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WOMEN IN ENGINEERING: THE GENDERED EFFECTS OF PROGRAM CHANGES, FACULTY ACTIVITIES, AND STUDENT EXPERIENCES ON LEARNING

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Abstract

Creating gender equity in engineering education is important for more reasons than simply being a matter of social justice or diversifying the engineering field. It is also a significant educational and public policy issue that will affect the future economic competitiveness of the United States in the global marketplace. Engineering is arguably the leading national example of a profession in which women are under-represented. Undergraduate engineering programs not only need to attract and retain female students, but they must also provide full access to the educational experiences women must have to develop the engineering skills to succeed in the engineering profession.

This study explored whether the shift to the "soft" or less technical skills in engineering encouraged by new accreditation standards could potentially have had differential effects for women in engineering from their male counterparts. In particular, this study examined the proposition that program practices and policies, faculty members' activities, and the experiences of engineering students in college, affect the learning of female students differently than that of male students. The three engineering skills chosen for this study were students' development of design skills, group skills, and awareness of societal and global issues. Data for this study came from a nationally representative sample of engineering program graduates who received their degrees in 1994 (n = 5,335) and 2004 (n = 4,158), 1,243 faculty, and 147 program chairs at 39 different institutions. This study relied on secondary analysis of data from the *Engineering Change* study, which assessed changes in student learning associated with the implementation of the new *Engineering Criteria 2000* (EC2000) accreditation standards.

The findings from the current study shed light on the complexity of the processes at work in female and male students' learning and the importance of creating models that can guide

research on both male and female students' development and change while in college. Changes in program and faculty activities affected both students' experiences and their learning, and those effects differed by gender. This study also revealed that students' in- and out-of-class experiences differed significantly in their influence on female and male students' development of selected engineering abilities. For learning that occurs in engineering programs, and perhaps many other professional and academic fields, gender seems to moderate the effects of programmatic and faculty activities, as well as the influences of students' undergraduate experiences.

It is important for faculty and administrators to understand the differences in learning by women and men in order to identify the best ways to produce female graduates with the skills needed in the workplace (Baxter Magolda, 1992). More needs to be done in engineering education than just helping women to adapt to a traditionally masculine field (Salminen-Karlsson, 2002). Responding to individual students' needs at each level of learning can strengthen the overall educational experience in and outside of the classroom (Baxter Magolda, 1992). After identifying gender patterns in development and learning, the significant differences reveal that males and females may need different challenges and support systems to ensure their future skill levels. In particular, faculty members can stress applied skills to positively affect female students' abilities to problem-solve and design solutions, and also use active learning pedagogies in their classes to encourage female students to develop their group skills. In addition, out-of-class experiences seem to be more influential on female students' development of all three learning outcomes than male students' development of those same skills. Thus, engineering programs and faculty members could encourage to get involved in activities outside of the classroom, such as studying abroad and involvement in professional society chapters.

Conversations about national policies shaping student learning in higher education are likely to suffer when researchers and policy makers discount comprehensive research designs and ignore the role of gender in student learning. National policy probably should not overlook differences in the pathways to learning for male and female students. The desire to find the silver bullet that will enhance learning for all students narrows, rather than enriches, actions and policies. If academic and policy decision-making ignores gender differences in students' experiences and learning outcomes, a true transformation of male-dominated fields will never occur and women's experiences and levels of learning will not reach their ultimate potential.

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Chapter 1

Introduction

Women leave the engineering field at nearly twice the rate of men (Bix, 2004; Kardash & Wallace, 2001; Michel, 1988). In addition, the problem of undergraduate women's persistence in engineering is particularly troubling because women enroll in engineering at a lower rate than in other fields. In 2002, only 1.6 percent of women who earned degrees at four-year institutions received their degrees in engineering compared to 8.6 percent of men, and women compose only 20 percent of all engineering degree graduates (National Science Foundation, 2006). Even those women who successfully graduate with engineering degrees are twice as likely as male graduates to be unemployed (Iversen & Douglas, 2004).

In addition to the lower rate of female educational attainment in engineering, disagreement has existed in the literature over the past few decades about whether a gender gap between male and female students' academic achievement still exists among engineering students. Several single-institution studies (Bannerot, 2006; Greenfield, 1982; Marra, Palmer, & Litzinger, 2000; Mbarika, Sankar, & Raju, 2003; Orabi, 2007; Whigham, 1988) and one multi-institution study (Takahira, Goodings, & Byrnes, 1998) found no significant difference in the academic performances of male and female students. In contrast, according to Felder, Felder, Mauney, Hamrin, and Dietz (1995), women on average enter college with stronger credentials than men and by the end of their college career have grades that are significantly lower than those of males.

