the questionnaire were organized into word processing documents and then coded using an inductive analysis approach. Bogdan and Biklen defined qualitative data analysis as "working with data, organizing it, breaking it into manageable units, synthesizing it, searching for patterns, discovering what was important and what was learned, and deciding what to tell others" (1982, p. 145). Questions about the individual educational differences among students, role models, previous experiences in science classrooms, and societal messages formed the basis for the questionnaire.

The short answer questions were analyzed using raw percentages. The questions requiring a longer response were coded along generalizable themes for these questions. For example, “teachers as engineering mentors” and “group work favored over lecture,” might be generalizable themes for questions 4 and 15, respectively.

Interviews

In quantitative analysis, the numerical data tell the story. In qualitative analysis, it is the words that tell the story through the voice of the respondents. The interviews were recorded using a digital recorder to insure accuracy and to support the need to extract the themes from the interviews. The accuracy of generating verbatim transcripts using iListen software proved very inaccurate. Verbatim transcripts were generated using a system of listening multiple times to extract the necessary data.

The value of recording each interview had many benefits and must not be overlooked or underutilized. There were many opportunities for listening. Listening more than once allowed the interviewer to gather data that might have been overlooked from just one listening. The reading of the transcriptions provided accuracy of the written word, while the listening provided the nuances that transcribed data did not capture. Through the process of multiple listening, the themes emerged as words or short phrases that may be repeated and categorized during the analysis process.

Since the questions in this interview were open-ended, the development of a category system of critical themes was required. The critical themes tend to emerge out of the data through the process of inductive analysis (Patton, 1990). The theoretical propositions provided the relevant categories and opportunities for explanation building, and patterns of causal relationship. Analysis begins with the identification of tentative, critical themes. This is known as *open-coding* (Strauss & Corbin, 1990). There were three initial theoretical propositions, plus the codes for the theoretical propositions:

1. Engineering is a societal endeavor (S)
2. The image or view of engineers and engineering is changing (I)

3. The change in engineering education through outcomes-based learning objectives (A)

"What distinguishes qualitative analysis from quantitative analysis is a loop-like pattern of multiple rounds of revisiting the data as additional questions emerge, new connections are unearthed. Qualitative analysis is fundamentally an *iterative* set of processes" (Berkowitz, 1997, p. 2). Additional categories or codes developed as the data was collected and analyzed.

In summary, a three-step inductive analysis approach to data processing drove the analysis section of this proposal.

1. Reduce the data. Data reduction refers to the process of breaking down, selecting, focusing, simplifying, condensing and transforming the data (Miles & Huberman, 1994) into manageable chunks.

2. Through inductive analysis, identify the themes that will be singled out for description.

3. Reexamine the categories to determine how they are linked. Categories identified in open-coding are compared and combined in new ways to create a "big picture" (Hoepfl, 1997).

The three initial categories—(S), (I), and (A)—based on the theoretical propositions had been determined. This was only a beginning, as new information was unearthed, and new categories emerged.

Addressing Reliability and Validity in Qualitative Research

It is very important to maintain reliability, internal and external validity that are found in traditional research. This can be accomplished through the process of triangulation and structural corroboration. Graham suggested "persistent observation, checking multiple sources of data through a comprehensive literature review, recording field notes, and clarification of categories and narrative stories with participants as techniques of structural corroboration" (1997, p. 51). Since this qualitative study used "thick description" with a small sample of participants, generalization to the wider population was not possible.

> Thus, generalizations to other subjects and situations are always modest and mindful of the context of individual lives. That is, phenomenological research uses sampling, which is idiographic, focusing on the individual or case study in order to understand the full complexity of the individual's experience. For this perspective, there is no attempt to claim an ability to generalize to a specific population; but instead, the findings are relevant from the perspective of the user of the findings. (Bailey, as cited in Graham, 1997, p. 51)

Piloting the questionnaire and interview questions, and maintaining good investigatory skills systematically insured validity both external validity as well as internal validity to the study. During data collection, data analysis and in the research design, Table 3 demonstrates how the researcher can insure validity.

Table 3. Approach Toward Validity

Tests	Case study approach
Construct validity	Use multiple sources of evidence.
Have key informants review draft case study	Establish a chain of evidence.
Internal validity	Do pattern matching and explanation building. Do time series analysis. Do logic models.
External validity	Use rival theories within single cases and replication logic in multiple cases.
Reliability	Use case study protocol. Develop case study database.

If properly designed and well managed, using a variety of tools systematically added validity to the study, both external validity as well as internal validity. Internal validity demonstrates that certain conditions lead to other conditions and require the use of multiple pieces of evidence from multiple sources to uncover convergent lines of inquiry. External validity reflects whether the researcher strives to establish a chain of evidence forward and backward. Within each individual case study, the data should converge on why the particular theoretical proposition was supported or disconfirmed (Yin, 2003).

Bias

The researcher must be open to the findings whether or not they substantiate or disconfirm the propositions of the question. The researcher must be willing to accept contrary points of view that may be revealed during the gathering of data. Dangerous bias can be imported or smuggled into the research process. “Bias refers to ways in which data collection or analysis are distorted by the researcher’s theory values, or perspectives” (Bickman & Rog, 1998, p. 92). Bias lies in the perspective of the researcher, whose background and experiences can taint as well as bring richness to the study (Yin, 2003).

Bias is inevitable in qualitative research, as researchers cannot extricate themselves from the study. A researcher can only be aware of bias and understand the limitations of the findings.

Issues of Privacy and Consent

Participants need to be informed about their rights and the purpose of the study. This was accomplished through the Institutional Review Board process and appropriate consent forms. In this study, the risks were minimal except for the risks that are encountered in everyday life. Everything was done to insure that the rights to privacy of the participants were maintained. Questionnaires did not include any personal or identifiable information to further maintain privacy for the participants. At the culmination of the dissertation process, all transcripts, relevant documents and recorded interviews were destroyed.

Propositions

Understanding the propositions helps keep the study in focus and structures or restructures the data collecting tools as needed. "Engineering is Changing" is the overarching theme for the theoretical propositions of this case study. This paradigm shift will require a different focus in engineering education.

The Changing Role of Engineering in Society

The evolution of a biological and environmental engineering from its beginnings as the Department of Farm Mechanics, reflect the change in focus and societal need. The challenges facing the world are vital and important to all, and are different from the challenges that faced the world at the end of the 20th century. The degraded environment, the need for clean air and water are of great social and personal concern. This connection to evolving social concerns is one speculative reason for the increase in female participation in BEE.

The Newly Emerging Image of a New Engineer

The image of the engineer is changing. The new engineer will require new skills; working in problem solving teams, understanding every aspect of design, understanding the end-user, and working and interacting with people. There is a move from the image of the engineer as a cold, analytical nerd to a solver of the problems that face society. The image of the new engineer as a people person contrasts with the image of the driver of trains and the fixer of things. This creation of the new image of engineer may well appeal to a wider audience and in addition represent traditional female concerns and approaches to the world.

The Impact of Accreditation

Engineering education is changing. This is due to changes in the skills that both the engineer and engineering educator require. This is further speculation of the increase in gender parity in BEE. Demands of teaching to learning outcomes have brought about change through new accreditation procedures from ABET. Demands of accreditation, new understandings of teaching and learning trickle into the curriculum and move traditional instructional strategies toward a more inclusive teaching and learning environment. The "good teachers are born, not made" attitude about teaching needs to be replaced with a new view that teaching is a skilled profession, which can only be learned through diligent study and experience (Alberts, 1997).

Increasing the variety of instructional strategies will add those components of teaching and learning that traditionally appeal to a wider audience of learners, as in cooperative learning in addition to competition, active learning as well as passive learning, and learning in a socially constructed environment along with learning in isolation.

Case Study Rationale

Case study is an accepted form of qualitative research. It is especially meaningful when the issue is of a societal concern and the focus is on the emic perspective of the participants. Human beings are complex. The issues of gender are highly contextual and require a more flexible research methodology. It is for these reasons that case study makes an appropriate choice of methodology.

Qualitative and Quantitative Data

Educational researchers use a variety of methods to promote knowledge and understanding. Two main categories available to educational researchers are quantitative and qualitative research methods. “Quantitative research is grounded in the assumption that features of the social movement constitute an objective reality that is relatively constant across time and settings” (Gall et al., 2003, p. 634). The dominant methodology is to “describe and explain features of this reality by collecting numerical data that is subjected to statistical analysis” (Gall et al., p. 436).

By contrast, “qualitative research assumes that individuals construct their own reality in the form of meanings and interpretations” (Gall et al., 2003, p. 436). The dominant methodology is in the form of studying cases intensely, in order to cull out the meanings and interpretations (Colorado State University, 2004).

Differences in Sample Size, Data Collection and Analysis

Sample size, data collection and analysis also distinguish quantitative research methods from qualitative research methods. In this qualitative study, the sample size was smaller. There were 48 of the 173 possible women in the study’s sample and 9 women for the interviews. Additionally, data collection is less structured and analysis is nonstatistical. The outcome of qualitative versus quantitative research methods also differs in that the findings in qualitative research may not be generalized over other populations (Colorado State University, 2004). Initial understandings of women in an engineering program, can be gleaned from qualitative data and offer a sound basis for further exploration and decision-making.

Qualitative research presents a more holistic view of the phenomena. To describe qualitative methodology, Rudestam and Newton (1992) used the terms *naturalistic inquiry* or *discovery-oriented approach* in the natural environment. Case study methodology is a form of qualitative descriptive research. Qualitative research methods, as in this case study, permitted a more spontaneous and flexible exploration (Rudestam & Newton) than quantitative research methods.

Relevance of Case Study in this Context

Case study made an appropriate choice for this case study in that the researcher could examine the issue by looking at the interplay of all variables; uncover new variables, new ways of knowing, which could then provide the energy for further understanding (Colorado State University, 2004).

As issues of gender and society are complex and cannot easily be studied using quantitative research methods, case study research makes a suitable methodology. What is needed is a methodology that examines the interplay of participants; the teachers, the students, the family and society, and their interactions with the learning environment, much like the interactions in a natural ecosystem. In an ecosystem there are complicated interactions of living and nonliving components, intricately connected. Case study delivers this intricacy.

Examining Contemporary Phenomenon

Yin (1993) defined the case study research method as an empirical inquiry that investigates a contemporary phenomenon within the real-life context. Case study is especially meaningful when, “the boundaries between the phenomenon and the context are not clearly evident; and in which multiple sources of evidence are used” (Yin, 1984, p. 23).

Gall et al. (2003) defined case study research as the in-depth study of instances of a phenomenon in its natural context and from the emic perspective of the participants involved in the phenomenon.

Researchers collect data about participants and direct observations, as well as interviews, protocols, enrollment figures, engineering curriculum frameworks, and ABET requirements as a way of establishing converging evidence. Case study refers to the collection and presentation of detailed information about a particular participant or small group, frequently including the accounts of subjects themselves. Case study does not presume to generalize a universal truth, a frequent criticism of case study research. Instead, the emphasis is placed on exploration and rich description toward an analytical understanding (Yin, 2003).

Utilizing case study can illuminate this phenomenon via the personal stories through what Gall et al. called "thick descriptions" (2003, p. 439). Unlike traditional experiments with an independent variable and measured dependent variables, controls and constants, the case study would allow for a more thorough interpretation of the gender balance occurring in the biological and environmental engineering degree under discussion.

Types of Case Study

Of the three main categories of case study—exploratory, descriptive and explanatory—this research will use explanatory case study. Explanatory case study is used mainly when seeking a causal relationship. It is most appropriate when the research questions are of the "why" and "how" variety and the topic is of a contemporary nature (Tellis, 1997).

Reflections on the Qualitative Process

The process of qualitative data collection and analysis is labor intensive. Listening and gleaning information from hours of talk can be tedious and time consuming, decidedly a disadvantage. Understanding through analysis is not often immediately accessible, but requires a certain amount of processing (Miles & Huberman, 1994). This might include editing, correcting the language, and listening for inflection. When the data are ready for interpretation they are vulnerable to researcher bias. Bias lies in the researcher, so it is unavoidable, as qualitative data collection and analysis are subjective. Acknowledging it and introspection are two ways to manage bias.

On the other hand, the qualitative approach to understanding phenomena had several advantages. As time consuming as analyzing the qualitative data was, the richness of the narratives provided an opportunity to learn and understand from the perspective of the participants in this study. It enabled the researcher to view the experiences through the eyes of each participant as best possible.

Use of human subjects is complex and perplexing as well as informative, as each human responds differently to the same stimulus or the same words. All human experience is a combination of many complex interactions. Also, contributing to this complexity are the differences in each person's nature, personality, family life, educational experiences, the environment, and social and cultural conditions occurring during their lifetime. No situation has the same meaning for each person. Therefore, "Qualitative data are more likely to lead to serendipitous findings and to new integrations" (Miles & Huberman, 1994, p. 1). Each human places similar experiences in their own individual context, and responds appropriately.

Another advantage of qualitative methodology was the improvisational quality that conversation provided. It broadened the knowledge base and enriched the data for the researcher. Although a set of core interview questions was established, no two interviews were exactly alike. Each interview was based on the direction taken as participants reacted to prompts and core questions. It was flexible and inquiry driven. The flexible questioning permitted the exploration of each participant's unique experiences. The interviewer could then explore paths not taken by the other participants. Each participant carved out a different path and length of time needed to explore the questions.

Finally, "Qualitative data are sexy. They are a source of well-grounded, rich descriptions and explanations of processes in identifiable local contexts" (Miles & Huberman, 1994, p. 1). The stories have an enticing nature that numbers alone cannot provide.

Summary and Conclusion

This investigation employed case study as an appropriate method of inquiry. Case study is appropriate when dealing with complicated issues of social research that seek to answer the question of why women are choosing a biological and environmental engineering program over other engineering disciplines. Women are persevering and persisting in programs that historically have been male-dominated. The issue of equity and gender balance in engineering is complex and the method for uncovering knowledge must reflect this complexity.

This case study gathered and collected data using a variety of qualitative research instruments; including a questionnaire, live interviews, classroom observations and documents such as enrollment figures, course and accreditation information. Case study looked at the issue from a multidimensional perspective. Tellis (1997) called this the multiperspectival analysis that considers, not just the voice and perspective of the actors, but also of the relevant groups of actors and the interactions between them.

This case study focused on the explanation of the causal relationships of this phenomenon of female students in a biological and environmental engineering program. It can be a more appropriate method of uncovering the reasons behind this phenomenon than more quantitative approaches of inquiry, like surveys or experiments. In more traditional quantitative research methodology, generalizations are made from numerical information.

The issues of gender and science are complex and require the interpretation of information from a perspectival analysis. Unlike quantitative or statistically driven research, new questions, new ideas, new knowledge propels the researcher toward new ways of knowing.

Case study requires examining the phenomenon from a more naturalistic point of view. It is contextual. The issue of the gender balance of females in engineering careers occurs in a highly contextualized setting. It is played out in real time and in a real place: in a family, in a classroom, or in society at large.

Concerns of gender and society are high drama. Societal issues of gender have historically been powerful, as in a woman's right to vote, or the right to have the opportunity to choose an engineering degree. A case study would permit the drama to unfold.

CHAPTER 4. DATA COLLECTION AND ANALYSIS

Introduction

Live interviews and a questionnaire formed the core of this inquiry into the reasons concerning the gender balance that has occurred in a biological and environmental engineering department at a New York State engineering college.

One hundred and seventy-three undergraduate female students at Cornell University were invited to participate in this study that sought to examine the phenomenon of gender balance in the department of biological and environmental engineering. Forty-eight respondents provided the sample for this inquiry. Additionally, they were asked if they wished to participate in live interviews; 10 agreed. In addition to the questionnaire and interviews, classroom observations and relevant school documents were used to examine this phenomenon.

Chapter 1 introduced the problem of the low participation of women in the engineering technologies. Three research questions guided this inquiry.

1. Why has the biological and environmental engineering program at a major engineering university attracted a greater percentage of female participants than other engineering disciplines?
2. What are the attributes of this biological and environmental engineering program?
3. How can these attributes be used to inform the other areas of engineering in moving toward gender balance?

Chapter 2 discussed the research regarding women's lack of participation in the Science, Technology, Engineering, and Mathematics (STEM) careers, and the low rate their choosing engineering degrees.

Chapter 3 outlined the methodology used to understand the phenomenon being investigated. The research approach for this project was predominately qualitative in nature and utilized case study methodology.

Chapter 4 provides the in-depth view of the information gathered. This chapter includes the responses to the questionnaire (organized by question number), the interview, an analysis and a section linking the propositional themes to the data.

Chapter 5 presents an analysis and discussion of the findings and implications of the study. Conclusions and recommendations for future studies and for practical improvements are also described.

The Study’s Context

Enrollment statistics have demonstrated gender balance in the biological and environmental engineering program (BEE) at Cornell University for the past 2 years. Presently, the enrollment of females in BEE is 52% (Cornell University, 2005b). In contrast, other engineering disciplines at the university have an average enrollment of 28% females.

Qualitative methodology was used to develop an understanding of this phenomenon. One major feature of qualitative methodology is that it focuses on “naturally occurring, ordinary events in natural settings, so that we have a strong handle on what real life is like” (Miles & Huberman, 1994, p. 10). The questionnaire and interview questions were developed as a result of the literature review. An understanding of the gender balance that has occurred at Cornell's BEE can provide insight into how more females might be attracted to other engineering disciplines, making the creative and lucrative careers of engineering more accessible to women.

This case study explored the much-investigated topic of the degree choices women make and why these women have chosen the degree path in biological and environmental engineering. This inquiry permitted the voices of these women to tell the stories in their own words. The purpose was to develop the understanding of a complex phenomenon as experienced by the students themselves (Gall et al., 2003). The knowledge that emerged was based on the perceptions of the female participants in BEE, as well as an understanding of the program.

The Women of BEE

Forty-eight of the 173 undergraduate female engineering students volunteered to complete the questionnaire. Ten of the 48 students that completed the questionnaire volunteered to be interviewed by indicating so on the questionnaire. Nine students ultimately were interviewed with one cancellation. All undergraduate levels were represented. Of the nine that were interviewed, three students were from out of state and the remaining women were New York State residents.

Data Collecting Instruments

The Questionnaire

One hundred and seventy-three female undergraduate students in BEE received the questionnaire. Forty-eight responded. The questionnaire was delivered electronically (twice).

It consisted of 17 items with both short and extended response questions. A short note preceded the e-mail so that students would not discard the e-mail as junk mail. Short answer items provided demographic information about the students, while extended response questions provided information concerning their attitudes and preferences.

The questionnaire went through an initial piloting process during which questions were altered or added. Question 11, for instance, concerned academic support. It originally asked about "support for women engineering students." The women that read this question were offended by the idea that there would be a special support system based on gender. Therefore, the question was altered to read, "support for all engineering students." Item 12 also evolved to include a much broader list of options for students.

Forty-eight students responded. To prevent duplication, the 48 questionnaires were numbered as they were received. The questionnaire was divided into four sections: Prior Experiences, Campus Life, Why Choose BEE? and Learning Style Preferences. The short answer responses were sorted and raw data and percentages were placed in either a table or figure. Extended response questions were purposely open-ended to permit unforeseen information to emerge. All responses to extended response as well as interview questions are shown in italics.

A data reduction system was developed to reduce the data into manageable chunks.

1. For each question, extended responses were copied verbatim into a word-processing document.

2. After carefully reading all of the extended responses, similar key words and phrases were clustered using various methods, including the "find" feature in the edit menu.

3. Words and phrases were then sorted according to their synonymity.

4. A system of attributing themes based on these synonymous groups was used to establish broader categories.

5. Each broad category was then given an identifying letter or code. From the identification of themes, initial conclusions were drawn.

Prior Experiences

The section on Prior Experience outlined students' precollege experience, courses taken, models and mentors, and prior experiences with engineers and engineering.

Questions 1 and 2 asked students, "How many years of math and science did you take in high school?" Tables 4 and 5 show the number of years of math and science students completed in high school.

Table 4. Years of Math Study Completed by Students

Years of math	*N* of students	%
6	1	2%
5	3	6%
4	42	88%
3	2	4%

Of the 48 students that completed the questionnaire, 87% and 73% of the students had completed at least 4 years of math and science respectively. At least 4 years of math and science are necessary to be adequately prepared for a degree choice in engineering at this University.

Table 5. Years of Science Study Completed by Students

Years of science	*N* of students	%
6 or more	3	6%
5	5	10%
4	35	73%
3	5	10%

Question 2 asked students, "What courses, if you remember, did you take in high school?" Of the 48 students who completed the questionnaire, 73% of the students took Advanced Placement (AP) courses in high school including one student that took International Baccalaureate (IB) biology, chemistry and physics. For some students, AP courses were not offered. Additional course offerings completed in high school included: vertebrate zoology, cellular biology, zoology, physiology, genetics, and biotechnology.

Table 6 demonstrates the number of AP courses that were completed by students.

Table 6. AP Courses Taken in High School

Number of AP courses	*N* of students	%
0	13	27%
1	17	35%
2	12	25%
3	6	13%

Figure 1 shows the percent of students and the AP courses taken.

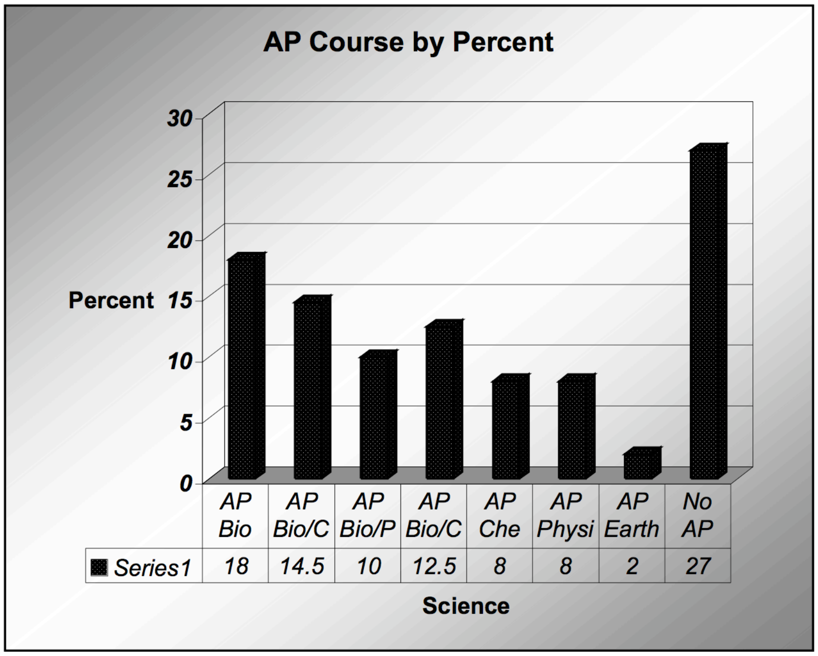

Figure 1. AP courses and student enrollment by percent.

One student, whose father and great grandfather were graduates of Cornell, said that her Dad was adamant that she not include her AP courses (36 credits) toward her degree. "My dad was adamant right from the start that if I was going to go there, I would not transfer my college level classes to Cornell. You'll have that background and that will help you."

Question 3 asked students, "Is there anyone in your family who is or was an engineer?" Figure 2 illustrates the percentage of those with and without an engineer in the family.

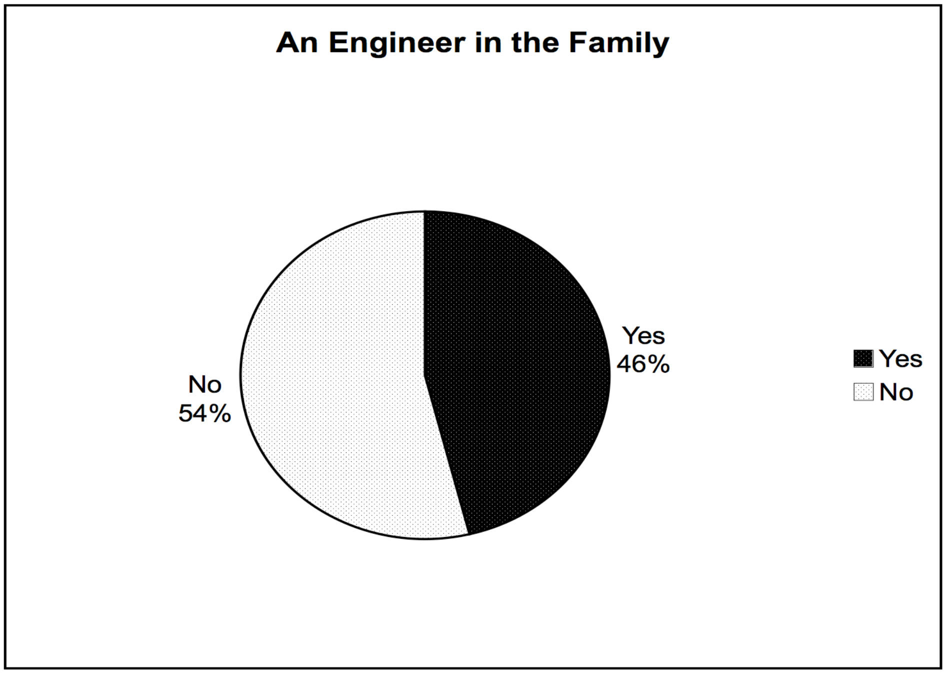

Figure 2. Engineer in the family.

Of the 48 students that completed the questionnaire, 26 students (54%) did not have a parent or relative serving as a role model for engineering. Twenty-two students (46%) had a parent or family member that served as a role model: including fathers, mothers, uncles, brothers and sisters. Two students had both parents as engineers.

During the interview process, more than students acknowledged that having a parent or relative as an engineer supported a broader, more positive definition of what it means to be an engineer, something that the K-12 educational environment and the media did not do. Three students commented that the traditional definition of the engineer, which, according to students, is the mechanical engineer, served as their only definition. Both a new definition of engineering and engineer may be emerging, but the old definition prevails.

Question 4 asked, “Did you have a role model other than a family member that served as a model for engineering?” Six students listed engineering experiences that served as models for a degree choice in engineering, such as summer programs; CURIE, a Cornell/SWE sponsored program for high school students that excel in math and science, Architecture and Construction Mentoring Program, as well as working with engineers on project teams and summer internships. Two students learned about engineering only after coming to the university.

Question 5 asked students, “Do you think that high school adequately prepared you for a degree choice in engineering?” Table 7 shows the information provided by students regarding this question.

Table 7. Did High School Adequately Prepare You?

Yes	No
71%	29%

Question 6 asked, “In what way could high school have better prepared you for engineering?” Although 34 students (73%) were satisfied with their preparation for an engineering degree, 14 students (29%) cited the following reasons for inadequate preparation for a degree choice in engineering.

1. Insufficient knowledge of what engineering is and what engineers do
2. Lack of challenging courses to prepare them for the engineering experience

3. Poor career direction

4. Lack of sufficient encouragement

Selected responses by students concerning this question can be seen in the following quotes (see Appendix E for all student responses to Question 6):

> Poor Direction: "No one felt that engineering was relevant to my overall education as a woman. I was often discouraged from incorporating more science and math courses than was required for graduation into my high school education by both my parents and school administration."

> Poor Preparation: "Needed are tougher math and science training, as well as classes that actually exposes students to engineers and what they do."

> Lack of Course Challenge: "I think more challenging problem solving techniques could have been given."

The need for better preparation in high school for the STEM careers is substantiated in the literature (Felder & Silverman, 1988) as well as by student responses. Not all high schools provide Advanced Placement courses; therefore providing AP courses, or similar courses is essential in making STEM careers an option for everyone. Counselors can include more supportive assistance regarding direction for women who may choose a nontraditional career.

Campus Life

Question 7 asked for information regarding the undergraduate year in college. Table 8 indicates the number of students according to the undergraduate year at Cornell. Both the respondents to the questionnaire and the interview showed a higher participation of seniors than the other undergraduate years.

Table 8. Undergraduate Year of Study

Year of study	*N* of students	%
Freshman	11	23%
Sophomore	10	21%
Junior	12	25%
Senior	15	31%

Question 8 asked students "Are you aware that BEE is attracting more female students?" Of the 48 participants that competed the questionnaire, 47 provided a response. Table 6 shows the distribution of responses to the following question:

Table 9. Are You Aware?

Yes	No
83%	17%

Question 9 asked students, "What do you think the reason might be for this gender balance phenomenon at Cornell?" Question 9 was deliberately open-ended to allow for as many kinds of additional themes to emerge. Ultimately, these themes were placed into broader categories and then coded.

Based on similar meanings, the central themes that emerged as a result of question 9, fell into five broad categories. The explanation of those categories is as follows:

Theme 1: Life Issues (LI)

The Life Issue (LI) theme is defined as anything related to life; including the relationship of engineering to biology, biological systems, the environment, societal concerns, medicine, premed opportunities, personal and public health. Life Issues (LI) encompassed a variety of key words and phrases with similar meanings.

Theme 2: Curricular or Academic Issues (CI)

The Curricular Issues (CI) theme is defined as having the components of teaching and learning. This might include listening, reading, writing, discussing, comparing, and contrasting. Additional components are the aspects of a nontraditional discipline, with varying instructional approaches to engineering education, the natural interdisciplinary quality of the subject matter, including the problem solving and application approaches to learning and instruction, and the connection of engineering education to relevant real-world topics.

Theme 3: Perceptual Issues (PI)

Perceptual Issues (PI) theme included either relevance or nonrelevance to the prior learning experiences of the students, the perception that biological engineering is less rigorous, less math intensive, easier for women, more manageable and includes issues of stereotypes.

Theme 4: The Supportive Department (SD)

The Supportive Department theme is defined as believing that the department and or the University support academic success. BEE is mentioned as a department whose culture is supportive to the concerns of students.

Theme 5: The Financial Incentive (FI)

The Financial Incentive (FI) theme may indicate the financial incentive to families with limited resources. Since Cornell University is a land-grant college, New York State residents can apply to the College of Agricultural and Life Sciences (CALS) and receive a reduction in tuition for BEE as compared to the other engineering colleges.

One student acknowledged that BEE might be attracting more women because of changes in societal attitudes concerning women and the STEM fields.

Table 10 shows the frequency of choice regarding Question 9.

Table 10. Theme Category by Frequency

LI	CI	PI	SD	FI
32	13	13	3	2

Students mentioned more than one theme in their narratives, so each response included an overlap of categories. The Life (LI) theme was mentioned 32 times, the Curriculum (CI) theme 13 times and the Perceptual (PI) theme 13 times.

The connection to biology or Life Issues (LI) was cited most often as the reason that students felt BEE is seeing an increase in female participation. Second, the (a) curricular issues (CI) as in an interdisciplinary approach to learning and third, (b) the perceptions (PI) associated with a degree in biological and environmental engineering.

Responses by students concerning this question of the reason why more women are choosing BEE can be seen in the following quotes (see Appendix F for all student responses to Question 9):

> Life: Inclusion of the biological sciences in the engineering degree. Fields like biology and chemistry have seen more female involvement than the math and physics departments. These subjects make the BEE department more accessible to females than other engineering departments. Additionally, it seems that more women are in the healthcare field than are in engineering, so this facet of biological engineering makes it easier for women to access the department.
>
> Perceptual and Life: There is still the feeling that BEE is not "true" or "hard-core" engineering. It's a less intimidating environment and material than other engineering disciplines. Girls seem to be far more interested in biological systems than in buildings, etc.
>
> Curricular and Life: BEE is interdisciplinary, so students can choose their focus based on interests within the field. It is also closely related to problems people see in the world, pollution, or medical issues so, it seems to apply directly to life.
>
> Support: Cornell goes to great lengths to ensure that females are treated equally in the engineering disciplines. Cornell also provides a variety of resources for female engineers.
>
> Supportive Department: I feel that I can walk back to any of my professors if I have more specific questions, I can contact Brenda (coordinator of graduate or undergraduate instruction) has been more than helpful. That's going to draw people.
>
> Perceptual: I originally began as a mechanical engineering major. However, I found that sitting in a metals' shop with guys talking about cars quickly lost its appeal. I think many women in engineering find the intro courses to BEE much more gender-friendly, courses such as Bio 101/102, ergo, thermo, chem. as opposed to some of the more male-dominated intro courses in CS (computer science), mechanical engineering and civil.
>
> Perceptual: Maybe women want to be engineers but because they lack the confidence, they go into an engineering field that they feel will be not as rigorous as the "hard sciences" and therefore, more manageable.

Question 10 asked, "Have you experienced any marginalization on or off campus?" The definition for marginalization was left for respondents to define for themselves, as meaning can vary from one context to another. Table 11 shows the distribution of responses from students to Question 10.

Table 11. Have You Experienced Marginalization?

Yes	No
37.5%	62.5%

According to students, the issue of marginalization manifests itself in making (a) assumptions about achievement and ability based on gender, (b) underestimating student ability, in the form of lower expectations based on gender, (c) different treatment based on gender as in Professors or TAs treat male students differently than female students.

Although 62% of the 48 students did not experience marginalization, it remains important to understand this issue by examining the responses of those that have had experience with marginalization. Responses by students concerning Question 10 can be seen in the following quotes (see Appendix G for all student responses to Question 10):

> Inaccurate Assumptions: I have been treated as dumb by some of my teaching assistants and professors throughout my college experience. It may be perhaps because I did not excel as much in mechanically oriented classes that were still part of the engineering curriculum. I have to say I did worse in these types of classes as opposed to biologically applied engineering classes. I have felt biased just by classmates too. Oftentimes male classmates treat female ones like they are inadequate. I remember I had a TA once who only would put females with females in lab groups because he said when females were put with males the males would take over and not let the females do the work. In some sense I think he is right, because I have experienced it myself, but not in all cases is this applicable.

> Different Treatment: For example today I worked on a group project with a male partner in my group. We needed help from the TA. The TA sat with us and said nothing to me and explained the entire project to my partner. Even going so far as to turn his back on me. I often have people tell me I don't look like an "engineer" or that I should be in hotel school . . . such comments only promote the kind of treatment I receive in class as an engineer.
>
> Assumptions: I have often had questions blown off in class or been treated as though I would not understand what is being explained.
>
> Lower Expectations: I've had several of my guy engineer friends tell me I should consider a major in another field when I did poorly on an exam and I've had professors question my abilities.
>
> Lower Expectations: Sometimes when I ask a male student for help on a problem he immediately explains it in an almost child like manner, as if I, possibly due to me being female, would not understand it any other way.
>
> Different Treatment: A professor I have now in the BEE department refers to all females as "Ms." while using the first names of his male students. He refers to groups of women as "ladies" frequently while not using the same language for groups of men. Normally I wouldn't perk at these inconsistencies, but he also treats his female students as if math is much more difficult for them and he seems surprised when they have relevant, insightful criticisms and correct mathematical assessments for given case studies. He has also discussed an example in which an industry task was solely appropriate for women (specifically the reproduction methods used on dairy farms). In other departments I have typically been assigned to all female groups by male TAs and LAs. The general treatment women receive in these departmens indicates that women are not as good at math and the engineering sciences in general, and that we need to be treated with great sensitivity because we could erupt emotionally at any time.

One student acknowledged that these experiences are sometimes just a feeling. “In high school I was definitely doubted. That lessened in college but I have still felt on certain occasions in classes or groups that I wasn't quite as good as a male, just because I was female. I've never really had direct comments made to me or any serious incidents, I've had the feeling though.”

Inaccurate assumptions can also lead to serious inappropriate ethical conclusions. "I had a math professor who was surprised to see me, a woman, doing well in his class and he thought, initially, that I had been cheating."

Concerns over gender-based grouping were expressed in both the interviews and the questionnaires. Women felt marginalized when they were grouped according to gender. "It's not the real world." Although it was acknowledged that sometimes this is necessary, one student thought a better approach would be to allow voluntary grouping according to the expressed needs of the class.

In one interview, the participant noted that feelings of "being less" come from inside herself, "It's my own self-conscious thing." She said," I need to be better than the guy, just to be considered as good as."

Question 11 asked, "What kind of academic support is available for all engineering students at Cornell?" Of the 48 students that completed the questionnaire, 47 responded positively concerning the available academic support, with one nonresponse. As previously mentioned, this question was altered from, "What kind of support is available for female engineering student?" to the present version. Students responded with the following:

> On the University level, the professors provide flexible office hours, free tutoring, good advising. The advising department is wonderful.
>
> AEW is a like a supplemental course. If you're taking calculus for instance, you have calculus, the class that you go to, then they have the section with the TA you can add this class for 1 credit. It's a really great program. I am not really sure if other colleges have it.
>
> Lots of places to go for help. Peer tutors, TAs office hours Academic Excellence Workshops.

Academic support is available in many forms in the department. Comments suggest that it is flexible in order to meet the demands of the student population. One main theme emerged. BEE is perceived as a supportive educational community almost 100% of the respondents. There is free tutoring, flexible office hours, willingness of professors to help and good advising. Clubs offer additional academic support through student organizations like Society of Women Engineers (SWE), the Academic Excellence Workshops (AEW), National Society of Black Engineers (NSBE), and the Society of Hispanic Professional Engineers (SHPE).

Thus support lies within the community of learners and instructors in terms of, "Office hours, various clubs (SWE), befriending other engineers to do homework and to study together."

Figure 3 illustrates how the support is passed along from the University through the support structures and then down to students. The University, along with the department administrator and helpful professors, creates a favorable climate that trickles down and is felt by the student body.

The support is further communicated so that the students themselves become part of the vision for academic success.

Background: Academic Excellence Workshops and Society of Women Engineers

Academic Excellence Workshops (AEW) and Society of Women Engineers (SWE) were mentioned as being supportive 13 and 9 times respectively. AEW are peer-learning workshops that meet once a week and are led by a trained peer facilitator. The purpose of the workshop is to support and enhance learning through the use of team approaches and research-based instructional strategies. There are no projects or quizzes. This pass-fail course is offered for one university credit. Attendance is the only requirement. AEW features noncompetitive group-learning and team approaches to instruction. The small-group setting is an additional advantage. Evaluation is ongoing and research is conducted on the effectiveness of the program and facilitators. Although sponsored by the University, trained students facilitate AEW. Lockheed Martin, Intel Corporation and Noyce Foundation fund the program.

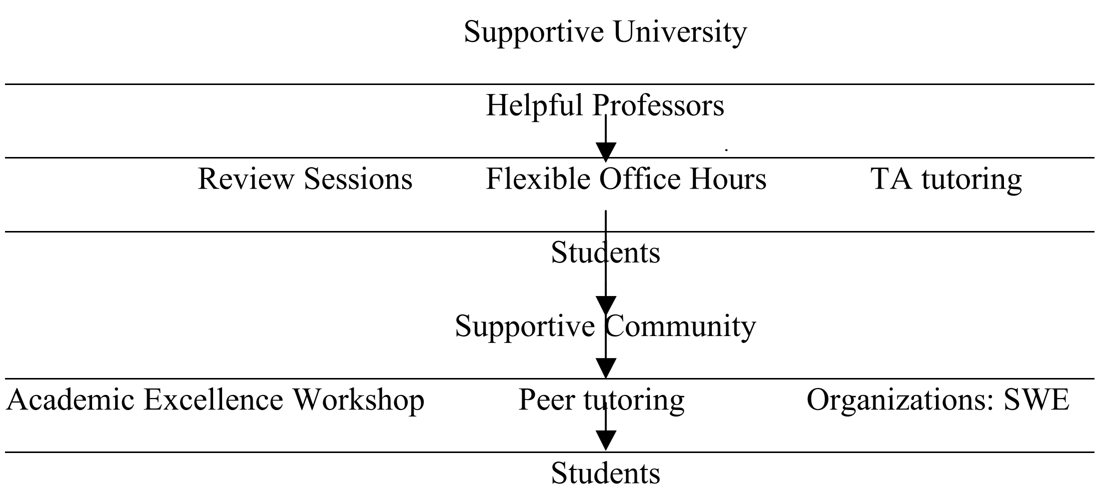

Figure 3. Academic support structure.

AEW began in 2000 as a pilot program designed to lessen fear of computers, provide hands-on training engineering experiences, and demonstrate the exciting aspects of problem solving with programming. AEWs are weekly 2-hour cooperative learning sessions designed to enhance student understanding on problems at or above the level of course instruction. Academic Excellence Workshops provide an enriching environment for students, especially women and minorities, to consider engineering and computer science as fields of study (Schwartz, 2000). A similar program was initiated at the University of Buffalo School of

Engineering. Student Excellence Initiatives showed that 90% of students in the experimental group (those that participated in the initiative) returned for their sophomore year compared to 63% in the control group (Longenecker, 2002).

The campus chapter of Society of Women Engineers also provides support for students. “The Society of Women Engineers (SWE), founded in 1950, is a not-for-profit educational and service organization. SWE is the driving force that establishes engineering as a highly desirable career aspiration for women” (SWE, 2001, p. 1). Society of Women Engineers has chapters in universities across the country. The chapters provide a sense of community for female student engineers and support outreach to the lower schools.

The Caring Environment

Along with academic support, the other component that has had an effect on student retention is the warmth and helpfulness of faculty. Common adjectives used to describe the faculty were: wonderful, warm, helpful, supportive, available, approachable, caring professors, with the word “tons”[respondents’ term] used three times. As one student phrased it, “I know the degree of involvement and care shown by the faculty sets BEE apart from preconceived notions I had about collegiate faculty.”

Question 12 asked, “Why choose BEE?” Students could choose from a list of 17 options for their decision to follow a degree choice in biological and environmental engineering, and one opportunity for students to insert their own option. Students chose anywhere from one choice to 12 choices. Students could endorse all that applied. Each choice had a corresponding letter from “a” through “q.” Option “q” which is not included in Table 9 provided an opportunity for students to submit an individual choice that might not have been available. Table 12 shows the choices that were available to students and the number of responses that each category received.

Table 12. Categories and Response Code

Response	*n*	Histogram code
Biology is interesting.	35	a
Environmental science is interesting.	19	b
I know it will be easy to get a job.	4	c
It's creative.	21	d
It's lucrative.	6	e
It's challenging.	32	f
Interdisciplinary, involving many areas of engineering.	37	g
I am good at math.	29	h
It benefits society.	27	i
It is easier than other kinds of engineering.	4	j
I am good at biology.	26	k
It is less rigorous than some of the other programs in engineering.	7	l
The program offers a lot of career possibilities.	28	m
I want to work with people more than I want to work with things.	17	n
BEE has a large percentage of women already.	1	o
I can enroll in the College of Agricultural and Life Sciences and do engineering for 3 years.	17	p

Students checked off an average of seven options for “Why choose BEE?” The range of number of responses was from 1 to 12. What they chose was then examined. Various categories along with frequency of response were placed in an Excel spreadsheet. A histogram was then constructed. Figure 4 shows the frequency of responses to categories in decreasing order.

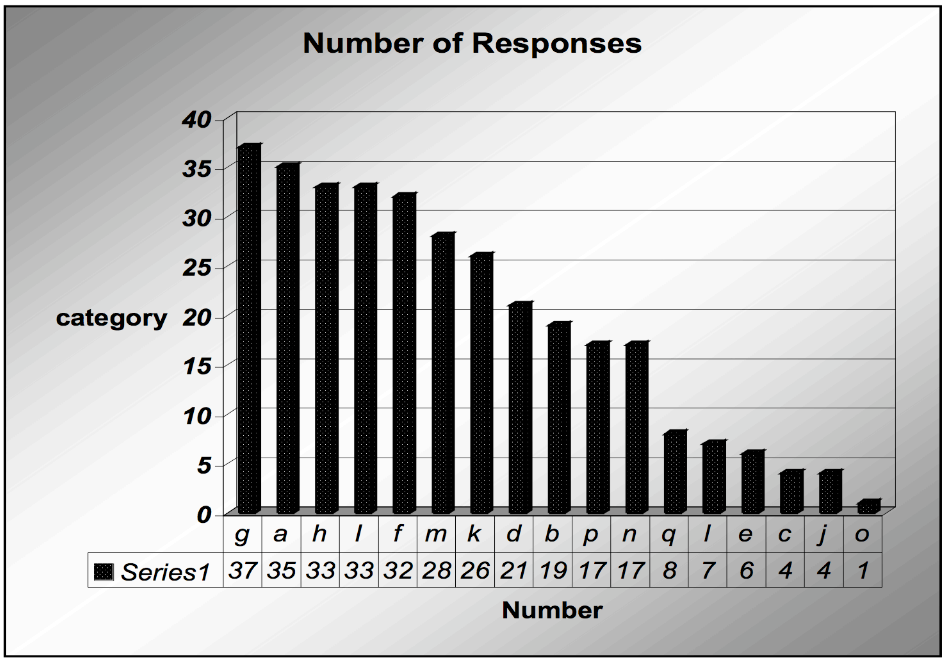

Figure 4. Why choose BEE?