Several studies that considered grades and individual skills needed to be an engineer, however, discovered gender differences (Bannerot, 2006; Felder, Felder, Mauney, Hamrin, & Dietz, 1995; Felder, Felder, & Dietz, 2002; French, Immekus, & Oakes, 2005; Haines, Wallace,

& Cannon, 2001; Hecht et al., 1995; Kaufman, Felder, & Fuller, 2000; Kilgore et al., 2007; Knight et al., 2002; Peters, Chisholm, & Laeng, 1995; Sax, 1994; Sax & Harper, in press). The majority of these studies found that male students had higher grades and more developed engineering skills than their female counterparts (Felder et al., 1995; Felder, Felder, & Dietz, 2002; Haines, Wallace, & Cannon, 2001; Kaufman, Felder, & Fuller, 2000; Knight et al., 2002; Peters, Chisholm, & Laeng, 1995; Sax, 1994; Sax & Harper, in press). Five studies found that female engineering students might be better prepared in certain areas than their male counterparts for the engineering workforce (Bannerot, 2006; French, Immekus, & Oakes, 2005; Hecht et al., 1995; Kilgore et al., 2007; Knight et al., 2002).

The inconsistency in the literature over both the performance gender gap and the best measure of academic performance leaves open the question not only of whether the performance gender gap still exists, but also whether certain instructional factors and student experiences may have a differential affect on engineering learning depending on whether a student is male or female. In the next section, the discussion turns to differences in the manner in which women learn and the ways in which instructional factors, faculty activities, and student experiences can contribute differentially to female and male students' learning.

Women as Learners

Biologically speaking, women use different parts of their brains than do men for problem solving (Carey, 2005; Geary, 1998; Kimura, 1999; Sax, 2005). Men are better able to perform more focused tasks, such as mathematics, while women excel at integrating ideas and solving problems from a complex perspective (Carey, 2005). These differences do not suggest that one sex is more intelligent or can solve engineering problems more effectively than the other, but that each sex has its own distinctive set of skills and perspectives. "Children's socialization is

assumed to have consequences for their later lives" (Lever, 1978, p. 481). Chodorow (1974) argued that roles are reproduced within each generation through socialization. Thus, childhood socialization can affect beliefs about social roles. For example, boys play more complex games than do girls. The games that girls play are "spontaneous, imaginary, and free of structure or rules" (Lever, 1978. p. 481). Boys play structured games that help them develop and believe in their own math and science abilities (Lever, 1978).

Whether due to biological differences or socialization, the differences in the way men and women think also suggest that the sexes might differ as well in how they learn. In the higher education literature, Baxter Magolda (1992) and Belenky, Clinchy, Goldberger, and Tarule (1986) suggested that men and women have different developmental patterns. Research on learning in engineering also supports the presence of these separate learning patterns between genders (Dee & Livesay, 2004; Knight, Sullivan, Poole, & Carlson, 2002; Rosati, 1997; Rosati, 1999; Wise, Lee, Litzinger, Marra, & Palmer, 2004). The learning style of many women encourages them to prefer small, more interactive courses (Knight, Sullivan, Poole, & Carlson, 2002). Engineering education, however, tends toward competitive pedagogies based on male, not female, learning styles (Felder & Brent, 2004a; Lawal, 2007). The competitive nature of engineering has been raised as one factor in fostering the belief that women cannot succeed in this field (Baker, Krause, Yasar, Roberts, & Robinson-Kurpius, 2007; Brainard, Metz, & Gillmore, 1998; Hathaway, Davis, & Sharp, 2000; Sonnert, 1995).

Studies of women in engineering tend to consider the effects of climate, curriculum and pedagogy, and student experiences. The literature reveals a "chilly climate," along with the importance of collaborative learning and participation in a professional society, have effects on the learning process and the development of female students' academic abilities.

Academic climate. For years, the literature has suggested that the climate in engineering is not conducive to female students' persistence or learning (Harris et al., 2004; Lee, 2002; Salter & Persaud, 2003; Seymour & Hewitt, 1997). "Male-normed classrooms, often dubbed 'chilly' climates for women, have generally been described in the literature as competitive, weed-out systems that are hierarchically structured with impersonal professors" (Vogt, Hocevar, & Hagedorn, 2007, p. 339). Women who were confident of their abilities in high school, after entering the engineering climate, questioned whether they fit in the engineering program at all (Bergvall, Sorby, & Worthen, 1994; Collins, Bayer, & Hirschfeld, 1996; Ginorio, 1995; Lawal, 2007; Nauta, Epperson, & Kahn, 1998; Rosser, 1995; Seymour, 1995; Seymour & Hewitt, 1997).