According to the questionnaire, selection “g,” the interdisciplinary nature of the discipline received the most responses (37), with biology or “a” a close second (35). The link to biology “a” and the interdisciplinary quality of the discipline was again substantiated. Category “o” was chosen only once and deals with attending BEE because of the increase in critical mass of women currently enrolled in BEE. Twenty-two students (46%) of the participants made the similar choices of; a, f, g, and h. Table 13 demonstrates the categories of choice that received the most responses.

Table 13. Most Frequently Chosen

Letter category	Response	*N* of students who selected that choice
a	Biology is interesting.	35
f	It is challenging.	33
g	It is interdisciplinary.	37
h	I am good at math.	33

For "other," students listed a variety of reasons why they chose the BEE degree. Figure 13 highlights some of the student responses to this question. Of the seven students that offered additional options for category "q," four mentioned that it was connected to a degree in medicine. Here is what they said.

> My mother has MS and I want to be a part of the mission to find better medications and treatments for such diseases. My younger sister has had several knee surgeries involving cutting edge biological technologies, and again, I wanted to be part of the help.
>
> It was the only engineering degree that made being premed possible.
>
> I wanted to go into vet research. It seems like a very good research degree.

Question 13 asked, "Was biological and environmental engineering your first choice?" Table 14 shows the percent and the number of students and their response to this Question 13.

Table 14. Was BEE Your First Choice?

Yes	No
75%	25%

Thirty-six students (75%) acknowledged that BEE was their first choice. Twelve students (25%) wrote that it was not their first choice, some transferred from other disciplines, and one student said, she would not have chosen an engineering degree. Selected responses by students concerning question 13 can be seen in the following quotes (see Appendix I for all student responses to Question 13):

> Chemical engineering was my first choice.
>
> I am in the new Environmental Engineering major, which is a joint program with BEE and CEE.
>
> I started in Materials Science but realized it wasn't going to be the right fit for me, it wasn't what I had expected. BEE was my next choice, I just didn't know that until I got here!
>
> I started in ChemE and MSE but realized it was gong to be way too hard to be premed in those majors.

Some students voluntarily offered reasons for the switch, but a “Why did you switch?” option was an unfortunate omission by the researcher.

Question 14 asked, “ Where did you first learn about biological and environmental engineering?” University brochures, Cornell Web site, the application process, a brother, searching for colleges, and having taken a BEE elective, were some of the ways that students heard about the program. Selected responses by students concerning Question 14 can be seen in the following quotes (see Appendix J for all student responses to Question 14):

> From my own exploration and research of the various fields in engineering after I decided I didn’t want to be a theatre major anymore.
>
> Took a BEE elective.
>
> Had an interest in genetics.

Question 15 asked students, “ Is BEE considered “female friendly?” Table 15 illustrates the distribution of responses to this question.

Table 15. Do You Think BEE is Female Friendly?

Strongly agree	Agree	Neither	Disagree	Strongly disagree
13%	37%	35%	2%	6%

One student’s response can be found in the following quote:

> I don't believe there is a correlation between the difficulty of the BEE curriculum and the number of female engineers, and if there is determined to be such a correlation, I would be more likely to believe that it is more of a result of coincidence rather than more women choosing BEE because it is “easier.”

Although 50% of the students agreed with the statement that BEE was female friendly, those that disagreed had strong feelings about this question. To those students that disagreed, the word *female-friendly* connoted “easy” and was clearly not appreciated by more than one student. Since no definition was provided, it demonstrated student sensitivity toward the issue. One student alerted the researcher to the following; she noted that, “In looking back at that question, which went under many alterations, the definition for ‘female friendly’ was not provided, so participants responded based on their own definition.”

Question 16 asked, "Tell me something about BEE that would help me to better understand the department." Thirty-four students (71%) responded to this question. Selected responses by students concerning Question 16 can be seen in the following quotes (see Appendix K for all student responses):

> The BEE department has outstanding faculty, at least as far as I have become involved thus far. All of my BEE professors, and my advisor, have been more than willing to offer me extra help, and meet with me whenever I needed to, in order to address issues or problems I was having. I'm not familiar with other departments on campus, or even at other schools, but I know the degree of involvement and care shown by the faculty sets BEE apart from preconceived notions I had about collegiate faculty.
>
> It's slightly more flexible than other engineering disciplines in terms of coursework. But not much more flexible.
>
> The department on the whole is *extremely* laid back. Professors are very, very supportive of students and I have enjoyed working with them much more so than working with professors of other departments.
>
> It's a warm department that keeps a global outlook tangible in its environmental classes. Cornell has one of the best environmental engineering programs in the nation, and that's why I transferred into this department in particular.
>
> BEE is a hugely diverse program that integrates the principles learned in the engineering discipline with the skills needed to help our society and people in our society.
>
> The major is rigorous, but manageable.

Student responses also included: Great supportive professors, a department that is extremely laid-back, warm, has a global outlook, very, very supportive, best environmental engineering program, and even, "I absolutely love the department in general" create a picture of the department's friendly and encouraging personality.

Question 17 asked, "Which type of instructional strategy do you prefer?" Students responded with their first choice. Problem solving approaches to learning were in first place more often over lecture, group work and labs. Table 16 shows the distribution of responses to this question.

Table 16. Preferred Instructional Strategy

Problem-solving	Lecture	Group work	Labs
15	8	5	3

Not everyone was able to respond to this question due to a flaw in the questionnaire.

Emergent Knowledge

The questionnaires both substantiated the propositions toward understanding the achievement of gender balance occurring at Cornell's BEE as well as raising some others.

The Importance of Academic Support

The value of academic support and a supportive community was a revelation. The idea of a "ton" (respondent term) of academic support, "I find there is plenty of support on campus and no excuse to fall behind." and the value that a warm and friendly faculty provides was another surprise. A student said, "The professors are friendly and approachable, it feels less cut-throat than other majors and more like a home than an unfriendly and emotion-less workplace," or, "Warm professors willing to help. I love the BEE." The following story also underscores the helpfulness of faculty.

> Although I tried to get tutors on different occasions for different classes during my freshman and sophomore years, I never had much luck with it. The peer tutors were there and available but sometimes not good enough for my needs, nonpeer tutors were

tough to find (one exception, an advisor set me up with a professor who tutored me in calculus over winter break, freshman year. A huge favor on his part but a very helpful experience for me).

Image of Engineers

The traditional engineering stereotype still prevails despite the availability of new and more relevant categories of engineering. The stereotype is that of the mechanical engineer who crunches the numbers. “There is a very solid stereotype on campus that students use to define an engineer. It is difficult to even work on a group project when your fellow engineers have already labeled you as a ‘ditsy’ sorority girl.”

There is a perception that BEE students are not considered real engineers in the engineering culture on campus, an interesting topic worthy of further exploration. BEE is considered of lower status in terms of respect as an engineering discipline. When you are in BEE or OR (Operations Research and Industrial Engineering), which “suffers a similar complex” as stated by one student*,* you are considered the “wanna-be” (respondent term) engineers, but “when you are in Applied and Engineering Physics, then you are a real engineer.”

Although treated as an annoyance by many of the women, this researcher puts this issue in the category of marginalization. Varying levels of respect toward engineering disciplines is marginalization. Biological and environmental engineering is a legitimate and accredited engineering college at the university.

The Interviews

Overview

The interviews took place in a conference room on the Cornell campus in Ithaca, New York. There were 10 appointments, but only nine students participated in the interview portion of this study. Other than the one cancellation, all that were interested were interviewed.

The nine women could be characterized as intelligent, interested, alert, caring, and just great young women. These women appear to have a strong sense of purpose, suggesting that they understand a lot about themselves and how they learn. Interviews covered a lot of additional subjects that emerged through conversation. The questions that will be discussed in this chapter are:

1. Why did you agree to be interviewed?
2. Have you experienced any marginalization on or off campus?
3. Is BEE considered fake engineering?
4. Do you think that it is true?
5. How do you learn best?
6. What is your favorite class and why?
7. Why did you decide on Biological and Environmental Engineering?

The women offered a lot of personal background information (not included here) and had many stories to tell about their experiences in engineering. In some cases, the participants began their narratives without prompting. There was representation from every undergraduate level. One freshman, two sophomores, two juniors, and four seniors comprised the group of nine interviewees. Of the nine that were interviewed, three students were from out of state (Florida, Massachusetts, and New Jersey). The remaining women were New York State residents.

All of the women cited reasons why they decided to be interviewed. Four students said they supported the cause of increased participation of women in the STEM fields. Four students were active in on-campus organizations that support women in engineering. One participant had participated in interviews before and thought it seemed interesting.

Four of the nine were actually involved in organizations and programs that provided outreach for women and their learning in engineering. The two mentioned were Society of Women Engineers (SWE) and the Academic Excellence Workshops (AEW). Discussions about SWE came up in the questionnaire as well as the interview. This University has a strong and active SWE chapter for Region E.

Learning style was another topic covered in the interviews. Preferred learning styles ranged from favoring lecture, PowerPoint Presentations, interactive discussion, labs, problem solving/ application approaches to learning best on their own. Lecture is still valued by students as a viable mode of instruction, but not lecture alone. The data also indicate that these women do not all learn in the same way.

More than half of those that were interviewed had experience with marginalization. Some of these women seemed nonchalant about it, while others thought it was inappropriate.

Each one spoke of their favorite class as hard and challenging. According to students, BEE is not "cop-out" (respondent term) engineering. It is real and meaningful. It is friendly and challenging and it is supportive and rigorous. BEE women feel that they are doing important work. Biological and environmental engineers are preparing for the problems that have not yet evidenced themselves.

Answers to the Interview Questions

Question 1 asked, “Why did you agree to be interviewed?” Some students chose to be interviewed because of the need to encourage more women into the engineering fields. At least four of the nine interviewees were involved in one of the support efforts (SWE or AEW). One student acknowledged that the difficulty experienced by her mother in the engineering workplace (the glass ceiling) provided the inspiration to encourage other females toward a degree choice in engineering and become an engineer herself. One student was interested in the inquiry approach itself. Selected responses by students concerning Interview Question 1 can be seen in the quotes below.

> Something I strongly believe in and I’ve worked hard for is encouraging women into engineering.
>
> I really encourage other women, it’s trying to help the cause. It’s just not happening.
>
> I’m involved in outreach programs, in SWE we try to get girls from age of elementary to middle to high school interested in science and technology and engineering. I have noticed Cornell in general engineering is 28% women, but In chemical and biological engineering the ratio is half and half. I was interested in what you were interested in, so I volunteered.
>
> I am always interested in why things are the way they are. I liked the questionnaire and I am interested in the “why” things have been the way they are. I think it would be a neat experience. I’m always willing to help.

Interview Question 2 asked student, “Have you experienced any marginalization?” Responses varied from experiencing marginalization to never having experienced it. Selected responses by students concerning Interview Question 2 can be seen in the following quotes.

> No incidence. No time when I noticed that happened because I was a woman. I think that I experienced it in high school, but never in college.”
>
> My physics teacher in high school told me that I had a learning disability. I move through problems slower than other people. It’s hard stuff. I know what a learning

> disability is. I do not have a learning disability. I never felt any. I've had a good experience here.
>
> I don't feel marginalized because I am a women.
>
> My AP chem. teacher told me, "You're going to fail out of Cornell. You just don't have it! I'll prove it to you that you're wrong." My AP English teacher also said that I will fail out of Cornell. I've done great here. I had a great experience here [graduating senior].
>
> One time in my mechanics class, the professor put all of the girls together. He thought the boys would overpower us, that's not the real world.
>
> I've never received any treatment that I would call marginalization.
>
> I haven't experienced marginalization. Never felt like I was singled out. Have heard from CE and ME [chemical and mechanical engineering]. I try not to over analyze the situation. I have never had any situation with TAs or professors about me being a female.
>
> It is impossible to find a bathroom or they are located in inconvenient areas in many of the buildings in the engineering quad.

Interview Question 3 asked, "Is BEE considered 'fake' engineering?" Students commented on a number of reasons why there was this perception. The connection to biology appears not to fit the image of traditional engineering disciplines. Students noted that a lack of knowledge of newly emerging forms of engineering and the association with the College of Agricultural and Life Sciences contribute to a lack of respect toward the BEE. Selected student responses concerning Interview Question 3 can be seen in the following quotes.

> Yes, it's a lot of biology. They look at the biology part and not the engineering part, but we're taking exactly the same basic engineering courses, thermodynamics, fluids, mechanics, we're definitely an engineering school. We take a lot of the classes through the other engineering departments. You can do the engineering degree through the Ag [agricultural] school. So that's possibly where one perception comes from.
>
> They ignore the engineering part and focus on the biology part. People outside of school when you say that you're a biological engineer, they say, "Oh you're studying biology?"

> People's perception carries over into industry as well. When you go to career fairs they don't think that you'll have the skills, they don't understand the major. They would rather you had a traditional major and then take upper level bio courses. I've been better trained this way. It is really frustrating. We're doing what's best for ourselves. The chem. majors can't do what I can do. They are just being engineering snobs.

> Fake engineer? I think some people think that it's easier. You don't think of the science. They don't understand what BEE is all about.

> Some people that I know don't understand our major. Oh BEE, the fake engineers, the wanna-be engineers.

> Oh, she's in OR [operations research] you're totally taking a cop-out. Engineering and applied physics, then you're *really* an engineer.

> I don't know what it is. Maybe because it's a nontraditional major.

> Because I am not in the engineering department but in CALS. I think that's where the perception comes from.

> It's not a traditional major. The respect is not there as much.

Interview Question 4 asked, "Do you think it is true that BEE is fake or 'cop-out' engineering?" Students overwhelmingly disagreed with this idea and supported their position with evidence. All core courses in engineering are the same. BEE students take the same courses with the rest of the engineering population. Some are enrolled in the College of Agricultural and Life Science (CALS, a land-grant college) and not in the private Engineering College. Figure 21 Selected responses by students concerning Interview Question 4 can be seen in the following quotes.

> I don't know if that's true. Our core requirements are so much the same. Many of my friends who can program a computer, but if you give them some bio problem they are lost. We're all good in engineering. My friend is in computers. I can't do her computer stuff and she can't do my biology stuff.

> If I hear someone say that one more time [gritting her teeth]. We take the same courses, we do better than you, and we understand it better than you. You make fun of us, but we're the ones that will be making all the money.

Interview Question 5 asked students, “How do you learn best?” Student noted the various ways that professors make the knowledge accessible to students. Most of the approaches augmented lecture with various add-ons. An alternative to the traditional handout is one in which certain information has been omitted to be filled in during the lecture by the attentive students. Students also acknowledged group work as a preferred learning and instructional style. Selected responses by students concerning Interview Question 5 can be seen in the following quotes.

> One difference between this department and a lot of those core classes, they would write it on the overhead as they were doing it. As soon as they were done, away it went. Oh, my life is over. Or, they would write it on the chalkboard, away it went and never showed up again. Here, I find a lot more professors use PowerPoint. It’s a lot more organized. It is up there in front of you to access it. You can check it and make sure you got it right. Lot of handouts that I like.

> Some professors block out certain parts of the notes. You still have to pay attention in class. Everything is there except the equation. They leave the equation blank. You don’t have to write down everything. They leave out crucial information.

> I get more learning on my own. Does not have anything to do with professors. Lecture and ask questions. Sometimes I read the text while the professor is lecturing. I take my textbook and read the text during the lecture.

> I like PowerPoint. Interaction, I like to ask questions.

> I love “one on one” or as close to “one on one” as I can get. I usually hit the mean on the first exam. I didn’t go to get the extra help. I find myself needing something in additional to just lecture. I want to be monitored. Being a freshman, I want some degree of supervision. I need a little more structure.

> I get a lot out of the group work because I am a hard worker and can motivate anyone to do anything. Females are better at that. I was with two males and they didn’t do anything. I wasn’t the smartest but I did the most work. They expected me to. People just rely on other people.

> I like the group work [as in 453] on a group project. Great group, interesting project, nice mix of computers and noncomputers.

One student noted that, "I haven't figured that out yet. I'm definitely visual, and a sequential person. I start to do well at the end. Then, I get the hang of it."

Knowledge of learning styles and an appreciation of their best mode of instruction was apparent to these interviewees. The fact that people learn in different ways and at different rates was part of the knowledge base of these women. Although one interviewee noted that her AP physics teacher commented, "She told me that I move through problems much slower. I just move through physics slower, it's hard stuff!"

Interview Question 6 asked students, "What is your favorite class and why?" Students mentioned integration and application of knowledge as well as courses that were challenging and interesting that formed the basis for the favorite class. Also mentioned were the classes where knowledge from prior experience was finally applied and where real problems were solved. The function of labs was noted as an important consideration. "You can't take something outside the classroom and apply it? The labs put it all together for me." Selected responses by students concerning Interview Question 6 can be seen in the following quotes.

> Principles of Biological Engineering [260] is a really tough class. First taste of what bioengineering is really about. You use all of the math, physics and the chemistry that you learned. It's exciting to see it [prior knowledge] pop up. I actually get to use this. All the knowledge is integrated with biological systems, you're solving real problems, hands-on, you write. Used every single class, use all of the math prior to the class. I like solving real problems.
>
> Metabolic Engineering [484] was the hardest class taken at Cornell. I might not have done as well as I did in other classes, but the amount of knowledge gained was incredible.
>
> Green Cities was my favorite class. It was not in bioengineering but offered through the city and regional planning board. It was a nice blend of science, history, and government policy. It had a great professor who was down to earth and approachable. He respected us as students. "It's okay," he said, "you can work for some small company. You're still good enough." No professor ever told me that I would be good enough.

> It's a linguistics class. It was that "why" in the back of my head. Testing the instinct of language.

Interview Question 7 asked student, "Why did you decide on a degree choice in biological and environmental engineering?" Biological and environmental engineering was seen as providing high interest in students' favorite subjects, math and science. Biological and environmental engineering is suggested as having a variety of career options in the biomedical and bioengineering field, a field that is growing. The field also suggests an opportunity for a different kind of engineer, one that requires good communication skills and offers an opportunity to help others. Selected student responses concerning Interview Question 7 can be found in the following quotes:

> I always liked math and science. They were always my favorite subjects. BEE combined the biology and engineering. I'm interested in medicine and interested in the research aspect. BEE provides the biology with the background in research.

> The bridges are here already, but the bio engineers will solve the problems that have yet to happen.

> I was always good in math. It was the middle school thing. I was involved in Craftsman competitions [an NSTA project]. In middle school you have to choose between two tracks; the arts track and the science/math track. I chose the arts track and a math teacher saw that and yanked me out of there and put me in the math/science track.

> The amount of career opportunities in the biomedical field has tripled in the last few years.

> Not really sure how I ended up in bioengineering. That's a funny question. I choose the CALS route. Made more sense. One of the grant schools. It was the financially smart thing to do.

> Engineering would give me a better technical background for what I would like to pursue in the future. I visited 22 other schools. Cornell affords me a great opportunity, because it is not only a technical school.

> Women are more "relationship-y type" people. They like to help people. They care about people and earth. Biological and environmental engineering is that clear path toward that goal.

> Both my parents are engineers. I love helping people, loved biology, wow, a marriage of biology and engineering.
>
> I went with materials as a freshman, looked like I was having a miserable time with math and chemistry. Get me out of this now. My advisor was head of advising. They're really nice [at BEE], not as intense; I think you'd really like it. It seemed like a better place. I always liked biology.

Class Visits

Six engineering classrooms were visited. All classes occurred in lecture halls or lecture-type rooms. Lecture halls are constructed to seat between 100-300 students. The six classes were as follows:

1. Renewable Energy Systems
2. Engineering Entrepreneurship, Management and Ethics
3. Principles of Aquaculture
4. Bio-Engineering and Thermodynamics
5. Computer-Aided Engineering: Applications to Biomedical Processes
6. Introduction to Metal Fabrication

Professors provided access to knowledge in a variety of ways. Please note that Figure 24 illustrates only one class period over the semester. For example, many more of the professors may use an online resource for students, but it may not have been evident to this researcher. Although classes took place in lecture halls or large rooms, no instructor used lecture as a sole instructional strategy. One class used a group approach to instruction, with students in their groups clustered throughout the lecture-type room. All other classes used PowerPoint presentations with handouts, ancillary materials accompanied the handouts (also available on-line prior to class), demonstrations, field trip follow-up discussion, and problem-solving approaches using a rubric. Professors used strategies such as periodically checking for understanding by asking students questions. One professor used a simulation as he asked students to prepare a mission statement for their emerging business. Another professor provided the necessary equation only at the very end of the session after the concept was operationalized, a technique encouraged by the inquiry science education movement.

Professors were welcoming and provided opportunity for the researcher to ask questions. Professors also provided the researcher with handouts. The researcher found the content both interesting and challenging. The environment was helpful and welcoming. Being able to observe classes and obtaining needed technical support from administrative personnel were also further evidence of the quality of helpfulness described by all respondents.

In addition to lecture, students have laboratory experiences, but no lab classes were visited. Table 17 demonstrates the various ways that professors made the knowledge available to students.

According to the ABET regulations, each professor must provide evidence on how the content and concept align with learning outcomes as outlined in course documents (see Appendix D).

School Documents

The school documents reviewed to better understand the University and the BEE department were

1. Undergraduate Programs; Biological and Environmental Engineering, Cornell University, 2005-2006

2. Lecture handouts

3. Accreditation Board for Engineering and Technology (ABET) learning outcomes

4. Enrollment figures

5. University brochure for College of Agricultural and Life Sciences (CALS)

6. Program Requirements in Environmental Engineering

Table 17. Access to Knowledge

Course	Lecture	Demonstration	PowerPoint with handouts	Online access	Simulation	Field trip	Group work
Renewable Energy Systems	X		X	X			
Engineering Entrepreneurship	X				X		
Principles of Aquaculture	X		X			X	
Bioengineering and Thermodynamics	X	X					
Computer-Aided Engineering	X		Rubric on board				X
Introduction to Metal Fabrication	X		Notes on board				

Linking the Data to the Initial Propositions

The initial propositions for this study considered the increase of females in the department due to

1. Biological and environmental engineering as a social endeavor (S, social)
2. A change in the academic environment through outcomes-based learning (A, academic)
3. A change in the image of the engineer (I, image).