As a heavily male-dominated field, engineering has been said to have a climate that contributes to women's propensity to enroll in other majors at the beginning of their undergraduate careers or to leave the major after experiencing an unwelcoming atmosphere. After World War II, the government funded engineering programs through its increased emphasis on research. To ensure their ability to win research grants, engineering programs hired faculty with skills in research rather than practical engineering (Prados, Peterson, & Lattuca, 2005). Thus, between 1950 and 1960, a practical focus shifted to a scholarly focus (Prados, 1992). By the 1980s, however, educators and employers began to realize that students needed practical skills to be globally competitive (Prados, Peterson, & Lattuca, 2005). By 1993, the science focus of engineering accreditation produced graduates with high technical abilities, but, according to employers, a lack of the more creative and "softer skills", such as communication and teamwork (Todd et al., 1993). At the same time, employers stated the importance of the softer skills, in addition to the technical competencies, in performing as an engineer in the work world. Because employers know the needs of society and are hiring graduates, engineering

programs have listened to those in industry and included more of the soft skills in the higher education curriculum (ABET, 1997).

In *Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States* (ABET, 1997), the Accreditation Board for Engineering and Technology (ABET) changed its accreditation standards. When ABET altered the focus of engineering programs from technical engineering skills to include more professional, or "soft", skills, the new standards may have changed the learning environment of engineering as well. The accreditation criteria placed greater emphasis on collaboration due to the need for students to develop communication and group skills (Kedrowicz & Nelson, 2007; Laeser, Moskal, Knecht, & Lasich, 2003). As previously discussed, female students tend to excel in the softer skills and to learn more readily from collaborative pedagogies, so this shift to the soft skills in engineering might create a more women-friendly environment with experiences that meet their learning needs more readily.

Today, researchers question whether the chilly climate still exists or if factors other than subtle discrimination contribute to women's departure decision. Zhao et al. (2005) discovered evidence of an inhospitable climate that women were finding ways to deal with through the formation of social networks. Harris et al. (2004) found that even in a department with equal numbers of female and male students, women still perceived a slightly negative atmosphere. However, Steele, James, and Chait Barnett (2002) reported finding a less negative atmosphere than reported in other studies, and Serex and Townsend (1999) found no difference in men's and women's perceptions of the program climate in engineering. Both sexes rated it low. In contrast with these assumptions, however, 2004 graduates actually reported less satisfaction with their program's diversity climate than did 1994 graduates. Graduates described a significantly cooler climate for women and minority students (Lattuca, Terenzini, & Volkwein, 2006). Possible

explanations for their differences include greater student awareness, openness to discussion, and willingness to challenge discrimination based on gender or racial/ethnic diversity. With these inconsistent findings, the question arises about the factors, other than overt discrimination, that may create a climate or situation in which women feel uncomfortable and whether these other factors contribute to a new kind of chilly climate.

Curriculum and pedagogy. Most theorists seem to agree that women are more likely than men to learn through their interactions with others. Talking their ideas out in a group and hearing the personal experiences of others help women develop various skills. A theme running through the dominant theories in higher education is that females seek out and develop through connections (Belenky, Clinchy, Goldberger, & Tarule, 1986; Gilligan, 1982; Josselson, 1987). According to Cross (1998), female students are "connected learners" (p. 6). Baxter Magolda (2001) found that in the receiving stage of development, where most first and second-year college students fall, females rely on peers for support, while male students expect faculty to share knowledge with them. Thus, using active learning techniques, such as collaboration, rather than more traditional methods, such as lecturing, may be more conducive to female learning than to male learning.

Engineering over the decades has been a competitive field, and competition is not conducive to collaboration (Grayson, 1977; Seymour & Hewitt, 1997). Traditionally, lecturing has dominated engineering pedagogies (Felder & Silverman, 1988; Prados, Peterson, & Lattuca, 2005). With changes in accreditation, employers have stressed the need to develop skills, such as communication and the ability to work in groups, to ensure graduates' success in the workforce. Thus, engineering programs have had to change their curricula to be more inclusive of

pedagogies that increase opportunities for collaborative learning. These changes have led to alterations in some student classroom experiences as well.