The initial propositions were narrow in focus. The social endeavor proposition was substantiated, but it was embedded in a much broader category of issues related to life. The change in academic environment (A) which also was substantiated, now includes a much broader range of instructional strategies with engineering students having access to handouts, online support, group work, cooperative learning, and small group noncompetitive instruction as in the Academic Excellence Workshops. Therefore, included in the interview was, "How do you learn best and were classes addressing your learning needs?" Lecture is still an important and valued vehicle for instruction.

Summary

The analysis of the questionnaire and the live interviews revealed that the 52% of female students enrolled in the biological and environmental engineering program can be attributed to a number of factors as described by female BEE students.

The role that the study of biology plays and its connection to engineering were strong in their decision of a degree choice in engineering. This connection of biology and engineering was substantiated in both the questionnaires and the interviews. The name alone suggests a field that is biologically connected and has a broad interpretation with many opportunities. The BEE department was renamed in 2002 from the Agricultural and Biological Engineering (ABEN)—a significant event, according to students—in a decision to enroll. The track toward a medical career is also a draw to women.

The Cornell University Department of Biological and Environmental Engineering (BEE) is perceived by the participants of the questionnaire and the interviews as possessing qualities that encourage academic success through significant support; including extra help, AEW groups, peer tutoring and additional learning opportunities. As a participant noted, "There is no excuse to fall behind." It possesses high academic rigor and has the national reputation of being an excellent school. Additionally, the participants of the questionnaire and the interviews perceive the faculty as being warm, approachable, helpful, and caring.

The tradition of families attending Cornell is also evident. Parents, grandparents and even a great grandfather graduated from Cornell. One student commented; "Both my parents went to Cornell. They knew me well enough to know it would be a good place for me."

Of the 22 faculty members in BEE, only 4 are female. No one mentioned gender ratio among faculty. This researcher cannot say whether it is an issue, but there was a notable absence of discussion. Perhaps the question should have been raised. An inference here might be that warm, caring, approachable may indeed be qualities that affect student learning more than gender.

Some females experience marginalization on campus. Not everyone experiences it, not everyone recognizes it, but it does occur. All of the respondents in the interviews stated that the BEE, because of the nontraditional nature of the department, the interdisciplinary nature of the discipline, the association with CALS, or a lack of understanding of what BEE is all about, is perceived by students on campus as being less rigorous, less math intensive, easier and not “real” engineering During the first 3 years, students in BEE take the same core engineering courses as any other engineering student (chemical, civil, mechanical) in the College of Engineering, but at a reduced tuition rate. BEE students can transfer out of CALS (late in junior year) and graduate from the engineering school, with a real engineering degree. There is nothing fake about BEE. It should be mentioned here that the building that houses BEE is physically separated and located in another section of the college campus.

Professors provide academic support and also use a variety of instructional strategies to support learning for a diverse population. Academic Excellence Workshops are also perceived as being a benefit to retaining students in engineering through small group instruction and noncompetitive teaching strategies.

The word biology or the Life Issue combined with a supportive academic and caring community, challenging and interesting content, and a variety of instructional strategies, have created the condition that is attracting and retaining women in this department.

When asked the question of how more females can be encouraged into the engineering fields, one of the interviewees replied, “Most of the people in SWE come from families where there is an engineer already. It’s outreach. That’s what is going to make a difference for encouraging more women in engineering.”

Engineering is Changing

“Engineering is Changing” is the overarching theme for the theoretical propositions of this case study. This paradigm shift requires a different engineering focus with a new set of skills. The challenges that face the world are vital and important, and are different from the challenges that faced the world at the end of the 20th century. The 6 years that have passed since the end of the 20th century have had a tremendous impact on engineering. The world faces new challenges. A world made smaller by the electronic information highway requires engineers with different communication skills and team skills. As well, the global population now exceeds six billion people. The degraded environment, the need for clean air and water, and the complicated ethical biological understandings are of great social and personal concern. This connection to evolving social concerns is one speculative reason for the increase in female participation at BEE.

The image of the engineer is also changing. Biological and environmental engineering requires the engineer to have new skills: working in problem solving teams, understanding every aspect of design, understanding the end-user, and working and interacting with people.

There is a move from the image of the engineer as a cold, analytical nerd to a solver of the problems that face society. The image of the new engineer as a “people person” contrasts with the image of the driver of trains and the fixer of things. “The guy at the desk crunching the numbers, he must have been a mechanical engineer. I defined a mechanical engineer. Mechanical was way too boring for me. Get me out of here.”

Another noted, “I’m socially outgoing. I can communicate and that’s more than I can say about other engineers. I can get people going. Why shouldn’t an engineer have those skills?”

This creation of the new image of engineer and a new kind of engineering may well appeal to a wider audience and in addition represent traditional female concerns and approaches to the world (Fennema, 2000).

Chapter 5 provides an opportunity for a discussion of what the data mean regarding this gender balance in biological and environmental engineering. It will include answers to the research questions and a discussion of how Renaissance engineering has its roots in life and as an interdisciplinary endeavor. Also included are recommendations for every level of the educational environment linked to the research. Equity in science and engineering education is the responsibility of every instructor.

CHAPTER 5. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Overview of the Study

The purpose of this qualitative study was to examine the reasons for the gender balance that has occurred in a biological and environmental engineering department at an engineering college in New York State. This study used a variety of instruments including a questionnaire, live interviews, classroom visits and university documents to understand the occurrence of gender balance.

Insight was sought as to the characteristics (attributes) of a program or department that might be affecting the increase in the female population at a Department of Biological and Environmental Engineering (BEE) and that might have the potential to inform other engineering programs regarding gender balance. The questionnaire (Appendix A) and the live interviews questions (Appendix B) focused on aspects of high school preparedness (years of science and math instruction), campus life, why the subjects chose biological and environmental engineering, and learning style preferences.

Previous research focused on the reasons for the limited representation of women in majors that are mostly dominated by white males. A wide body of knowledge (Caplan et al., 1997) no longer supports the theory that the differences in males' and females' brains correlates to the lower participation of females in the STEM fields.

Research examined societal, institutional, and individual factors as well that impact degree choice. Society imposes restrictions on women regarding certain careers. Institutions (schools and classrooms) promote environments where there are lower teacher expectations for females in science and math related activities as compared to males (Gutbezahl, 1995). Inadequate math and science preparation (Felder & Silverman, 1988), and poor career direction contribute to the problem. Individual factors, such as low self-esteem and unrealistic self-efficacy (Bandura, 1994) tend to work against the best interest of females in their degree choices in science and math.

Felder and Silverman (1988) found that when females have made a degree choice in engineering, many drop out during the first year due to a combination of poor grades, dissatisfaction with the climate and a poor institutional fit. "A growing body of knowledge has suggested the effect of environmental and social factors such as institutional fit, the climate and the culture of engineering education, and social networks and support for persistence" (Graham, 1997, p. 94).

In seeking answers to the research questions, this study examined relevant factors, such as student academic history, reasons for the degree choice in biological and environmental engineering, and institutional support and climate. Three research questions guided the study:

1. Why has the biological and environmental engineering program at a major engineering university attracted a greater percentage of female participants than other engineering disciplines?
2. What are the attributes of this biological and environmental engineering program that are attractive to women?
3. How can these attributes be used to inform the other areas of engineering in moving toward gender balance?

This study revealed specific components, guided by the research questions, that influenced females' degree choice and also uncovered the program characteristics operating that permit them to stay the course.

Qualitative methodology included both a questionnaire and individual live interviews. The data were collected in the spring of 2006 at a large land-grant college in the northeastern United States. Participants included the undergraduate female engineering students in BEE at Cornell University.

Profiles of BEE Women

Eighty-seven percent and 73% of BEE women have had at least 4 years of math and science respectively. Seventy-three percent had taken Advanced Placement (AP) courses. Exceptions included one student from Canada and another student whose high school had not provided AP courses, but permitted course offerings through a local community college.

Just less than half (46%) of the BEE women that participated in the questionnaire had an engineer in the family. Knowing an engineer provided the necessary knowledge of engineering that was positive. The remainder of the women (54%) did not have a relative to serve as a role model for engineering. Their knowledge of engineers and engineering came from a variety of experiences. Some had a negative image and a lack of knowledge of engineering. Others participated in engineering activities in high school, attended summer programs, and worked with engineers. Their image of engineering was more positive.

BEE women appeared helpful, and provided additional notes to the questionnaires that read, "I hope this is helpful," and "Good luck with your research." All interviewees appeared to this researcher as intelligent, animated, upbeat, positive, assertive, warm, friendly, and willing to help.

The race and ethnicity of the participants in the questionnaires were unknown. Cornell has no Native American students in BEE. Table 18 illustrates the breakdown of ethnicity for enrollment years Fall 2004 and Fall 2005.

Table 18. Female BEE Students by Ethnicity

BEE	Asian	Black	Hispanic	Foreign	White	Unknown	Refused	Total
2004	18	2	1	12	40	3	2	78
2005	17	1	3	9	44	10	2	84

Note. From *Enrollment Statistics*, by Cornell University, 2005b, Ithaca, NY: Cornell University. Copyright 2005 by Cornell University.

The racial identities of the nine interviewees were as follows: eight Caucasian and one Asian. All nine interviewees had academic strengths in science and math and appeared to have achieved academic success. Nevertheless, two interviewees questioned the strength of their skills in math and science. One was quoted as saying, “I may not be the smartest in the group, but I work the hardest.” The student assumed that her success was connected to her ethnic background and work ethic.

Interpretation

This section provides an interpretation of the data related to each research question.

Research Question 1: Why has the biological and environmental engineering program at Cornell University attracted a greater percentage of female participants than other engineering disciplines?

Based on information from the questionnaires and the interviews, the women in this study were drawn to and remained in the department for the following reasons:

1. The University's reputation as a quality academic institution in engineering
2. The inclusion of the words *Biological* and *Environmental* in the department name
3. The marriage of biology with engineering, a relatively new engineering discipline
4. The engineering link to social concerns
5. Increased opportunities in the field of biotechnology
6. The supportive academic environment and personnel

The University itself is a draw. More than one student had a parent, parents, or a great-grandparent as a graduate. The University is a high quality university of long history and valued reputation. The university's philosophy reflects this heritage of egalitarian excellence. It is both a private university and a land-grant institution in New York State. Additionally, the University is the most educationally diverse member of the Ivy League (Cornell University, 2005c). Additionally, it was the first university in the eastern United States to admit women.

The Department of Biological and Environmental Engineering is affiliated with the College of Agricultural and Life Sciences, and is one of the university's engineering schools. In 2002, the name of the department changed from Agricultural and Biological Engineering

(ABEN) to the present Biological and Environmental Engineering (BEE). The name change is relevant as one participant noted, “I enrolled in 2002. If the name had the word agriculture in it, I would have never enrolled.” She continued, ”The word chemical in Chemical Engineering suggests petroleum to some women, and Industrial Engineering is also a turn off to some women, until you understand it.”

The nature of the field and the name make the discipline appear more flexible in terms of career and degree paths, giving choices like premed as well as research possibilities. As it is a land-grant institution, it has the benefit of a reduction in tuition through the College of Agriculture and Life Sciences (CALS).

Biological and environmental engineering is a relatively new engineering discipline. It is biologically based, multidisciplinary, inextricably connected to aspects of chemistry and physics and to relevant societal concerns, thus drawing a wider audience. During an interview, one participant created this mental image of BEE. “BEE is like a huge wheel that sits on top of all of the other disciplines.”

Respondents noted that because BEE is a relatively new discipline, perhaps biological and environmental engineering does not suffer the traditional gender biases that other engineering disciplines have suffered. As a nontraditional engineering discipline, new course descriptions, ABET regulations, and respondents’ information, new ways of accessing knowledge as in the use of cooperative groups and problem solving teams have provided alternate means of accessing knowledge. For example, respondents noted that new ways of instruction now supplement the traditional lecture.

The students perceive BEE as a supportive environment. The perception comes from a faculty willing to help promote academic success. This is manifested in flexible office hours, good advising and free tutoring. To use one woman's words, "The department is not cutthroat, but manageable, supportive, warm and friendly." It appears that the department is an institutional fit for many women, thus drawing and retaining women in an engineering discipline.

The BEE department does not support a "chilly climate," contrary to the literature on traditional engineering educational environments. The attitude of " weed-out" is apparently not part of the culture from the perspective of the participants. It has been supplanted by a culture that supports academic success.

A question was asked of an interviewee in a 1997 study on *Persistence in Engineering* (Graham, 1997)."What recommendations do you have for retaining women in engineering?" To which the interviewee replied, "I always got the feeling they weren't trying to keep us." In contrast, BEE students perceive the department and the university as making an effort in trying to keep students.

Active support groups like Academic Excellence Workshops (AEW) and Society of Women Engineers (SWE) add to the picture of a supportive community. AEW uses innovative noncompetitive instructional strategies to support academic excellence. SWE provides a sense of community and networking for students as well as providing outreach for all levels of the lower schools.

Research Question 2: What are the attributes of this biological and environmental engineering program?

BEE has interdisciplinary course offerings, high-level instruction, and quality professors, in a warm and caring educational community. Students can access BEE in a number of ways. They can enroll in the College of Engineering, but also access engineering through College of Agriculture and Life Sciences (CALS). New York State residents can enroll in CALS, from which they can access engineering for the first 3 years at a reduced tuition rate, and then transfer into the College of Engineering. They take the same core engineering courses that all engineering students take.

There is a form of marginalization that ranks engineering disciplines in a hierarchy of prestige on campus. Because of the affiliation to CALS, and other perceptions discussed earlier in this document, students acknowledged that BEE is perceived as less rigorous, less math intensive, and not “real” engineering.

The connection to CALS may well add to the fact that BEE suffers a lack of respect as an engineering discipline. Graham (1997) found a hierarchy of prestige within the culture of engineering and among the various disciplines. The perception of BEE being “less” in the eyes of other engineering students from within the engineering community is a form of marginalization nonetheless. Graham continued, “It is those engineering disciplines that are viewed as more ‘people oriented’ or more applied-those that typically appeal to women-are seen as less valuable and prestigious among the engineering faculty and students” (p. 98).

Other students experienced more traditional forms of marginalization. It occurred in various ways from being ignored, being treated differently than male engineering students, being doubted and being treated as dumb. Marginalization appears to still exist in this academic environment, although to a lesser degree than what was found in the literature. Each woman deals with it in a personal way. Some don’t overanalyze and others are annoyed.

Research Question 3: How can these attributes be used to inform the other areas of engineering in moving toward gender balance?

The attributes of this biological and environmental engineering program can easily inform other engineering disciplines. Creating caring climates and setting a tone of inclusiveness can be accomplished by increasing awareness among faculty and students of instructional and gender issues. Increasing the participation of women in the engineering technologies cannot however, be accomplished by higher education alone. It requires systemic educational reform in the lower schools, as well.

There are lessons for everyone in improving the gender balance in the engineering disciplines. As well, the emergent knowledge gained from this study indicates many recommendations for parents and families, as well as the K-12 schools. Trends in education usually inform the curriculum developers as well, as in the launching of Sputnik igniting the inquiry science movement.

Validation and Triangulation

Validating the evidence in this explanatory case study was accomplished by finding sources of evidence in more than one place through triangulation. The purpose of using more than one data-collecting instrument is to provide opportunities to either support or refute the findings. The propositions noted in Table 19 represent substantiated evidence for both the initial propositions and those that were uncovered as a result of this study.

Implication of the Research Findings

Many of this case study's findings substantiate the information found in the literature. Some of the findings although substantiated, were found, but to a lesser degree than was noted in the literature, for example the issue of marginalization. This section links the findings to the propositions and to the literature.

Table 19. Propositions and Triangulation Sources

Propositions	Literature	Questionnaire	Interview	Classes	Documents
Biology link	X	X	X	X	X
Interdisciplinary	X	X	X	X	X
Social concerns	X	X	X	X	X
Academic support	X	X	X	X	X
Learning environment	X	X	X	X	
Marginalization	X	X	X		
Caring environment	X	X	X		

Related literature highlighted the following issues involved in the low participation of females in the STEM fields.

Barriers that Hinder Participation

The literature review provided the understanding regarding what discourages women from choosing a degree in engineering and other STEM fields. In order to understand how to encourage women into the STEM fields, it is a benefit to first understand the barriers that discourage them. Question 1 asked, “Why has the biological and environmental engineering program at Cornell University attracted a greater percentage of female participants than other engineering disciplines?”

One of the barriers that women experience is lower self-esteem, self-efficacy, and self-confidence than their male counterparts. Some of the women that participated in this case study had experiences with lower self-confidence. The research states that females tend to underestimate their abilities even though they demonstrate success in a STEM field. More than one of the participants in the questionnaire as well as two of the interviewees spoke openly about their feelings of self-confidence. This represented some serendipitous findings that emerged from the interview process.

Although competent to grow organ tissue in a petri dish, this graduating senior felt that her hard work and extreme work ethic have compensated for her lack of perceived ability. This is also substantiated through the work of Tobias (1978) and Dweck (1986), who asserted that females might believe that ability in a subject is something that one either has or does not have and girls do not have it. This is called entity theory. Females may also tend to assume that success in an academic area is due to an external factor, which is fickle (unstable). Males, on the other hand, believe that success is internal and stable.

The idea that girls might see themselves as inferior to boys was noted in the words of one woman who needs to perform better in order to feel as good as the boys. One of the interviewees, a graduating senior was also very responsive to a professor who was encouraging, “No one ever told me I could be good enough.” Of the nine women who were interviewed, only two spoke of these feelings. However feelings of inferiority were only expressed in a few of the questionnaires, "I do, however, still feel like I'm always proving myself to some extent."

Regardless, these students have persisted in their programs. This case study confirms the assertion from Bandura (1994) that through persistence and modification, feelings of unrealistic self-efficacy can be overcome.

Another barrier for females in science and math activities is that teachers may have lower expectations for girls than boys. This was described in the literature through the work of Good and Brophy (1987), Feldman and Theiss (1982), and Rosenthal and Jacobson (1968). One of the interviewees recounted the story of the high school teacher who told her she would fail out of engineering school or that she did not move through the problem fast enough. She responded with an "I'll show them" attitude.

All of the women that participated in this study have obviously overcome many of these discouragements. This confirms Krumboltz's idea that it is the "sequential cumulative effects of numerous learning experiences affected by various environmental circumstances, that cause a person to make a decision to enroll in a certain educational program" (1979, p. 37).

Tonso (2003) and Sandler (1999) asserted that marginalization is still part of the environment of higher education. This study confirms that marginalization plays a role in the campus culture. Marginalization plays a role in discouragements, as women feel unwelcome in the academic environment when it relates to science, math and engineering technologies.

Drawing the Line, a report from the American Association of University Women claims that two thirds of the female population on campus experiences some sort of sexual harassment (AAUW, 2006). This study was not about sexual harassment, though it did concern marginalization. In this context, marginalization means to treat as insignificant or to denigrate the intellectual capabilities of any student. It is still unwelcome by students.

Examples of legitimate questions being "blown off" or a female student being provided an explanation in a "child-like" manner are further examples of how lower teacher expectations manifest themselves in the classroom. Other examples validated the research as in the student who was accused of cheating because she was doing well, or a recommendation to the student (from a peer) to change majors when she received a low grade on an exam. These findings were established in both the interviews and the questionnaires, but emerged through the discussion of marginalization.

Although individuals experienced marginalization, there is evidence, however, that the department (BEE) experiences it as well. Marginalization toward BEE affects the amount of respect BEE receives due to a perceived hierarchy of prestige. This confirms both Graham's (1997) and Tonso's (2003) assertions that the hierarchy of prestige is due to the applied nature of the discipline or that it may be more people oriented. Tonso contended that the preeminence of academic engineering is affiliated with mathematical equations and conventional courses that reflect male approaches to the world. On the other hand, actual engineering is a combination of complex activities common to everyday life that is more apt to serve the needs of women. Both the questionnaires and the interviews confirm these assertions.

Another speculation might be that BEE's perceived lower status is a more covert expression of marginalizing women. It can be likened to the versatility of a shotgun, as it sends out multiple projectiles. One can denigrate a lot of people at one time.

The characteristics of any program influence student participation. Question 2, asked, "What are the attributes of a biological and environmental engineering program?" Students responded based on their own experiences. These following characteristics are based on available research of how people learn.

The Learning and Instructional Environment

Changes in the learning and instructional environment in this context may be appealing to a broader audience, thus drawing more females. Instructional strategies that include learning by doing, application of knowledge, and group projects confirm the work of Felder and Brent (2005), Felder and Silverman (1988), and Barger and Hoover (1984) that the mismatch of student and the engineering environment has contributed to the decline in engineering enrollment. Conversely, the closer match of student and the engineering environment might contribute to the increase in engineering enrollments. Students come with more than one learning style and professors may need to adopt more than one teaching style. The inclusion of noncompetitive activities through AEW, as well as use of cooperative groups validates the assertion of Fennema (2000), that cooperative and noncompetitive tasks were more favorable to girls' learning.

Additionally, handouts, online access to notes, and PowerPoint presentations in addition to lecture increase the learning for visual learners and those that may need additional time to process the information. This substantiates the work by Corno and Snow (1986) and Howard Gardner (1983). It appears that the educational climate of this engineering department may be an institutional fit for these students and has contributed to student retention.

The assertion by Felder and Brent (2005) that engineering faculty still views attrition in a positive light was not validated in this study. The amount of support that students have access to in BEE supports the idea that professors and students are committed to academic success, and not to weeding out perceived untalented engineering students.

Academic support is an important part of an academic community. A strong component of BEE is the amount of academic support that is available to students. Academic support is found in free tutoring, flexible office hours, good advising, and on-campus organizations. Organizations like SWE and AEW workshops also support retention and success.

The learning environment is also characterized by the connection of engineering to life processes. Biology is life. It is an extremely diverse subject, some of whose mysteries were uncovered during the last century, the Century of the Genome. It is the strong connection between engineering and life that has encouraged the participation of women in this study. Females are still more apt to take higher-level biology and chemistry than physics (Feldman, 2002). Biological and environmental engineering is appealing to women for this reason. It is of high interest, is multidisciplinary, offers challenge and is connected to social concerns and life.

What is learned from one context can be applied to other similar contexts. Question 3 asked, “How can these attributes be used to inform the other areas of engineering in moving toward gender balance?” One way to move toward gender balance is to embrace a more interesting image of engineer and engineering. It must be based on new interpretations of engineering and the needs of society.

The Image of Engineer

Goldstein (2004) asserted that the current image of the engineer, that of the mechanical engineer, is not appealing to women. This assertion is substantiated in both the questionnaires and the interviews. This may be changing as the first graduating class for Cornell's biological and environmental engineers enters the work force and society better understands the newly emerging engineering technologies.

The New Engineering

Wulf and Fisher (2002) noted that engineering education appeared to be out of touch with the practice of engineering. Changes in curriculum, skill acquisition, focus, and name appear to suggest that attempts are being made in this department, to better align engineering education with current needs.

Changes in educational practice asserted by Felder and Brent (2005) also support the skills necessary for the new engineers, including better communication skills.

Caring Professors in a Caring Community

The concept of a student-centered, and nurturing educational environment is generally associated with an elementary school environment. Middle schools as well attempt to create environments where classrooms are student-centered. According to the responses to the questionnaire and interviews, the students may be responding to the student-centeredness of this educational environment, as asserted by Felder and Brent (2005) and Felder and Silverman (1988).

Discussion

What does an engineer look like? Engineers suffer from an image that may be unattractive to a wide population. Encouraging more females into the STEM fields requires an image of engineer that is different from the present one. Although students do not have to have a parent as an engineer to enter the STEM fields (although it helps), a more positive and encompassing image of the engineer is necessary. Currently, the image does not benefit anyone, male or female. As one participant noted, "Society tends to have a negative image of female engineers. Female engineers are stereotyped to be masculine and unattractive, antisocial, among many other things."

Not everyone agrees with the definition of what an engineer looks like or what engineering does. Engineers apply their knowledge and skill to solve societal problems. Some see engineering as a creative endeavor that fuses imagination and skill, while others view the discipline in narrow unattractive terms.

The traditional view of engineer from the perspectives of the students in this study is that of the mechanical engineer, "a man sitting behind a desk crunching the numbers," an image that was way too boring for this student. Not everyone shares this image. Those students who had a relative as an engineer, had a much richer and interesting image to draw upon. This current view of engineer must be broadened to embrace other perceptions of engineers and engineering.

American folklore, until very recently, favored another image of the engineer as the "lone surveyor in boots and Mackinaw (blanket), the wizard inventor in his workshop and the master of the industrial dynamo" (NRC, 1989, p. 31). Where is the man behind the desk?

The image of engineer has also evolved through the centuries. There is historical precedence for engineering as an inherently interdisciplinary endeavor and tied to biology and social concerns. The Renaissance favored the knowledge of various disciplines and skills fused with the understanding of aesthetics (Johansson, 2006).

Engineering can then include Michelangelo Buonarroti or perhaps Antonio Stradivari in the discussion of what engineering is and what an engineer looks like (gender aside). They used engineering disciplines and math to create technological masterpieces, including Michelangelo's *David* and the Stradivarius family of viols.

Michelangelo was a painter, a sculptor, an architect, and an engineer. Not only was Michelangelo considered a good systems engineer as well as a military engineer, but also a good project manager (Baker, 2006). He saw the big picture as well as managed the details. Sculpting *David* required a good background in materials and tools. Also required was the knowledge of anatomy and physiology, gained through extensive experiential work with cadavers.

Another example of the interdisciplinary quality of Renaissance engineering was the invention of the family of viols: violin, viola, violoncello, and contrabasso. The designer of the violin, Amati and then Stradivari during the 16th and 17th centuries needed expertise in geometry. The original design of the violin was created with compass points and arcs. The violin is an exquisite design of perfect ratio, influenced by the teachings of Pythagoras.

Early violinmakers like Stradivari must have needed expertise in chemistry to understand the nature and value of varnish. They needed knowledge of the acoustic properties of various woods for their tone, strength and flexibility, and an extensive understanding of the acoustical properties of materials, oscillation and frequency vibration.

The traditional number of strings on present instruments is four. The strings are tuned in intervals of a perfect 4^{th} and 5^{th}, depending on the instrument. The relative intervals of a perfect 4^{th} and 5^{th} are not serendipitous, but based on the overtone series of frequency vibration that occurs naturally as a result of wave energy. Lastly, the violin, or any of the stringed instruments, in the hands of a human being brings engineering to life, and life to engineering.

The image of the engineer and engineering must change. Engineering must reflect a broad understanding of many disciplines. The image of engineer must move away from the coldly analytical nerd or the unattractive, antisocial masculine woman to include even a sorority girl that communicates and is more "relationship-y," as well as one who works out mathematical equations. It must embrace the beauty and emotion that engineering actually possesses. As one student noted, "There's an emotional side to BEE."

The connection of the physical world to life has been understood for centuries. DaVinci wrote, "Man is said to be the minor world by the ancients and this expressions is surely well reckoned, inasmuch as man is made of earth, water, air and fire, his body is earth's simile" (as cited in Cianchi, 1998, p. 5). DaVinci continued:

> Man has bone as a support and armour for flesh, the earth has stones as a support for the soil, where man has a pool of blood, wherein the breathing lung increases and decreases, the earth body has the its ocean sea, that too floods and ebbs every six hours to let the earth breathe; where blood vessels branch out from the mentioned pool of blood through the human body, likewise the ocean sea fills the earth's body with countless vessels of water. (as cited in Cianchi, p. 5)

DaVinci considered the human body as the convergence of all interests (disciplines). There too, biological and environmental engineering is a natural focus of all the engineering disciples.

Recommendations

The reflections of female BEE students as well as relevant literature suggest changes that can benefit equity in science and the STEM fields. These recommendations are based a both the literature review of early experiences of students in science and math, and also on the reflections and recommendations of the BEE women themselves.

Recommendations for Parents

Families can support and encourage potential engineers by not feeding into stereotyped views of narrow career choices for women (Gutbezahl, 1995). Parents must be mindful that science and math are no longer considered genetic proclivities belonging to males alone (Gutbezahl). The notion that girls are better in reading and the arts and boys are better in math and science is no longer valid. The research on the influence of media suggests that it can have a huge influence on students' interest in math and science (Witt, 2000). Parents can be mindful of the children's books available that reflect a wide variety of activities and nontraditional careers for women.

It is suggested that parents and families ask for quality science instruction. Parents can make sure, through their PTA organizations, that hands-on, meaningful science experiences are being provided for their children and that teachers have the tools and materials they need to support instruction. Parents need to be alerted to the missed opportunity inherent in taking minimum requirements in math and science.

Recommendations for Elementary Schools

The recommendations for schools and teachers are intended to support learning for a broad audience, not just for females.

The teacher plays an important role in students' attitudes toward science (Feldman & Theiss, 1982; Good & Brophy, 1987; Rosenthal & Jacobson, 1968). Based on the reflections of students' experiences, teachers can either encourage or discourage girls regarding the STEM fields. Teachers must be alerted (both male and female) to the dangers of expecting less from any student based on gender, race, or ethnicity. Historically, the elementary teacher, predominantly female, has not been comfortable with teaching science nor has she been adequately prepared to do so (Horizon Research, 2002).

It is important that teachers have access to professional development (Horizon Research, 2002), especially for female teachers, so that they can allay fears and anxieties associated with science and math content and instruction. Training is important in understanding the role that gender bias plays in classroom environments. The professional development should be ongoing and not something that occurs once for an hour every few years. Ongoing professional development ensures that the ideas are reinforced and revisited to include any newly hired personnel.

National and regional conferences provide a valuable source of professional development. Participation should be encouraged to join organizations like NSTA or comparable state organizations. Conferences not only provide a sense of professionalism and networking, they demonstrate what is changing in the field, what materials and instructional tools are available and what is being developed.

Principals can encourage and support daily science instruction in the K-5 environment, not just those grades that require state assessments. The adoption of a district-wide grade-by-grade articulated curriculum framework based on the work of the National Science Education Standards (NRC, 1996) is a valuable and mandatory first step in supporting instruction (No Child Left Behind [NCLB], 2006). Understanding and adhering to a grade-by-grade curriculum framework ensures that valuable skills are not being overlooked, thus creating gaps in student learning.

Findings from the research, particularly question 17, which referred to students' preferred learning styles, suggest that a variety of instructional formats benefits student learning. Teachers can be encouraged to explore alternate ways of doing science in a mixed gender environment. Teaching and learning preferences, as noted by students can include; adding cooperative groupings, problem-based learning, issue-oriented science, hands-on experiences, and application to the traditional instructional strategies (Felder & Brent, 2003). Students can then display their special interests through various modes of learning through science fairs and expositions, furthering their intellectual development.

When making hiring decisions, ask prospective teachers to provide a demonstration lesson in science inquiry. Ask how they intend to link literacy issues to science and to the other content areas. Science instruction is unfortunately neglected in favor of reading and math (those subjects that are assessed through NCLB legislation). Teachers need to know that teaching science through inquiry can enhance literacy skills, not detract from them. Each skill can illuminate the other (Thier, 2001).

Computer use on all levels is a mandate of NCLB legislation. It is recommended that elementary teachers integrate computer technology into instruction and make computer use as commonplace in classrooms as the use of dictionaries and encyclopedias.

Less Emphasis On, More Emphasis On

The following tables are adaptations of the charts available in the National Science Education Standards (NRC, 1996). Table 20 offers a change of emphasis for the elementary schools.

Table 20. Less Emphasis, More Emphasis for Elementary Schools

Less emphasis on	More emphasis on
Valuing the subjects that are required for state assessments like math and reading (teaching to the test).	Providing a quality science program around inquiry as well as content. Teaching toward a scientifically literate population as well as preparing for state assessments
Reading about science	Giving students something to do or a problem to solve along with something to read
Providing only one mode of instruction that serves a narrow range of learners	Incorporating a variety of instructional strategies to serve more learners
Learning about a subject in isolation	Connecting the disciplines and then to real world application

Recommendations for Middle School

A supportive professional atmosphere is essential for teachers, so that they may develop and improve (Horizon Research, 2002). Attending conferences, reading journals, journal writing, collegial circles, making conference presentations, conducting action research, and grant writing can accomplish this. These activities allow teachers to keep up with change, as do all other professionals. Middle school teachers, through professional development, also need to be aware of the role that gender bias plays in classroom learning. It is recommended that professional develop supports teaching with equity as a goal.

It is required through learning and teaching standards and mandates that teachers integrate computers into instruction beyond traditional Internet searches and PowerPoint presentations. Data collecting technology, such as computer peripherals (probes and sensors), can be added to instruction and support science teachers in the development of those skills (International Society for Technology Education, 2006). Students need problems to solve and things to do as well as something to read in order to apply important scientific skills. Course offerings should be interesting and challenging to engage the adolescent learner. Teaching evidence-based decision-making and the role that science plays in society supports scientific literacy.

Counselors play an important role in middle school. It is suggested that counselors rid themselves of old stereotyping attitudes of what is gender appropriate for their middle school constituents. They can provide career day events that bring a wide variety of STEM careers to students. A new image of engineers and engineering can emerge with the addition of an Engineering Day.

Middle school (grades 5-8) is a vulnerable time for young girls. It is a time when a decline in interest in the STEM careers and self-esteem is particularly evident (Sadker & Sadker, 1994). It is recommended that teachers not make predictions concerning future achievement of any student before he or she has been given an opportunity to demonstrate ability in an area, especially those areas that are of a nontraditional nature. Telling a student, "You will fail out of Cornell," is not professional and may contribute to the student's feelings of low self-esteem (Gutbezahl, 1995). Table 21 highlights a change of emphasis for middle schools.

Table 21. Less Emphasis, More Emphasis for Middle Schools

Less emphasis on	More emphasis on
Valuing only those subjects that are required for state assessments like math and reading; teaching to the test	Providing a science program around inquiry as well as content; teaching toward a scientifically literate population as well as preparing for state assessments
Reading about science	Giving students something to do or a problem to solve as well as something to read
Providing only one mode of instruction that serves a narrow range of learners	Incorporating more problem solving and real world application to instructional strategies
Learning about the subject in isolation	Connecting the disciplines and then to real world application
Creating elitist courses with limited enrollment	Encouraging more students to take high-level courses (Regents)
Science for potential scientists or doctors	Science for everyone in societal and personal decision-making

Recommendations for High School

Based on student recommendations, high schools can offer science programs that are challenging to all students. Advanced Placement courses could be included in their offerings as well. Students commented on the value of the Advanced Placement courses on their academic success. Based on students' responses, success in engineering is enhanced having taken AP courses. “If I hadn't been in AP classes I never would have survived at Cornell.” And, “The AP classes were still nowhere near as hard as they are in college.” High school math and science teachers could be provided with professional development in sensitivity training regarding gender issues, so that no student need experience a teacher making a prediction of future academic success.

Based on student responses, counselors could provide more direction to students that support women in the STEM fields. It is recommended that counselors maintain close contact with their constituents and encourage all girls to continue the math and science sequence that includes AP courses. Based on students’ responses, particularly in question 6, school math and science departments might consider updating their courses so that they maintain academic rigor and adequately prepare students for a challenging college experience. High schools might contact the SWE for literature on the latest research regarding the encouragement of women into the STEM fields. Table 22 provides a change of emphasis for high schools.

Recommendations for Engineering Colleges

Question 3 asked, “How could these attributes be used to inform the other areas of engineering in moving toward gender balance?” Cornell’s BEE program contains certain characteristics that have provided the incentive for students to both engage in an engineering discipline and remain in the program. These characteristics have promoted equity in the STEM fields.

Table 22. Less Emphasis, More Emphasis for High Schools

Less emphasis on	More emphasis on
Watered down science curriculum	Interesting and challenging science courses
Highlighting career opportunities that are considered gender appropriate	Offering a broad spectrum of available degree choices for all students
Achieving minimum requirements for graduation	Supporting all students toward completion of science and math courses including AP
Lecture only	Use of a variety of instruction strategies
Allowing student to work in isolation	Providing opportunities for group work
Learning that focuses on competition	Focuses on collaboration and competition

It is recommended that other engineering schools broaden the engineering degree offerings through curriculum and name changes. Consider a name change that offers a more flexible engineering outlook that would appeal to a broader audience. “A broad engineering education leaves engineers better prepared to communicate with each other, to avoid technological obsolescence, and to learn new skills as technology advances” (NRC, 1989, p. 68). Cornell University now offers degrees in a variety of newly designed engineering disciplines, which include:

1. Biomedical Engineering
2. Chemical and Biomolecular Engineering
3. Civil and Environmental Engineering
4. Biological and Environmental Engineering

It is recommended that engineering schools provide training for engineering faculty that supports other modes of instruction to include group work, application, problem-solving activities as well as lecture. ABET (n.d.) learning outcomes define the skills necessary for engineers in “Challenge 2000.” Understanding global solutions, working in teams, a multidisciplinary curriculum, and the development of communication skills, are all required as part of accreditation guidelines.

Adding handouts or including online accessibility to classroom and lecture materials can increase the value of lecture. Good teachers are not born; they evolve and develop through experience and understanding of how people learn. This can be accomplished through ongoing professional development.

Findings from the research suggest that both students and teachers can benefit from understanding their own learning and teaching styles (Felder & Silverman, 1988). Students can benefit from understanding the best way that they learn and professors can benefit from learning how to mix strategies to accommodate more than one learning style. Colleges can make the engineering experience welcoming to all learners by providing a wide array of instructional materials.

Faculty and Teaching Assistants need professional development in sensitivity training regarding gender issues so that the classroom does not become an uncomfortable environment for anyone. Marginalization and stereotyping have been around for a long time and are not likely to go away anytime soon. Universities however, can support a better understanding of this issue through discussion among faculty members and students alike. Colleges can then better prepare the students with ways to deal with marginalization, if it bothers them. Heads of Departments can foster a climate that supports a caring environment through best hiring practices and evaluations.

Based on the research, particularly in the response to question 11, it is recommended that the culture known as "weed-out," the process of eliminating perceived untalented and unskilled students, be replaced with a culture that supports academic success for every student. As a way of accomplishing this goal, colleges could make hours for extra help and tutoring reasonably flexible to meet the needs of students. Engineering education might consider adopting alternative support strategies as in AEW that feature small group and cooperative instruction. Colleges can make the engineering experience welcoming to all learners by valuing academic success and supporting success through better instruction.

As the needs of society change, new engineering disciplines are required (Goldstein, 2004). Engineering disciplines that are newly developing or are of a nontraditional nature must not be deemed "fake" or "cop-out." This requires sensitivity training that helps others understand the nature of the newly emerging engineering disciplines. Engineering students can reach out to high schools and make presentations regarding newly evolving career opportunities in engineering. It is recommended that the engineering experience be welcoming to all learners, by not giving in to elitist attitudes concerning engineering.

Table 23 provides a change in emphasis for engineering schools.

Recommendations for Curriculum Developers

Certain events have catalyzed the educational market. The launching of Sputnik in the 1950s encouraged the development of many programs based on how children learn. As well, in 1996, with the publication of National Science Education Standards, all books and related materials were tied to standards. NCLB high-stakes testing has created changes in the materials that students use. Recently published books advertise that content is tied to standards and support both instruction and test preparation. It is recommended that curriculum developers create instructional materials geared to providing the connection to engineering that makes it a more positive, interesting, and challenging endeavor.

Table 23. Less Emphasis, More Emphasis for Engineering Schools

Less emphasis on	More emphasis on
Weeding out alleged potentially weak students	Providing flexible and comprehensive support systems that encourage retention
Lecture only	Strategies that increase the value of lecture: handouts, online access
Providing only one mode of instruction that serves a narrow range of learners	Incorporating other instructional strategies that appeal to a broader audience
An extensive in-depth specialized curriculum	A broad engineering curriculum with courses that are shared by students in all disciplines
The idea that good teachers are born	Improving instruction based on learning theory

Based on BEE students' remarks and comments in the questionnaire and interviews, the curriculum should be

1. Of high interest
2. Intellectually challenging
3. Based on the research of teaching and learning

4. Offer a mixed instructional strategy approach to include many learning styles

5. Interdisciplinary; include many engineering disciplines

The target audience should be middle school students when many females and minority populations begin to loose interest in the STEM fields. Funding could easily come from small grants like TAPESTRY and National Science Teachers Association funding opportunity for teachers, or larger NSF grants for STEM research. Students confront engineering daily, but may not recognize it. It is valuable to understand the creative and challenging opportunity that engineering provides through school experiences.

Recommendations for Industry

As science needs to develop ways to return products to the earth through biological means, industry may indeed require the expertise of the biological and environmental engineers. As engineering changes, industry needs to make appropriate changes as well. Today, women have many more options regarding work and family. Industry needs to keep an open mind so that they do not lose potentially valuable and innovative women in the work force due to preconceived notions regarding women, family, and work. They need to update their concept of what engineering is and what engineers look like based on new paradigms and disciplines.

Industry can be a valuable partner with schools, especially the middle level, to broaden the image of the engineer and introduce the creative and lucrative opportunities available to perspective engineering students.

Recommendations for Further Study

This study focused on the gender balance that has occurred in one engineering discipline in an engineering school in the northeast. It was narrow in focus as it dealt with the understanding of this phenomenon in one department and only through the lens of gender. This study was conducted in the northeastern portion of the United States. As mentioned by one of the participants, New York State is considered a liberal state. Other studies in other universities could be conducted to determine if there are differences based on cultural and political climate. Other engineering disciplines that are also approaching gender balance, like chemical engineering, could be investigated through comparative studies.

Another area of potential research might be to better understand why some females are aware of marginalization and others are not. Presumably, the students in BEE take the same classes with the same professors and Teaching Assistants, yet some of the students feel negatively affected by the remarks by professors, TAs and peers, and others do not.

At Cornell, there is a small representation of Hispanic and African American engineering students. There remains a great social disparity in engineering, both for males and females of underrepresented minority groups. The percent of African-American and Hispanic engineers currently enrolled in engineering at Cornell is 2% and 4% respectively. It is still very small when compared to the total percentage of women in engineering in general (28%). More research and outreach are needed to encourage both women and men of color into the engineering disciplines.

Another area for further research is how to best serve the growing English Language Learners (ELL) population regarding their academic needs in the STEM fields. Currently, the ELL population in the United States, regarding STEM fields is underserved (Echevarria, Vogt, & Short, 2000). The ELL population is growing faster than teachers' ability to understand their needs.

English Language Learners will need to continue their content learning while they learn English. Skill acquisition in the content area and in English needs to increase simultaneously in order to be able to access STEM careers. Often, English language acquisition is accomplished at the expense of content knowledge in the sciences and other academic fields. Five to 7 years on average (Cummins, 1999) are needed to develop the competencies in English to fully participate successfully in an academic setting. ELL are more likely to have dropped out or graduated before this may happen. The opportunities in the STEM careers have either been lost or will be deferred.

Conclusion

The average percentage of women in all of the engineering disciplines at Cornell is 28% female (including BEE), while the percentage of females in BEE is 52%. The questionnaire and interviews revealed that the BEE department's academic environment is generally receptive to women and vice versa. It is a good institutional fit with the participants of this study. The BEE department makes an attempt to demonstrate through its support, outreach, advising, and caring, that it is generally interested in increasing the diversity of the university. Additionally, it offers a rigorous interdisciplinary program of instruction that is of interest and relevance to women.

Encouraging more women into the engineering technologies is a complex interaction of variables, which are operating throughout the first 18-22 years in the lives of individuals. Those variables include individual differences, prior school experiences, family dynamics and history. Therefore, all educational levels must work in synchronicity to keep talented young women in the engineering pipeline.

The fact that 52% of BEE students are women means that something positive has already occurred even before they got to the university level. Positive change is occurring in many places: in society, in schools and classrooms, in the media, in families, and in the heads and hearts of many young women.

Although the image of the engineer may be changing, the traditional engineer as the mechanical engineer persists on campus, in the lower schools and in society at large. From the interviews and experience with these engineering students, however, it is natural to recreate an image of the emergent engineer. She is female, articulate, helpful, smart, and sociable with good communication skills. The image of the engineer has changed for these women.

The emergent knowledge that was most surprising was the importance of the academic support and institutional fit provided all students. Clearly, women in this context have responded well to the supportive and caring environment created by the University and the BEE department.

BEE women do not want special treatment. They do not wish to be singled out, nor are they in engineering to affect the gender ratio. BEE women want to be judged on the basis of their accomplishments, not on their gender. There was no sense that these women are looking for an easy way through engineering school. Their favorite class was often times the hardest. They do not want to be grouped according to gender, as it does not mirror the real world.