Compared with 1994 engineering graduates' reports of their experiences, 2004 engineering graduates cited significantly higher levels of collaborative learning in the classroom. The 2004 graduates were more likely to spend time working in groups with other students, interacting with peers, and learning from those connections (Lattuca, Terenzini, & Volkwein, 2006). Theorists and researchers suggest that with this increased emphasis on collaboration has come a greater inclusively in engineering programs to the ideas of all students through increased opportunities for student dialogue.

Student experiences. Most research on colleges' effects on students has included either in- or out-of-class experiences, but few have explored both at the same time. Some exceptions exist, however (see Kuh, 2001; Lambert, Terenzini, & Lattuca, 2007; Pascarella et al., 1996; Reason et al., 2006; Springer, Terenzini, Pascarella, & Nora, 1995; Terenzini, Springer, Pascarella, & Nora, 1995). These studies assess the effects of each group of experiences on learning while controlling for the other. To understand the full range of influences of college on engineering students' learning outcomes, both in and out-of-class experiences should be included in analyses. Lattuca, Terenzini, and Volkwein (2006) included students' in- and out-of-class experiences in their examination of engineering students' learning outcomes. While this study was comprehensive in its explanation of the predictors of engineering students' learning outcomes, the next step will involve specific attention to the potentially differential, gender-based effects of student experiences on female engineering students' learning outcomes.

Studies also often consider a subset of either the in-class or the out-of-class experiences to explore differential effects on female students (Eccles, 1992; Felder & Brent, 2005; Koehler,

1990; Laeser et al., 2003; Peterson & Fennema, 1985; Vogt, Hocevar, & Hagedorn, 2007). For example, interaction with faculty and advisors has been shown to exert greater influence on women than men. Female engineers described their relationships with faculty either as the most beneficial or most detrimental experience while in college (Robinson & Reilly, 1993). When assessing their own performances, female students tend to attribute failure in engineering to a lack of ability, while male students relate failure to lack of effort (Burton, 1986). Poor advising in engineering was a concern for nearly 20 percent more women than men (Seymour, 1995). When faculty responded positively to female students, women gained confidence in their skills (Seymour & Hewitt, 1997). Zeldin and Pajares (2000) also found that supportive faculty members had a positive effect on female students' development of a sense of self-confidence in their math-related abilities, which are critical for engineering. Female students need faculty and advisors to support and reassure them of their skills.

Out-of-class experiences also differentially affect female students' learning. Involvement in a professional society has been suggested to have a greater influence on females' student learning than men's, providing female students the support and confidence they need to succeed (Chubin, May, & Babco, 2005; McLoughlin, 2005). Studies have had mixed results, however, when considering the differential effects of participation in design competitions. Design competitions integrate ideas and skills; some studies suggest that women in a design competition gain higher levels of skills than women who do not participate in them (Laeser et al., 2003), while another study suggested that women engaged in a design competition are at a disadvantage because design competitions only reinforce the competitive nature of engineering (Colbeck, Cabrera, & Terenzini, 2000; Tonso, 1996a). For all these reasons, a comprehensive model of

students' in-class and out-of-class experiences must be used to understand how different experiences affect women's student learning.

Many studies have explored the effects of different student experiences on students' levels of learning outcomes in engineering (Lambert, Terenzini, & Lattuca, 2007; Lattuca, Terenzini, & Volkwein, 2006; Strauss & Terenzini, 2005). While these studies have provided insight into which in- and out-of-class experiences work best when examining learning outcomes in the aggregate population of engineering students, exploring the specific experiences of female students might reveal that these experiences have different effects for women than they do for men. Thus, studies that examine ways to improve student learning in engineering programs may inadequately portray the influence of these changes on a critical portion of the population—women—if the analyses only consider the aggregate population of students.

Some studies have examined learning outcomes for female and male students (Dym et al., 2005; Felder et al., 1995; Greenfield, 1982; Laeser et al., 2003; Mbarika, Sankar, & Raju, 2003; Peters, Chisholm, & Laeng, 1995; Takahira, Goodings, & Byrnes, 1998; Whigham, 1988), but each of these studies includes only a few student experiences rather than the effects of a more comprehensive list of possible experiences. Research suggests that the dynamics are more complex and inter-related than has been shown in the results of studies focusing on one segment of the process (see Kuh, 2001; Lambert, Terenzini, & Lattuca, 2007; Pascarella et al., 1996; Reason et al., 2006; Springer, Terenzini, Pascarella, & Nora, 1995; Terenzini, Springer, Pascarella, & Nora, 1995). Certain student experiences that have not been explored could be more influential for female students than for male students.