The department and the women have experienced marginalization; as in calling BEE students fake engineers or “wanna-be” (respondent term) engineers. Women have dealt with marginalization and lack of respect for the department in individual ways. It is a way to make students feel as if they are fraudulent, their efforts are worthless and that they are pretending. There is no doubt that BEE students are real engineers. Their courses for the first 3 years are the same. They take their core courses in the engineering quad on the other side of campus and are in the same classes with the students in chemical engineering, mechanical engineering and civil engineering. Some believe that BEE, because it is less math intensive, less "cut throat," more "laid-back" or relaxed, or more "manageable" than the more traditional engineering disciplines, it must not be "real" engineering. BEE is real engineering.

The connection of women to the department of biological and environmental engineering can be understood by respondent's words: "Women are more 'relationship-y type' people. They like to help people. They care about people and earth. Biological and environmental engineering is that clear path toward that goal."

Things Have Changed

At Career Day in 1958, at the Isaac E. Young Junior High School, offered girls only those career choices that were considered gender appropriate at the time: nursing, airline stewardess, a test kitchen technician at General Foods, and a department store window dresser. With the exception of nursing, these options were not even degree choices. Additionally, at that time mandatory retirement age for a stewardess was 26 years. In contrast, Career Day 2005, offered students a wider selection of nontraditional opportunities for males and females.

In the past 40 years, many science-related fields, with the exception of engineering, have seen a greater participation of women. More females are taking the advanced classes in science and math that can prepare them for a degree choice in the STEM fields. From 1990 to 1998, both male and female high school students experienced gains in mathematics course enrollment, an increase from 13% to 23%, and advanced science courses from 49% to 60% (NSF, 2001).

The interest in the study of biology is both reflected in the preferences of BEE women (73% of women chose BEE based on the connection to biology) and in female high schools students as well. In 1998, female high school graduates were more likely than their male counterparts to have taken biology and chemistry, and males were more likely than females to have taken physics.

Once they make the choice of an engineering degree, it is up to the colleges and universities to nurture and cultivate females through academic support and good instruction. The world, as it addresses the challenges of the 21st century will need the skill and technological expertise of the biological and environmental engineers. Women can fill that need.

Knowledge needs to be accessible to all learners (Felder & Silverman, 1988), whether female, minority, the disabled or those with varying learning styles. Interviews and questionnaires suggested that students have a variety of preferred learning styles and that access to copies of the lecture has an impact on instruction and learning. This study suggests that it may require only simple adjustments to a professor's instructional strategies to make learning more accessible to the broader audience. A student need not have to perceive that, "My life is over" when the instructor removes an acetate before having the opportunity to copy the relevant information. The simple task of providing an additional visual can support the student's learning. In this way, the instructor can be sensitive to the needs of the learning community. This provides the opportunity for an instructor to make knowledge more accessible to students. A simple visual is all that may be needed to support teaching and learning for everyone.

Equity in education is as relevant in engineering education as it is in the lower schools. It is all about teaching and learning. It is about making the learning and knowledge accessible to the broad audience and not just to the top 10% of the class; not just to males, not just to Caucasians, not just to the privileged. Everyone deserves the right of access to knowledge, whether it is free or not. It is the teacher's responsibility, with support from the administration, to see that equity in education is served.

Biological and environmental engineering (BEE) brings engineering to life, in a caring and supportive learning community. The connection of life to engineering is not such a far stretch. It is hardly "fake" or "cop out" engineering. DaVinci believed that man (life) was the model, center, microcosm reflected in the macrocosm. "That is where one had to start and that was where one had to end if one truly intended finding the general law holding together the world universe" (Cianchi, 1998, p. 5). Biological and environmental engineering reflected that connection, and the women came.

REFERENCES

20 U.S. Const. Amend. IX, § 1681 (1972).

About the land grant system. (2005). Retrieved January 20, 2006, from http://www.wvu.edu/~exten/about/land.htm#what

Accreditation Board for Engineering and Technology. (n.d.). Retrieved March 11, 2003, from http://www.abet.org/

Alberts, B. (1997). *Science teaching reconsidered: Teaching reconsidered: A handbook*. Washington, DC: National Academy Press.

American Association of Engineering Societies. (2003-2004). Retrieved March 17, 2005, from http://www.aaes.org/

American Association of University Women. (1992). *How schools shortchange girls*. New York: Marlow.

American Association of University Women. (1998). *Gender gaps: Where schools still fail our children*. Retrieved January 7, 2007, from http://www.aauw.org/research/GGES.pdf

American Association of University Women. (2006). *Drawing the line*. Retrieved December 28, 2006, from http://www.aauw.org/research/dtl.cfm

American Society of Civil Engineers. (2005). *Report card for America's infrastructure*. Retrieved April 1, 2005, from http://www.asce.org/reportcard/2005/page.cfm?id=103

Arkin, R. M., & Baumgardner, A. H. (1985). Self-handicapping. In J. H. Harvey & G. Weary (Eds.), *Attribution: Basic issues and applications* (pp. 169-202). Orlando, FL: Academic Press.

Baker, A. (2006). *NASA homepage*. Retrieved August 15, 2006, from PM Perspectives Web site: http://pmperspectives.gsfc.nasa.gov/engineer.htm

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

Bandura, A. (1986). Self-efficacy theory in contemporary psychology. *Journal of Social and Clinical Psychology, 4*(3), 359-373.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press. (Reprinted in H. Friedman [Ed.], *Encyclopedia of mental health*. San Diego: Academic Press.)

Bandura, A. (2003). Role of affective self-regulatory efficacy in diverse spheres of psychosocial functioning. *Child Development, 74*, 769-782.

Barger, R. R., & Hoover, R. L. (1984). Psychological type and the matching of cognitive styles. *Theory into Practice, 23*(1), 56-63. Retrieved December 28, 2006, from http://www.applestar.org/capella/MBTI%20in%20Education.doc

Basow, S. A. (1992). *Gender stereotypes and roles* (3rd ed.). Pacific Grove, CA: Brooks/Cole.

Beal, C. (1994). *Boys and girls: The development of gender roles*. New York: McGraw-Hill.

Benbow, C. P., & Stanley, J. C. (1980). Sex differences in mathematical ability: Fact or artifact? *Science, 210*, 1262-1264.

Berglas, S. (1985). Self-handicapping and self-handicappers: A cognitive/attributional model of interpersonal self-protective behavior. In R. Hogan & W. H. Jones (Eds.), *Perspectives in personality* (Vol. 1, pp. 235-270). Greenwich, CT: JAI Press.

Berkowitz, S. (1997). Analyzing qualitative data. In J. Frechtling, L. Sharp, & Westat Inc. (Eds.), *User-friendly handbook for mixed method evaluations* (Chapter 4). Retrieved November 16, 2004, from National Science Foundation, Directorate of Education and Human Resources Web site.

Betz, N. E., & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational Behavior, 23*, 329-345.

Betz, N. E., & Hackett, G. (1998). *Manual for the occupational self-efficacy scale*. Retrieved January 1, 2007, from http://seamonkey.ed.asu.edu/~gail/occse1.htm

Bickman, L., & Rog, D. (1998). *Handbook of applied social research methods*. Thousand Oaks, CA: Sage.

Bogdan, R. C., & Biklen, S. K. (1982). *Qualitative research for education: An introduction to theory and methods*. Boston: Allyn and Bacon.

Brainard, S. G., & Carlin, L. (1998, October). A six-year longitudinal study of undergraduate women in engineering and science. *Journal of Engineering Education, 87*(4), 369-375.

Brent, R., & Felder, R. M. (2000, June). *Helping new faculty get off to a good start*. Proceedings from the 2000 annual meeting of the American Society for Engineering Education.

Brown, A. (2000, May). *Women in engineering: Work and school settings affect career development*. Retrieved March 11, 2003, from http://www.spectrum.ieee.org/inst/may2000/women.html

Brown, C. (1987). *Women in the aquaculture professions*. Retrieved January 20, 2006, from http://www.fao.org/docrep/S4863E/s4863e0c.htm

Brugere, C., & Lingard, J. (2001, September). *Evaluation of a livelihoods approach in assessing the introduction of poverty-focused aquaculture into a large-scale irrigation system in Tamil Nadu, India*. Paper presented at the 74th EAAE seminar on Livelihoods and Rural Poverty: Technology, Policy and Institutions, Imperial College at Wye, Kent, UK.

Burton, L., & Wang, J. (1999, February). *How much does the U.S. rely on immigrant engineers?* (NSF 99-327). Arlington, VA: National Science Foundation.

Bussey, K., & Bandura, A. (1999). Social cognitive theory of gender development and differentiation. *Psychological Review, 106*, 676-713.

Campbell, P. B. (1991). *Girls and math: Enough is known for action*. Retrieved December 30, 2006, from http://www2.edc.org/WomensEquity/resource/MST/Digest/mathdig.htm#Math

Caplan, P. J., Crawford, M., Hyde, J. S., & Richardson, J. T. (1997). *Gender differences in human cognition*. New York: Oxford University Press. Retrieved December 26, 2005, from Questia database: http://www.questia.com/PM.qst?a=o&d=57129791

Cerro, G., & Duncan, N. (2002, June). *Assessing success: Female engineers at the Cooper Union*. Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition, Montreal, Quebec, Canada.

Chang, J. C. (2002). *Women and minorities in the science, mathematics and engineering pipeline*. (Eric Document Reproduction Service No. EDOJC0206) Retrieved January 1, 2007, from http://www.gseis.ucla.edu/ccs/digests/dig0206.htm

Cianchi, M. (1998). *Leonardo anatomy*. Florence, Italy: Giunti Gruppo Editoriale.

Colorado State University. (2004). *Writing@CSU: Writing guides*. Retrieved November 5, 2004, from http://writing.colostate.edu/references/research

Cornell University. (2006a). *BEE: Biological and environmental engineering. About the department*. Retrieved October 16, 2006, from http://www.bee.cornell.edu/ABOUT/about.htm

Cornell University. (2006b). *The Cornell women's handbook: History of women at Cornell*. Retrieved January 18, 2007, from http://www.rso.cornell.edu/cwh/historyn.html

Cornell University. (2006c). *Enrollment statistics*. Retrieved July 7, 2005, from http://www.engineering.cornell.edu/student-services/registrar/enrollment-statistics/index.cfm

Corno, L., & Snow, R. E. (1986). Adapting teaching to individual differences among learners. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed.; pp. 605-629). New York: Macmillan.

Covington, M. V., & Beery, R. (1976). *Self-worth and school learning*. New York: Holt, Rinehart & Winston.

Crawford, M., & MacLeod, M. (1990). Gender in the college classroom: An assessment of the "chilly climate" for women. *Sex Roles, 23*, (3/4), 101-122.

Cummins, J. (1999). *Basic interpersonal communicative skills and cognitive academic language proficiency*. Retrieved July 7, 2004, from http://www.iteachilearn.com/cummins/bicscalp.htm

Damarin, S. K. (1990). Teaching mathematics: A feminist perspective. In T. Cooney & C. Hirsch (Eds.), *Teaching and learning mathematics in the 1990s: 1990 yearbook* (pp. 174-182). Reston, VA: National Council of Teachers of Mathematics.

Damarin, S. K. (1995). Gender and mathematics from a feminist standpoint. In W. G. Secada, E. Fennema, & L. B. Adajian (Eds.), *New directions for equity in mathematics education* (pp. 242-257). New York: Cambridge University Press.

Danielson, C., & McGreal, T. (2000). *Teacher evaluation to enhance professional practice*. Princeton, NJ: Educational Testing Service.

Devlin, K. (2000). *The math gene: How mathematical thinking evolved and why numbers are like gossip*. New York. Basic Books.

Drever, J. (1952). *Dictionary of psychology*. New York: Penguin Books.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist, 41*, 1041-1048.

Dweck, C. S., & Repucci, N. D. (1973). Learned helplessness and reinforcement responsibility in children. *Journal of Personality and Social Psychology, 25*, 109-116.

Echevarria, J., Vogt, M. E., & Short, D. (2000). *Making content comprehensible for English language learners: The SIOP model*. Needam Heights, MA: Allyn & Bacon.

Elgar, A. G. (2004). Science textbooks for lower secondary books in Brunei: Issues of gender equity. *International Journal of Science Education, 26*(7), 875-894.

Engle. C. R. (1987). *Women in training and extension services in aquaculture*. Proceedings of the Conference on Women in Aquaculture. Food and Agriculture Organization of the United Nations, Rome.

FairTest: The National Center for Fair & Open Testing. (2005). Retrieved September 17, 2005, from: http://www.fairtest.org/univ/2005SAT Scores.html-anchors57372

Feingold, A. (1988). Cognitive gender differences are disappearing. *American Psychologist, 43*, 95-103.

Felder, R. M. (1998, Spring). ABET criteria 2000: An exercise in engineering problem solving. *Chemical Engineering Education, 32*(2), 126-127.

Felder, R. M., & Brent, R. (2003). Learning by doing. *Chemical Engineering Education, 37*(4), 282-283.

Felder, R. M., & Brent, R. (2005). Understanding student differences. *Journal of Engineering Education, 94*(1), 57-72.

Felder, R. M., Felder, G. N., & Dietz, E. J. (1998). A longitudinal study of engineering student performance and retention. Comparisons with traditionally-taught students. *Journal of Engineering Education, 87*(4), 469-480.

Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education, 78*(7), 674-681.

Felder, R. M., & Solomon, B. (2003). *Learning styles and strategies*. Retrieved January 21, 2005, from http://www.ncsu.edu/felder-public/ILSdir/styles.htm

Felder, R., Woods, D., Stice, J., & Rugarcia, A. (2000). The future of engineering education II. Teaching methods that work. *Chemical Engineering Education, 34*(1), 16-25.

Feldman, R. (2002, Fall). *Gender equity in education*. Retrieved January 7, 2007, from http://www.nd.edu/~frswrite/issues/2002-2003/feldman.shtml

Feldman, R. S., & Theiss, A. J. (1982). The teacher and student as Pygmalions: Joint effects of teacher and student expectations. *Journal of Educational Psychology, 74*, 217-223.

Fennema, E. (2000, May). *Gender and mathematics: What is known and what do I wish was known?* Prepared for the Fifth Annual Forum of the National Institute for Science Education, Detroit, MI. Retrieved February 13, 2006, from http://www.wcer.wisc .edu/archive/nise/News_Activities/Forums/Fennemapaper.htm

Feuers, S. (1990). Student participation in mathematics and science programs. In D. P. Gallon (Ed.), *Regaining the edge in urban education: Mathematics and sciences*. Washington, DC: American Association of Community and Junior Colleges. (ERIC Document Reproduction No. ED341450)

Fitzgerald, L. F., & Crites, J. O. (1980). Toward a career psychology of women: What do we know? What do we need to know? *Journal of Counseling Psychology, 27*, 44-62.

Ford, M. (1998). *Gender gaps: Where schools still fail our children*. Washington, DC: American Association of University Women Educational Foundation.

Fox, L. H., Brody, L., & Tobin, D. (1985). The impact of early intervention programs upon course taking and attitudes in high school. In S. F. Chipman, L. R. Brush, & D. M. Wilson (Eds.), *Women and mathematics: Balancing the equation* (pp. 248-274). Hillsdale, NJ: Erlbaum.

Funderstanding. (2005a). *Observational learning*. Retrieved January 15, 2006, from http:// www.funderstanding.com/observational_learning.cfm

Funderstanding.(2005b). *Outcomes-based learning*. Retrieved January 15, 2006, from http:// www.funderstanding.com/outcome_based_edu.cfm

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational research: An introduction* (7th ed.). New York: Allyn and Bacon.

Gallagher, T. (2001, November 30). *Equal Opportunities Commission conference on boys and girls in the 21st century: Gender differences in learning*. Retrieved February 21, 2005, from http://www.eoc.org.hk/TE/edu/gendiff

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Gender, Science and Technology Gateway. (n.d.). *Policy toolkits in gender, science and technology*. Retrieved March 7, 2003, from http///gstgateway.wigsat.org

Goldstein, J. I. (2004, February). *The new engineer? Engineering trends regarding issues in engineering education*. Retrieved July 7, 2005, from http://www.engtrends.com/edit_02-2004.html

Good, T. L., & Brophy, J. E. (1987). *Looking in classrooms* (4th ed.). New York: Harper & Row.

Graham, L. P. (1997). *Profiles of persistence: A qualitative study of undergraduate women in engineering*. Retrieved January 7, 2007, from http://scholar.lib.edu/theses/public/etd-451862539751141/etd.pdf

Gray, L. (2001). Geeks or not, society faces an increasing need for engineers. *The Business Journal*. Retrieved November 7, 2004, from http://www.bizjournals.com/account/sign_in?uri=/kansascity/stories/2001/06/11/focus3.html

Gutbezahl, J. (1995). *How negative expectations and attitudes undermine females' math confidence and performance: a review of the literature*. Retrieved March 15, 2003, from http://www.inform.umd.edu/

Hackett, G., & Betz, N. E. (1981). A self-efficacy approach to the career development of women. *Journal of Vocational Behavior, 18*, 326-339.

Handelsman, J. (2005, August). *Despite gains, women still face bias in science careers*. Retrieved January 21, 2006, from http://www.eurekalert.org/pub_releases/2005-08/uow-dgw081505.php

Harding, S. (1986). *The science question in feminism*. Ithaca, NY: Cornell University Press.

Hargreaves, D., & Colley, A. (1986). *The psychology of sex roles*. London: Harper & Row.

Hart, G., & Rudman, W. (2002). *America—Still unprepared, still in danger*. Washington, DC: Council on Foreign Relations.

Heinemann South Africa. (2005). *Teaching tips*. Retrieved December 13, 2006, from http://www.heinemann.co.za/Default.asp

Helwig, R., Anderson, L., & Tindal, G. (2001). Influence of elementary student gender on teachers' perceptions of mathematics achievement. *The Journal of Educational Research, 95*(2), 93+. Retrieved December 26, 2005, from Questia database: http://www.questia.com/PM.qst?a=o&d=5001977524

Heyman, G. D., & Legare, C. H. (2004). Children's beliefs about gender differences in the academic and social domains. *Sex Roles, 50*(3-4), 227-239.

Hoepfl, M. (1997). Choosing qualitative research: A primer for technology education researchers. *The Journal of Technology Education, 9*(1), 47-63. Retrieved July 7, 2005, from http://scholar.lib.vt.edu/ejournals/JTE/v9n1/hoepfl.html

Horizon Research. (2002). *2000 national survey of science and mathematics education*. Chapel Hill, NC: Author.

Hyde, J. S., & Linn, M. (2005). *Gender similarities in mathematics and science*. Retrieved December 31, 2006, from http://www.sciencemag.org/cgi/content/summary/314/5799/599

Hyde, J. S., & McKinley, N. M. (1997). Gender differences in cognition: Results from meta-analyses. In P. J. Caplan, M. Crawford, J. S. Hyde, & J. R. E. Richardson (Eds.), *Gender differences in human cognition* (pp. 30-51). New York: Oxford University Press.

Ibarra, R. (1999). *Multicontextuality: A new perspective on minority underrepresentation in SEM academic fields*. University of Wisconsin-Madison. Retrieved December 28, 2006, from http://www.unm.edu/~isrnet/ford/DocumentFiles/AAASArticle.pdf

IMDiversity. (2002). *Women's village: A fact sheet on women and engineering*. Retrieved March 7, 2003, from http://www.imdiversity.com/villages

InGEAR. (1999). *Integrating engineering and reform. Professional development manual*. Arlington, VA: National Science Foundation under Grant No. HRD-9453106.

Institute of Education Sciences. (2004). *Trends in educational equity for girls & women*. Retrieved January 3, 2007, from http://nces.ed.gov/pubs2005/equity/Section2.asp

International Society for Technology Education. (2006). *Technology standards*. Retrieved July 7, 2005, from http://www.iste.org/Content/NavigationMenu/NETS/National_Educational_Technology_Standards1.htm

Jacklin, C. N. (1989). Female and male: Issues of gender. *American Psychologist, 44*(2), 127-133.

Janowski, P. (2004). *Guiding women to engineering careers*. Retrieved January 7, 2007, from http://www.theinstitute.ieee.org/portal/site/tionline/menuitem.130a3558587d56e8fb2275875bac26c8/index.jsp?&pName=institute_level1_article&article=tionline/legacy/inst2004/nov04/11w.fproj.xml&

Johansson, H. (2006). *Violin making*. Retrieved October 22, 2006, from http://www.centrum.is/hansi/

Keefe, J. W. (1982). Assessing student learning styles: An overview. In J. W. Keefe (Ed.), *Student learning styles and brain behavior* (pp. 43-53). Reston, VA: National Association of Secondary School Principals.

Keller, E. F. (1985). *Reflections on gender and science*. New Haven, CT: Yale University Press.

Kenney-Benson, G., Pomerantz, E. M., & Ryan, A. M. (2006, February 23). Approach to school affects how girls compare with boys in math. *Science Daily*. Retrieved January 1, 2007, from http://www.sciencedaily.com/releases/2006/02/060223090528.htm

Kessler, M. (2005). Fewer students major in computer. *USA Today*. Retrieved January 21, 2006, from http://www.usatoday/com/money/industries/technology/2005-05-22

Kline, B. E. (1991). The power of choice. *Roeper Review, 13*(4), 172-173.

Kloosterman, P. (1988). Motivating students in secondary school: The problem of learned helplessness. *American Secondary Education, 17*, 20-23.

Krumboltz, J. D. (1979). A social learning theory of career decision making. In A. M. Mitchell, G. B. Jones, & J. D. Krumboltz (Eds.), *Social learning and career decision making* (pp. 19-49). Cranston, RI: The Carroll Press.

Leedy, M. G., Lalonde, D., & Runk, K. (2003). Gender equity in mathematics: Beliefs of students, parents, and teachers. *School Science and Mathematics, 103*(6), 285+. Retrieved December 26, 2005, from Questia database: http://www.questia.com/PM .qst?a=o&d=5002562576

Leventman, P. (2001, September). *Generating intellectual excitement among women in engineering*. Paper presented at the SEFI (European Society for Engineering Education) Conference, Copenhagen, Denmark.

Linn, M. C., & Hyde, J. S. (1989). Gender mathematics, and science. *Educational Researcher, 18*, 17-27.

Longenecker, D. (2002, October 31). Initiative helps engineering students achieve success. *UB Reporter*, p. 34. Retrieved October 22, 2006, from http://www.buffalo.edu/ reporter/vol34/vol34n5a/articles/SEASinitiative.html

Malcom, S. (1996). *Women, science and the worldview*. Paris: UNESCO.

Marrapodi, J. (2004). *Myers-Briggs type indicator in education. Implications for adult literacy learners*. Retrieved January 2, 2007, from http://www.applestar.org/capella/ MBTI%20in%20Education.doc

Math SAT scores reach 36-year high. (2003). *CNN.com*. Retrieved January 21, 2006, from http://www.cnn.com/2003/EDUCATION/08/26/sat.scores.ap/

Matsui, T, Matsui, K., & Ohnishi, R. W. (1990). Mechanisms underlying math self-efficacy learning of college students. *Journal of Vocational Behavior, 37*, 225-238.

McClean, C., Lewis, S., Copeland, J., O'Neill, B., & Lintern, S. (1997). Masculinity and the culture of engineering. *Australian Journal of Engineering Education, 7*(2),143-156.

Meyer, M. R., & Koehler, M. S. (1990). Internal influences on gender differences in mathematics. In E. Fennema & G. C. Leder (Eds.), *Mathematics and gender* (pp. 60-95). New York: Teachers College Press.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage.

Morgan, D. L. (1988). *Focus groups as qualitative research*. Newbury Park, CA: Sage.

Munshi, A. (1999). *Identifying the gaps: Improving engineering programs for undergraduate women engineering students*. Retrieved March 11, 2003, from http://www.math .mcmaster.ca/lovric/2u3course/2u3critiques/alpna.html

The Myers & Briggs Foundation. (n.d.). Retrieved January 18, 2007, from MBTI Basics Web site: http://www.myersbriggs.org/my%2Dmbti%2Dpersonality%2Dtype/ mbti%2Dbasics/

Nash, S. C. (1979). Sex role as a mediator of intellectual functioning. In M. A. Wittig & A. C. Petersen (Eds.), *Sex roles* (pp. 95-113). New York: Springer Netherlands.

A nation at risk: The imperative for educational reform. (1983). Retrieved January 1, 2007, from http://www.ed.gov/pubs/NatAtRisk/index.html

National Center for Education Statistics. (2004). *Trends in educational equity for girls and women: 2004*. (NCES 2005-016). U. S. Department of Education. Washington, DC: U.S. Government Printing Office.

National Research Council. (1989). *Everybody counts: A report to the nation on the future of mathematics education*. Washington, DC: National Academy Press.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards*. Washington, DC: National Academy Press.

National Science Board. (2002). *Science and engineering indicators—2002*. (Report No. NSB-02-1). Retrieved December 28, 2006, from http://www.nsf.gov/statistics/seind02/toc.htm

National Science Foundation. (2001). *Women, minorities, and persons with disabilities*. Arlington, VA. Retrieved December 28, 2006, from http://www.nsf.gov/statistics/wmpd/sex.htm

National Science Teachers Association. (2006). NSTA position statement: Gender equity in science education. Retrieved January 13, 2006, from http://www.nsta.org/positionstatement&psid=37

No Child Left Behind. (2006). Retrieved January 7, 2007, from http://www.ed.gov/policy/elsec/leg/esea02/index.html

O'Neil, D. (2005). *Process of socialization: How we acquire our cultures, world views, and personalities*. Retrieved March 13, 2006, from http://anthro.palomar.edu/social/default.htm

Orsak, G. (2003, May). Engineering's new frontier. *IEEE Transactions, 46*(2), 209-210.

Partington, G. (2001). *Qualitative research interviews: Identifying problems in technique*. Retrieved January 28, 2006, from http://education.curtin.edu.au/iier/iier11/partington.html

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage.

Phillips, W. (n.d.). *Engineering for a new renaissance*. Retrieved April 21, 2005, from http://www.studyoverseas.com/america/usaed/engren.htm

Piaget, J. (1954). *The construction of reality in the child*. New York: Basic Books.

Pintrich, P., & Schunk, D. (1996). *Motivation in education: Theory, research & applications*. Englewood Cliffs, NJ: Prentice-Hall.

Pisces TT. (2004). *Assessment of women achievers in aquaculture workshop*. Retrieved April 18, 2005, from http://www.piscestt.com/pisces/educational/aquaculturewomen workshop_en.asp?&printable

Rayman, P., & Brett, B. (1995). Women science majors: What makes a difference in persistence after graduation? *Journal of Higher Education, 66*(4), 388-414.

Reyes, L. H. (1984). Affective variables and mathematics education. *Elementary School Journal, 18*, 207-218.

Richards, L. (2004). *Supply of petroleum engineers dwindles*. Retrieved November 7, 2004, from http://houstonchronicle.com/

Rosenthal, R., & Jacobson, L. (1968). *Pygmalion in the classroom*. New York: Holt, Rinehart & Winston.

Rudestam, K. E., & Newton, R. R. (1992). *Surviving your dissertation: A comprehensive guide to content and process*. Newbury Park, CA: Sage.

Sadker, M., & Sadker, D. (1994). *Failing at fairness: How America's schools cheat girls*. New York: Charles Schribner's Sons.

Sadker, M., Sadker, D., & Klein, S. (1986). Abolishing misconceptions about sex equity in education. *Theory into Practice,* 25, 219-226.

Sadker, M., Sadker, D., & Klein, S. (1991). The issue of gender in elementary and secondary education *Review of Research in Education, 17*, 269-334.

Sanders, J. (1997). Teaching gender equity in teacher education. *Education Digest, 68*(3), 25-29.

Sandler, B. R. (1996, June). *Classroom climate revisited*. Paper presented at the 1996 Women in Engineering Program Advocates Network Conference, Denver, CO.

Sandler, B. R. (1999). *The chilly climate: Subtle ways in which women are often treated differently at work and in classrooms*. Retrieved December 31, 2006, from http://www.bernicesandler.com/id23.htm

Scalise, A., Besterfield-Sacre, M., Shuman, L., & Wolfe, H. (2000, October). *First term probation: Models for identifying high risk students*. Paper presented at the 30th ASEE/IEEE Frontiers in Education Conference, Kansas City, MO.

Schwartz, D. (2000). *Annual report*. Retrieved October 16, 2006, from http://www.microsoft .com/msft/ar.mspx

Seymour, E. (1992, February). The "problem iceberg" in science, mathematics, and engineering education: Students' explanation for high attrition rates. *Journal of College Science Teaching, 21*(4), 230-238.

Seymour, E., & Hewitt, N. (2000). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview.

Shamos, M. H. (1982). Science for everyone? (White paper) *New York University Quarterly*.

Shaw, G. B. (1916). *Pygmalion*. New York: Brentano.

Singer, J. M., & Stake, J. (1986). Mathematics and self-esteem: Implications for women's career choice. *Psychology of Womens Quarterly, 10*, 339-352.

Skaalvik, S., & Skaalvik, E. M. (2004). Gender differences in math and verbal self-concept, performance expectations, and motivation. *Sex Roles, 50*(3/4), 241-252.

Society of Women Engineers. (2001). *Statistics about women in engineering in the USA*. Retrieved August 8, 2004, from http://www.swe.org/SWE/ProgDEv/stat/earnbach_graph.html

Solomon, K. (1982). The masculine gender role: Description. In K. Solomon & N. B. Levy (Eds.), *Men in transition*. New York: Plenum.

Stake, R. (1995). *The art of case research*. Thousand Oaks, CA: Sage.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Thousand Oaks, CA: Sage.

Strenta, C., Elliott, R., Matier, M., Scott, J., & Adair, R. (1993). *Choosing and leaving science in highly selective institutions: General factors and the question of gender*. (Report to the Alfred P. Sloan Foundation). New York: Alfred P. Sloan Foundation.

Summers, L. H. (2005, January 14). *Remarks at NBER conference on diversifying the science & engineering workforce*. Retrieved April 7, 2005, from Harvard Web site: http://www.president.harvard.edu/speeches/2005/nber.html

Tellis, W. (1997, September). Application of a case study methodology. *The Qualitative Report, 3*(3). Retrieved September 9, 2004, from http://www.nova.edu/ssss/QR/QR3-3/tellis2.html

Thier, M. (with Daviss, B.). (2001). The new science literacy. Portsmouth, NH: Heinemann.

Tobias, S. (1978). *Overcoming math anxiety*. New York: Norton.

Tonso, K. (2003, November). *Designing gender equity into engineering and science cultures: Have we met the enemy and is he us*. Paper presented at Wayne State University, Detroit, MI.

U.S. Department of Education. (1997). *Twenty-five years of progress*. Retrieved from http://www.ed.gov/pubs/TitleIX/title.html

U.S. Department of Labor. (2005). *Occupational employment and wages for 1999*. Retrieved March, 17, 2005, from http://stats.bls.gov/oes/home.htm

Wagner College. (2005). Retrieved August 16, 2006, from www.wagner.edu/career/choice/ index.html

Weiner, B. (1986). *An attributional theory of motivation and emotion*. New York: Springer-Verlag.

Witt, S. D. (2000). The influence of television on children's gender role socialization. *Childhood Education, 76*(5), 322. Retrieved December 26, 2005, from Questia database: http://www.questia.com/PM.qst?a=o&d=5002353336

Women in Science and Engineering. (2005). Retrieved December 28, 2006, from http://www .engr.washington.edu/wise/about_statistics.htm

World Bank. (2005). *Engendering ICT toolkit: Challenges and opportunities for gender-equitable development*. Retrieved December 28, 2006, from http://web.worldbank .org/WBSITE/EXTERNAL/TOPICS/EXTGENDER/EXTICTTOOLKIT

Wulf, W. A. (1999). *Testimony to the commission on the advancement of women and minorities in science, engineering and technology development.* Committee on the diversity of the engineering workforce. Retrieved August 8, 2004, from http://www.nae.edu/NAE/na.nsf/ehome

Wulf, W. A., & Fisher, G. M. (2002, Spring). A makeover for engineering education: Today's engineering schools are not preparing their graduates as well as they might for useful practice in the 21st century. *Issues in Science and Technology, 18*, 35+. Retrieved December 26, 2005, from Questia database: http://www.questia.com/PM .qst?a=o&d=5000750796

Yin, R. K. (1984). *Case study research: Design and methods*. Newbury Park, CA: Sage.

Yin, R. K. (1993). *Case study research: Design and methods* (2nd ed.). Beverly Hills, CA: Sage.

Yin, R. K. (2003). *Applications of case study research* (3rd ed.). Thousand Oaks, CA: Sage.

APPENDIX A. QUESTIONNAIRE

The questionnaire will contain 17 questions consisting of both short and extended response questions, and Likert scale.

The items include:

Prior Science Experiences

1. How many years of math_______ and science ___________did you take in high school?
2. What science courses, if you remember, did you take in high school? Check all that apply.

Physics_____ Chemistry_____ Biology_____ Earth Science ______AP Biology _____

AP Chemistry ___AP Physics_______ AP Earth Science_____other________

3. Is there anyone in your family who is or was an engineer? 1. Yes 2. No

   Who?______
4. Did you have a role model for engineering other than a family member? 1. Yes 2. No

   Who?
5. Did you think that high school adequately prepared you for a degree choice in engineering? 1. Yes 2. No
6. If no, then in what way could high school have better prepared you for engineering? Please explain.

Campus Life

7. Please check off your year in college; Freshman___, Sophomore___, Junior ___ Senior ____Graduate student_____
8. Attracting more females into engineering is a national and industry concern. Are you aware that BEE is attracting more females than the other engineering disciplines? 1. Yes 2. No
9. What do you think the reason might be for this gender balance phenomenon at Cornell?
10. Have you experienced any bias or marginalization regarding engineering as a woman on or off campus? If yes, then please explain.
11. What kind of academic support is available for all engineering students at Cornell?

Why Choose BEE?

12. I chose BEE as a degree choice because: (check all that apply)

a. ☐Biology is interesting
b. ☐I find environmental science interesting
c. ☐I know it will be easy to get a job
d. ☐It's creative
e. ☐It's lucrative
f. ☐It's challenging
g. ☐I am good at math
h. ☐It benefits society
i. ☐It is easier than the other kinds of engineering
j. ☐I am good at biology
k. ☐It is less rigorous than some of the other programs in engineering
l. ☐The program offers a lot of career possibilities.
m. ☐I want to work with people more than I want to work with things. 1. Yes 2. No
n. ☐BEE has a large percentage of females already. 1. Yes 2. No
o. ☐I can enroll in the College of Ag & Life Science and do engineering for 3 years before transferring into the College of Engineering, 1. Yes 2. No
p. ☐other

13. Was biological or environmental engineering your first degree choice? If not, then what degree choice would you have chosen?

14. Where did you first learn about biological and environmental engineering?

15. Is BEE considered a girl's engineering?

1. ☐strongly disagree, 2. ☐disagree, 3. ☐neither, 4. ☐agree 5. strongly agree

16. Tell me something about BEE that would help me to better understand the department.

Learning Styles Preferences:

17. Please number the following instructional formats by preference. One represents the most favored. Lecture Group work Labs Problem solving/application

I would be interested in participating in an interview. Please provide contact information.

APPENDIX B. INTERVIEW QUESTIONS

1. Why did you agree to be interviewed?
2. Have you experienced any marginalization on or off campus?
3. Is BEE considered fake engineering?
4. Do you think that it is true?
5. How do you learn best?
6. What is your favorite class and why?
7. Why did you decide on Biological and Environmental Engineering?

Explain. Thank you for agreeing to participate in the audio interviews concerning women in engineering. Your identities will not be revealed and I will be the only one who will be aware of them. Your input will be used solely for the purpose of understanding why BEE has been a choice of women.

APPENDIX C. OBSERVATION CHECKLIST

1. What is the name of the course and where does it belong in the engineering sequence?

2. What is the seating arrangement of the room (rows, tables, etc.)?

3. What instructional strategies does the instructor use provide access to knowledge?

4. If lecturing, what other kinds of instructional support does the instructor use?

5. If working in groups, how were the groups determined? Who is working with whom? What are the interactions within the team that is collaborating?

APPENDIX D. ABET LEARNING OUTCOMES

1. A: an ability to apply knowledge of mathematics, science, and engineering.

2. B: an ability to design and conduct experiments, as well as to analyze and interpret data

3. C: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

4. D: an ability to function on multidisciplinary teams

5. E: an ability to identify, formulate, and solve engineering problems

6. F: an understanding of professional and ethical responsibility

7. G: an ability to communicate effectively

8. H: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

9. I: a recognition of the need for, and an ability to engage in life-long learning

10. J: a knowledge of contemporary issues

11. K: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

APPENDIX E. RESPONSES TO QUESTION 6: DID HIGH SCHOOL ADEQUATELY PREPARE YOU FOR THIS DEGREE CHOICE IN ENGINEERING?

1. It did and it didn't. I think I took a lot of challenging courses in high school, but the AP classes were still nowhere near as hard as they are in college. I think more challenging problem solving techniques could have been given.

2. AP science courses were not offered when I was in high school. Additionally, because I was heavy into the performing arts and spent my first year in college as a theatre major, no one really considered a science background relevant to my overall education so I had to go about taking those classes myself. I was often discouraged from attempting to incorporate more science and math courses than was required for graduation into my high school education by both my parents and school administration. The greatest influence I had was from teachers in high school who did consider their science or math courses relevant to any student in any discipline. This kept the door open for me when it came to considering a new major when I made the switch in college from theatre to engineering.

3. Yes and no. I felt a little behind the rest of the students are Cornell but after a year or so I caught up. I feel that public high schools dumb down the material and do not challenge students (at least I felt that way about my high school).

4. Better foundation of calculus.

5. a tougher math and science training, as well as classese that actually exposes students to engineering and what they do.

6. It prepared me for engineering but maybe not quite Cornell Engineering :) Problem solving skills are so essential, as is calculus. I could've used more applied Math in high school, to better understand how imporatnt it would be once I got into engineering. I was well prepared with problem solving though, and I did a lot of practical engineering application in my technology classes (which almost no girls take).

7. A lot of the work I did and was instructed to do was on a very basic level. Critical and abstract thought processes were not encouraged as much as they could possibly have been.

8. I did not have a very strong background in chemistry and physics because in order to take science at my high school one had to waste 2 years in sort of introductory sciences classes that gave a sampling of chemistry, physics, biology--and it was impossible to learn any one concept in any one area proficiently until the upper level courses.

9. If I hadn't been in AP classes I never would have survived at Cornell.

10. My school has a horrible chemistry and physics department. Old and confused, I remember my chem. teacher telling me that hydrogen is a metal. In physics we were told not to take the physics regents if we didn't' need to mainly because our teacher knew he hadn't taught us enough to pass it. It was hard freshman year to compete with kids that have taken AP physics in introductory classes.

11. Although, I do believe that I could have used more science APs at my school (I believe that size was an issue).

12. The amount of work, the intesity, the speed of the course. Most importantly time constraints on exams, for me that is the hardest part of my engineering studies.

13. In high school i didn't understand exactly what engineering was and the sheer expanse of the field. I only thought of engineers in the traditional sense (bridge builders, etc.).

14. I didn't take any special tech or engineering geared courses because my father feared the teachers would have the old mind set that women were not fit for sciences. He thought this might discourage me from engineering before I really got a chance to study it.

15. My high school's honors classes were mostly girls, most of whom had no interest at all in math or science, so those programs were weak or there was enough of a fuss made by those girls that no one learned much in those classes.

16. It prepared me for engineering but maybe not quite Cornell Engineering :) Problem solving skills are so essential, as is calculus. I could've used more applied Math in high school, to better understand how imporatnt it would be once I got into engineering. I was well prepared with problem solving though, and I did a lot of practical engineering application in my technology classes (which almost no girls take).

APPENDIX F. RESPONSES TO QUESTION 9: WHAT DO YOU THINK THE REASON MIGHT BE FOR GENDER BALANCE PHENOMENON AT CORNELL?

1. I think because BEE has a lot to do with health concerns. Because females in general have more of a concerns about helping people.

2. Inclusion of the biological sciences in the engineering degree. Fields like biology and chemistry have see more female involvement that the math and physics departments. These subjects make the bee department more accessible to females than other engineering department. Additionally seems that more women are in the health care field than are in engineering so this facet of biological engineering makes it easier for women to access the department.

3. I think biology in general attracts more females, and when compared to the other engineering majors it is considered the easiest engineering major.

4. I think the biological sciences for some reason have always seemed easier for women to excel in compared to physical science like physics. I don't know if it is something to do with spatial orientation or natural mechanical ability but I have found that for myself it was always hare in physical sciences. Biological science has always made more sense to me and I have been able to excel in them.

5. I think part of it has to do with ties to the medical community, since many females are interested in medical careers. I'm interested in environmental engineering, however, though many women are also interested in the environment.

6. Females tend to care for the others, which is BEE feature.

7. I think females are more interested in social/environmental issues. Other engineering fields are not as directly linked to these issues.

8. It might be the stereotype that females are not "math and physics people" that discourage females from entering the more traditional fields of engineering. BEE is attractive to potential females engineers because it does not involve as much math and physics than the other engineering fields. Also, females may be intimidated by fields that are traditionally dominated by males, so many females tend to avoid them (i.e., computer engineering).

9. For some reason the subject of biology is more attractive to females. In majors such as ME you will find less girls.

10. Because BEE requires less mathematical skills.

11. I originally began as a mechanical engineering major. However, I found that sitting in a metals' shop with guys talking about cars quickly list its appeal. I think many women in engineering find the intro courses to BEE much more gender-friendly, courses such as Bio 101/102, orgo, thermo, chem . . . as opposed to some of the more male-dominated intro courses in computer science, mechanical engineering and civil.

12. Closely related to biology, which is a subject that most females excel in.

13. I think 1.) Females are attracted to the human/quality of life aspects f this major and 2.) BEE does a better job than other engineering disciplines of explaining how this major benefits society and people. There is an emotional aspect to BEE that other major don't have. A lot of girls tend to like biology more than physics or other sciences as well.

14. BEE is not a traditional engineering field; maybe more women are drawn to it because they are interested in biology, as opposed to civil engineering, chemE, ECE, MAE, etc.

15. I'm really not sure what the reason is, but it may have something to do with wanting to help. I think sometimes the helpful impacts of biological engineering are more easily seen than in some other engineering disciplines.

16. The nature of biological engineering may be more appealing to women than designing brides and writing computer programs, women can actually directly impact people and the environment around them through BEE.

17. BEE is great because it easily allows students the opportunity to be premed and engineering; unlike other engineering majors where this is more difficult .It also attracts more females due to their interest in biology, chemistry and health (life sciences) rather than mechanical systems. This may also be seen in the fact that the only engineering major to have a 50/50 ratio is chemical engineering.

18. I don't think it's just BEE, I think Chem. E., operation research and civil engineering have quite a bit of women as well. It's only the computer and physics based on engineering principles that have a huge discrepancy and I think that's mostly because it's really helpful to have an in-depth knowledge of those subjects before the undergraduate experience starts.

19. Maybe women want to be engineers but because they lack the confidence, they go into an engineering field that they feel will be not as rigorous in the 'hard sciences' and therefore, more manageable.

20. To be honest, I think women choose biological engineering because it is les of a pure engineering field. The emphasis on biology and medical application means that a lot of the classes are non-engineering-based. It I still scientific and challenging, its just not as isolated as the rest of engineering.

21. BEE is represented as a hard-core engineering discipline at Cornell. However, the way in which they portray BEE is more female friendly because it is a major that leads to many different career paths as well as the ability to directly interact with people.

22. Interest biology yet also interested in problem solving.

23. BEE is multidisciplinary and probably tends to attract girls interested in the biology, a more traditional girls' major.

24. I think the BEE attracts women because it can be a path into the medical sciences. There is still the feeling that BEE is not "true" or "hard-core" engineering.

25. I guess it's the subject itself that is attracting both male and female students.

26. Admissions possibly. I have not really thought about it that much. There are a significant number of females in my classes. Yes, we are outnumbered but I am not sure if it's a direct cause of anymore more than societal change. More and more women are becoming more interested in engineering so, out number will grow.

27. Perhaps the field application of the material. For me, the only reason that I initially chose any type of engineering discipline was because it was one of the major options in CALS. I think that because it is available as an engineering option in the SUNY school made it more available for more people in general, at least NYState residents. Statistically, an increase in students would also lead to an increase in females.

28. Biological engineering to me seems to combine the let and right side of the brain well. Problem solving and math are important, but it is also important to learn about the body. I feel like biological engineering is a good balance and I think that is why many females choose it.

29. Biological engineering isn't a typical engineering, AKA, AE, or ECE major. Everyone takes biology in HS, but no one takes mechanics or dynamic. I am female, and I picked it because it was familiar. I had many math and bio classes in HS. From being in BEE, I learned about the other engineering majors I never knew anything about, and found them interesting. I wish I knew more about them before cause I may have chosen that instead of BEE. It is too late to transfer, but I'm planning on majoring in MAE (mechanical and aerospace engineering).

30. I think that it is the subject matter that attracts women to bio. And env. eng. Why more women are attracted to bio and env. Issues (arguable more social issues than many other eng. Fields . . . there are many possible reasons. Additionally, women are not "trained' to work with computers, play with blocks etc. so maybe this affects choice on a subconscious level.

31. Without getting too political, I think we live in a fairly liberal state (NY that is). Women's rights and equality are emphasized more than it is in other parts of the country.

32. First pf all BEE attracts a lot of premed students which means more women also BEE is based on a life science, biology, rather than other engineering disciplines which are based in chemistry or physics. I think that in general biology is thought o be the type of science that women are best in) because it is more memorization etc, rather than logical thinking) so naturally an engineering based on biology would attract the most women.

33. I have no idea.

34. It does not have the reputation for being as hard of an engineering program as the others.

35. BEE is interdisciplinary, so students can choose their focus based on interests within the field. It is also closely related to problems people see in the world, such as pollution, or medical issues so; it seems to apply directly to life.

36. Many people in BEE are pursuing fields in medicine etc. I think that the prevalence of women in BEE therefore can be linked to more women entering the world of medicine. Many in BEE see it as the "softest" engineering fields.

37. In general, there seems to be more females interested in biology than males. I think the blend of engineering with biology appeals to many females who have a strong interest in math, but also want to pursue their interests in biology.

38. I really can't say why. It's possible that the BEE major is seen as being closer to biology and less math intensive than, say civil engineering.

39. Females are generally more interested in biology than areas such as physics and computer science.

40. Biological and environmental engineering is an interdisciplinary field of study and also there are opportunities to focus on areas that are of particular interest to each particular person. In addition, since BEE is part of CALS, it is less expensive than the engineering school for people in New York State.

41. Girls are more interested in biology because it relates to medicine and that field is already accepting of females.

42. I just think that more women are interested in biology and [an] environmental aspect. Mechanical engineering and other engineering are not interests that more girls grow up with.

43. Cornell goes to great lengths to ensure that females are treated equally in the engineering disciplines. Cornell also provides a variety of resources for female engineers.

44. Cornell has one of the best SWE programs in the country (I am not a member), also they push hard to recruit women into engineering; more than other schools at least.

45. [BLANK]

46. A higher proportion of girls may prefer biology better than physics? The biological engineering major is also not associated with any male stereotype such as the case with mechanical engineering.

47. Because females are underestimated in the filed and I believe Cornell is helping out the females that are undermined.

48. Less intimidating environment and material than other engineering disciplines. Girls seem to be far more interested in biological systems than in engineering, buildings, etc.

APPENDIX G. RESPONSES TO QUESTION 10: HAVE YOU EXPERIENCED ANY BIAS FOR MARGINALIZATION REGARDING ENGINEERING AS A WOMAN ON OR OFF CAMPUS?

1. One time in my mechanics of solids class, they put all the females together because they wanted to make sure that males did not dominate the group. I thought this was awful.

2. A professor I have now in the BEE department refers to all females as "Ms." while using the first names of his male students. He refers to groups of women as "ladies" frequently while not using the same language for groups of men. Normally I wouldn't perk at these inconsistencies, but he also treats his female students as if math is much more difficult for them and he seems surprised when they have relevant, insightful criticisms and correct mathematical assessments for given case studies. He has also discussed an example in which an industry task was solely appropriate for women (specifically the reproduction methods used on dairy farms). In other departments I have typically been assigned to all female groups by male TAs and LAs. The general treatment women receive in these departmens indicates that women are not as good at math and the engineering sciences in general, and that we need to be treated with great sensitivity because we could erupt emotionally at any time.

3. I have been treated as dumb by some of my teaching assistants and professors throughout my college experience. It may be perhaps because I did not excel as much in mechanically oriented classes that were still part of the engineering curriculum. I have to say I did worse in these types of classes as opposed to biologically applied engineering classes. I have felt biased just by classmates too. Oftentimes male classmates treat female ones like they are inadequate. I remember I had a TA once who only would put females with females in lab groups because he said when females were put with males the males would take over and not let the females do the work. In same sense I think he is right, because I have experienced it myself, but not in all cases is this applicable.

4. I had a math professor who was surprised to see me, a woman, doing well in his class and he thought, initially that I had been cheating.

5. Sometimes when I ask a male student for help on a problem he immediately explains it in an almost child like manner, as if I, possibly due to me being female, would not understand it any other way.

6. Society tends to have a negative image of female engineers. Female engineers are stereotyped to be masculine and unattractive, antisocial, among many other things.

7. I find that I often have a difficult time working with male TAs and some male professors. I have often had questions blown off in class or been treated as though I would not understand what is being explained. For example today I worked on a group project with a male partner in my group. We needed help from the TA. The TA sat with us and said nothing to me and explained all of the project to my partner.. even going so far as to turn his back on me. I often have people tell me I don't look like an "engineer" or that I should be in hotel school… such comments only promote the kind of treatment I receive in class as an engineer. There is a very solid stereotype on campus that students use to define an engineer…. it is difficult to even work on a group project when your fellow engineers have already labeled you as a "ditsy sorority girl."

8. In high school I was definitely doubted, that lessened in college but I have still felt on certain occasions in classes or groups that I wasn't quite as good as a male, just because I was female. I've never really had direct comments made to me or any serious incidents, I've had the feeling though. I have been pretty well respected in industry as a female, I think people are beginning to realize that they need to get used to it. I do, however, still feel like I'm always proving myself to some extent.

9. I feel people assume I am stupid or less intelligent because I am a white female.

10. I was given a spot in an engineering camp over my junoir year for minorities in engineering since I was female. Besides that I strive to be equal.

11. In some situations as an engineering female you are favored as companies strive at accomlish gender balance.

12. It is impossible to find a bathroom or they are located in inconvenient areas in many of the buildings in the engineering quad.

13. There are professors that treat female students different than the males. They have lower expectations etc.

14. I think it raised a few eyebrows in high school when I told people my intended major. Also, when applying to college, I wanted to get accepted on merit-- not just to improve the gender ratio.

15. I've had several of my guy engineer friends tell me I should consider a major in another field when I did poorly on an exam and I've had professors question my abilities.

16. My TA for Chemistry 211 was a male chauvinist, who picked on the two girls in the class.

17. Surprise, but other than that nothing serious.

18. A lot of older (male) professors don't take you very seriously, especially when you come to them to ask questions on coursework.

APPENDIX H. RESPONSES TO QUESTION 11:
WHAT KIND OF ACADEMIC SUPPORT IS AVAILABLE?

1. There is a ton. Cornell offers Academic Excellence Workshops which are free and serve as an additional tool to learn more problems to prepare you better you're your tests. Also they have free tutoring service. Also Diversity Programs in Engineering, which serves all minorities and women, serve as a resource to answer any questions you might have or they also provide a lot of workshops. Also TAs are more than willing to answer your questions.

2. There is a diversity office for the school of engineering that shows great support for minorities and women, but it is usually the minority women they are most concerned with instead of women in general. SWE seems more concerned with networking and club meetings than with establishing women as a normal presence among engineering students.

3. Tons. From peer tutoring to office hours to Academic Excellence Workshops.

4. There are Web sites that post lecture material, there are office hours for teaching assistants, and other students and textbooks.

5. Free tutoring, academic workshops, office hours.

6. Office Hour, TA, Review session, Tutor.

7. Warm professors willing to help. I love the BEE.

8. Professors and TAs provide office hours. There are Academic Excellence Workshops for certain classes. Peer tutoring is also offered.

9. lots of places to go for help. Peer tutors, TAs office hours Academic excielence workshops.

10. We can join SWE and diversity group. Also, other resources and advisors are available.

11. The academic support lies mainly in extra help classes that are available, advisors and engineering advising dept. I find there is plenty of support on campus and no excuse to fall behind.

12. Office hours, Acedemic Excellence workshops, peer tutoring.

13. Peer tutoring and academic workshops, the advising department is wonderful! Although I tried to get tutors on different occasions for different classes during my freshman and sophomore years, I never had much luck with it. The peer tutors were there and available but sometimes not "good enough" for my needs, nonpeer tutors were tough to find (one exception, an advisor set me up with a professor who tutored me in calculus over winter break, Freshman year. A huge favor on his part but a very helpful experience for me).

14. Tutoring, career advice, etc.

15. All of my professors, TA's, and friends have been incredibly helpful and supportive. It's definitely competitive, but not to the degree which I originally feared. You can always find someone to help you, or to refer you to someone else for better assistance. The AEW classes are also an excellent resource.

16. Engineering office, advisors, peer advisors, tutoring, additional office hours- all things that need to be sought out by the student.

17. Engineering Advising Office, AEW Courses, Tutoring, and Faculty Advisors.

18. Advising, and SWE (Society of Women Engineers), Diversity Programs Office (DPE).

19. The resources are incredible. Tons of teaching assistant office hours, professor office hours, extra review sessions, extra review classes, tutoring.

20. Advising and interest groups that provide support. Tutoring.

21. nything you need, there is someone to talk to, whether it be your advisor, academic advisors, faculty, staff, student mentors, there are tutoring programs and academic excellence workshops. Really if you need help all you.

22. Advising, tutoring, career advice, campus groups (SWE,SHPE, etc.), Professors, TAs, forming student study groups.

23. Review sessions and 00 classes help a lot for review. TAs are able to explain concepts at a level more thourough than the professors have time for.

24. There are tutoring services and 001 classes. All women engineers are given free tutoring services if they want.

25. Many support centers in the College of Engineering.

26. Tons, if people know about it. Office hours, very helpful professors and then the workshops for each class or a majority of the them. Also, there are all the different groups within each major/group (i.e., IBE, CAPES, SWE, etc.).

27. Math and Physics learning centers, availible faculty and TAs.

28. All professors and TA's have office hours available for extra help. You can sign up for Academic Excellence Workshops to get extra practice too.no resonseno to fall behind.

29. I don't know. But I know they have SWE club here, however I am not apart of it so I don't know what they do.

30. I think the primary mode of overall support is your academic advisor. Additionally peer teaching assistants are very helpful on a class basis.

31. Office hours, various clubs (SWE), befriending other engineers to do homework and to study together.

32. I am not really sure as I have not sought it out.

33. You you're your advisors to talk to as well as professors and peers. There are also special offices open for guidance like the career services office.

34. Tutoring.

35. Advising, cooperative workshops, tutoring.

36. Tutoring, Office hours, counseling.

37. Office hours.

38. Advising, tutoring, libraries with a lot of resources.

39. Engineering learning initiatives.

40. There is career support and academic advising. The faculty are all also doing research so there are opportunities to work in a lab.

41. Academic excellence workshop classes for undergrads, advising, etc.

42. AEW (Academic Excellence Workshops), SWE (Society of Women Engineers), and a tutoring system.

43. [BLANK]

44. [BLANK]

45. Office hours, tutoring.

46. There isn't a direct support line, but it is known that Cornell is trying very hard to diversify their engineering.

47. Office hours, tutoring, societies (SWE. DPE, etc.).

APPENDIX I. RESPONSES TO QUESTION 13:
WAS BIOLGOCIAL AND ENVIRONMENTAL ENGINEERING YOUR FIRST CHOICE?

1. I started in mechanical engineering.

2. Chemical Engineer.

3. Mechanical.

4. Chemical engineering.

5. I started in Materials Science but realized it wasn't going to be the right fit for me, it wasn't what I had expected. BEE was my next choice, I just didn't know that until I got here!

6. I started in ChemE and MSE but realized it was going to be way to hard to be premed in those majors.

7. Naval architecture.

8. I was mistakenly given a BEE advisor freshman year. When I decided not to be a mechE last year I had wanted to change my major to English and my advisor convinced me to try BEE.

9. I would not have chosen an engineering degree.

10. I am in the new Environmental Engineering major, which is a joint program with BEE and CEE.

11. Biomedical Engineering (only offered as minor).

12. But I think I might switch to environmental.

APPENDIX J. RESPONSES TO QUESTION 14: WHERE DID YOU FIRST LEARN ABOUT BIOLOGICAL AND ENVIRONMENTAL ENGINEERING?

1. From my own exploration and research of the various fields in engineering after I decided I didn't want to be a theatre major anymore.

2. Cornell.

3. My junior year of high school.

4. Cornell.

5. Cornell BEE Web site.

6. [BLANK]

7. Cornell list of majors.

8. While considering colleges to attend.

9. [BLANK]

10. Application.

11. My advisor.

12. CURIE program sponsored by Cornell SWE (The CURIE Academy is a 1-week residential program for high school girls who excel in math and science and want to learn more about careers in engineering).

13. I had heard of it before college but really learned about it after arriving at Cornell, my advisor got me really interested and helped me facilitate my "move" from Materials to BEE.

14. Looking through all the potential majors in the Ag school.

15. Cornell University information booklet.

16. High school- junior year, when looking at colleges and majors.

17. College application process.

18. Campus pamphlet.

19. Cornell's Web site when I was looking at colleges.

20. During my freshman year here at Cornell I met others who were BEE majors.

21. Duke University Program.

22. Cornell University brochure.

23. From Cornell.

24. Through my biotech class in high school.

25. In my high school AP Physics class.

26. When I was applying to Cornell.

27. The list of major options provided by CALS (College of Agriculture and Life Sciences).

28. Cornell Summer College.

29. I came in as a Biometry and Statistics major and then leanred about BEE my freshman year. I knew I wanted to switch out of stats but I wasn't sure if I wanted to do BEE until end of freshman year. I really never thought about being an engineering until I came to Cornell.

30. Internet, this program was why I applied to Cornell.

31. I was originally interested in environmental policy but thought engineering would make a greater impact.

32. Cornell Big Red Book or wesite I think.

33. Engineering; I first learned about at Northwestern, I think BEE, I learned about from the Cornell handbook.

34. My brother.

35. College brochures.

36. Interest in genetics.

37. Cornell's Web site containing descriptions about majors.

38. I took a BEE elective in my sophomore year.

39. Cornell Handbook received in mail.

40. At home.

41. Don't remember.

42. From my biology teacher.

43. At WPI, during a "Girls in Engineering, Math and Sciences" workshop that I attended during the summer between my junior and senior year of high school.

44. Searching through Cornell's engineering major listing when I was first thinking of applying.

45. Web site.

46. High school biology course.

47. As a freshman at Cornell, originally a bio major.

Students heard about bio/environmental engineering from a variety of sources, including: special outreach programs (CURIE, WPI), the Internet, a family member, a teacher, from taking summer courses and electives, college brochures, during the application process.

APPENDIX K. RESPONSES TO QUESTION 16: TELL ME SOMETHING ABOUT BEE THAT WOULD HELP ME TO BETTER UNDERSTAND THE DEPARTMENT

1. I really enjoy my classmates in BEE as opposed to other majors.

2. It's a warm department that keeps a global outlook tangible in its environmental classes. Cornell has one of the best environmental engineering programs in the nation, and that's why I transferred into this department in particular.

3. I really can't even pinpoint the general criteria the department is trying to teach us. There is the environmental side which is very clear cut towards becoming an Environmental Engineer but then there is the other biological side.

4. The department is very laid-back. It is not as stringent as other departments I guess. Since the field is so new, a lot of the classes don't even have texts because the professors just make their own course packets.

5. It integrates the life sciences with design tactics normally used in traditional engineering disciplines.

6. The department is very diverse, with courses that are focused on biological theories, to courses that are very practical and apply the theories. There is also a wide range of topics, from aquaculture to biosensors.

7. [BLANK]

8. BEE offers a lot of class so people with different interest can enjoy the classes.

9. The department on the whole is EXTREMELY laid back. Professors are very very supportive of students and I have enjoyed working with them much more so than working with professors of other departments.

10. The BEE department (this question) has outstanding faculty, at least as far as I have become involved thus far. All of my BEE professors, and my advisor, have been more than willing to offer me extra help, and meet with me whenever I needed to, in order to address issues or problems I was having. I'm not familiar with other departments on campus, or even at other schools, but I know the degree of involvement and care shown by the faculty sets BEE apart from preconceived notions I had about collegiate faculty.

11. The professors are friendly and approachable, it feels less cut-throat than other majors and more like a home than an unfriendly and emotion-less workplace.

12. Small enough that very few people slip through the cracks; professors are genuinely involved with students on an academic and nonacademic level.

13. It is a very old department, which was originally entitled ABEN, and knowledgeable faculty. However, the curriculum and faculty will have to modify and update itself to compete with students interests in biomedical engineering and retain students who might be compelled to go to Chemical engineering.

14. It's slightly more flexible than other engineering disciplines in terms of coursework. But not much more flexible.

15. The professors are very helpful and friendly. I don't know what to say about the curriculum—I've just been basically filling engineering requirements so far.

16. BEE is a hugely diverse program that integrates the principles learned in the engineering dicipline with the skills needed to help our society and people in our society.

17. It is unlike biomedical engineering, which is what I would have preferred to focus on since I am interested in medicine and medical devices, but is instead a general course of study that integrates biological principles and engineering problem solving so that solutions for environmental and biological problems can be solved. We are introduced to a wide variety of applications, but not focused entirely on one specific aspect.

18. Something you learn while you are here is that BEE still has a lot of holdover from the agricultural engineering days so that you have to be careful whether the classes you take really apply to what you want to learn. I think many of the students are going out to the biomed minor to get more rigorous engineering courses. A lot of the M&AE classes are very appropriate for BEE students.

19. The Environmental Engineering major is not accredited yet.

20. It's not some wishy-washy easy engineering major (most other engineers don't realize what it is about it so they tend to overwrite it). BEE is a great major with very interesting applications and focused on learning. It is also very neutral. (I have not a clue what makes people think that is "female-friendly."

21. It integrates biology with problem solving skills.

22. BEE combines design and problem solving in a way that truly benefits people. It is the perfect combination of my interest in helping people through medicine and my interests in problem solving and mathematics and science.

23. I feel that students who are premed tend to be female (or maybe i know more female premeds?) and since BEE has requirements that allow students to be fulfill premed requirements, there are more premeds in BEE then other engineering majors. And since more premeds are female, there are more females in BEE. Also again, every female has taken bio or chemistry (i feel there are a lot of females that are cheme too) so BEE is a more familiar area than electrical engineering.

24. I think of the department as being segregated between the biological and environmental side. There are many integrated ideas, but there are two obvious and very separate tracks that students can take during their undergraduate career. Environmental engineering is inherently biological and visa versa, but biomedical engineering is very different from watershed engineering.

25. It seems that all freshman engineers are taking roughly the same intro courses regardless of specific major, so I'm not sure yet.

26. As an environmental engineer I don't identify too closely with the BEE department, I almost identify equally with the CEE department as many of my classes have been in CEE.

27. There are lots of different people in different areas covering a vast arrangement of topics.

28. Even though BEE is one department, students can either major in biological engineering or environmental engineering. Students cannot receive a degree in biological and environmental engineering, as the department's name would imply. To get a diploma in biological and environmental engineering would require double majoring.

29. BEE is sort of two departments in one—biological and environmental engineering. That’s really good for somene who can’t decide which they like more for a while.

30. No one I have talked to is very clear about what Environmental Engineering is, because it is a relatively new field, and there are so many different directions that it can take.

31. The department is wonderful. All the professors are great and supportive. The major is rigorous, but managible. I absolutly love the department in general.

32. It is a department filled with caring faculty, who essentially make the department feel more like a family more than anything else.

33. [BLANK]

34. Most BEE students have more interest in biomedical than bioenvironmental fields.

APPENDIX L. CLASSROOM VISITS

Course Descriptions of Classroom Visited

BEE 222: Living systems rely on chemical and phase equilibria, precise coordination of biochemical pathways, and the release of chemical energy as heat, all of which are governed by the laws of thermodynamics and the rates of chemical reactions. The course covers concepts and laws of thermodynamics as applied to phase transformations, work, heat, and chemical reactions; and reaction kinetics applied to industrial processes and living systems, all with a focus on biological examples.

BEE 110: Principles and practices beyond the scope of BEE 110. Includes out-of-position, high- carbon steel and cast iron welding. Topics such as soldering and brazing of aluminum, hard surfacing, both tungsten (TIG) and metallic (MIG) inert gas welding, and plasma-arc and oxy cutting of metals. Planning, development, and fabrication of a metal construction project is required for the 2-credit option.

BEE 453: Introduction to simulation-based design as an alternative to prototype-based design; analysis and optimization of complex real-life processes using industry-standard physics-based computational software on a supercomputer or on high-end personal computers. Covers biomedical heat and mass transfer processes, including cryosurgery, hyperthermia treatment, laser eye surgery, detection of breast cancer, and drug delivery. Computational topics introduce the finite-element method, pre- and postprocessing, and pitfalls of using computational software. Students choose their own term project, which is the major component of the course (no final exam).

BEE 435: In-depth treatment of the principles of aquacultural engineering: mass balances, waste-treatment system design, gas conditioning, production economics, and fish processing. Presents nutrition and fish health in the context of global and local demand. Builds upon previous biology and engineering course work and emphasizes fish-production system design. Includes hands-on experiences and field trips.

BEE 401: Introduces energy systems with emphasis on quantifying costs and designing renewable energy systems to convert environmental inputs into useful forms of energy. Covers solar energy, small-scale hydropower, wind, bio-conversion processes, house energy balances. Focuses on the technologies and small-scale system design, not policy issues. Use of spreadsheets is extensive.

BEE 489: Focuses on engineering entrepreneurship, economics, management, and professional ethics. Covers prediction/probability of net returns; financial calculations (internal rate of return, time value of money, pro forma statements); legal structures of businesses; project management; developing an awareness of issues related to professional ethics; and technical writing and communication. Group project required to produce a business plan for a technology-driven concept suitable for a venture fair audience.