Learning Outcomes

Arguably, design skills are the central proficiency required to be a successful engineer (Simon, 1996). Design skills include the ability to devise a system, component, or process to fulfill desired needs and are linked with spatial abilities and the capability to solve unstructured questions. The spatial skills and experiences of freshmen engineering students differ by gender, with women being deficient (Osborn & Agogino, 1992). In comparison with male students, females report significantly lower levels of this skill (Felder et al., 1995; Knight et al., 2002). While more recent studies suggest that no one can any longer argue a female deficiency in design skills (Bannerot, 2006; Kilgore et al., 2007; Laeser et al., 2003; Moskal et al., 2002; Okudan, 2007; Okudan et al., 2002), design skills are so critical to the engineering profession that understanding how each gender develops this skill is worthy of study. The present study is not focused on gender differences in the levels of design skills learnt, but instead on gender-related differences in students' experiences that may affect learning or skill development (including two other outcomes) to the same degree for males and females but in different ways.

In contrast with design and problem-solving skills, the engineering community has more recently considered group skills a core skill. Having group skills means graduates have the ability to work effectively and efficiently in teams with other engineers. As previously discussed, the research suggests that female students' interactions with others are important to their development and learning. Women tend to be better communicators and listeners than men. Since group skills are often considered a soft skill and "more feminine," group skills might be an ability in which the self-reported academic development gap will be small, if significant at all, between male and female students.

Along with group skills, understanding the impact of engineering on society and the globe is a skill that has been added to the list of core skills required to be an engineer and is often cited as needed for future engineers' success (National Academy of Engineering, 2004). Societal and global issues awareness also includes knowledge of contemporary issues. Engineering programs are increasingly including this skill in their curricula to respond to industry's calls for graduates with greater sensitivities to the connections between engineering and the societies it serves (ABET, 1997). With respect to the importance of societal and global issues awareness for industry, females tend to be more concerned than males with the "social good" of their career choice (Hayes & Flannery, 2000; Sax, 1994). Thus, understanding the social good engineers do might be more important for female graduates than male graduates in their persistence in the engineering field.

The studies previously discussed in this chapter suggest a need more in-depth research. In the past, studies have included a few student experiences at a time when looking at gender conditional effects rather than the influences of a more comprehensive list of possible experiences. This study includes a more complex list of student experiences. In addition, the inconsistency in the literature over the performance gender gap leaves open the question not only of whether the performance gender gap still exists, but also whether certain instructional factors and student experiences may have a differential influence on engineering learning by gender. The next section will explore the exact research questions that focus on the possible dissimilarities in the ways in which women and men learn and how instructional factors, faculty activities, and student experiences can contribute differentially to female and male students' learning.

Statement of the Problem

The study sought answers to the following questions:

1) Have the changes made by programs and faculty members in response to EC2000 produced gender-related differences in students' experiences?

2) Have gender gaps in design and problem-solving skills, group skills, and societal and global issues awareness closed?

3) Have the changes made by programs and faculty in response to EC2000 varied by gender in their effects on students' experiences while in college?

4) Have the changes in program curricula and faculty practices had a different effect on female engineering students' development of design and problem-solving skills, group skills, and societal and global issues awareness than that of men?

5) Do engineering students' in-class and out-of-class experiences have the same effects on female students' development of certain engineering abilities as on male students' development of the same abilities?

In particular, the study examined possible gender-related conditional effects of program changes, faculty activities, and student experiences on the development of design and problem-solving skills, group skills, and societal and global issues awareness. In addition, the engineering programs' decision to include more opportunities for connected learning could have a more substantial effect on female students than male students. The importance of studying conditional effects resides in the fact that our knowledge of the effects of college on students is based largely on studies with samples that are not disaggregated by important student characteristics such as gender (Pascarella & Terenzini, 1991, 2005). Ultimately, learning is a process that is unique to each individual. "Nevertheless, enough similarities exist within each group to warrant an attempt at generalization" (Josselson, 1987, p. 188).

Significance of the Study

The shortage of females in the engineering field is a problem for several reasons, including social equity, misspent resources, equity in public funding, and global economic competitiveness. Each of these topics is discussed below.

Social equity. In 2001, women earned only 16.8 percent of the doctoral degrees in engineering (NSF, 2004), and in 1999, women comprised only 10 percent of engineers in the workforce and earned a lower salary than their male counterparts (National Science Board, 2004). In 2006, females received only 19.5 percent of the engineering degrees awarded, a number that had decreased from 20.3 percent the previous year. Even more troubling is the fact that the female graduates in six of the engineering disciplines (mechanical, aerospace, computer, computer science, electrical, and electrical/computer) represented as little as 11.3 percent of the graduates (Grose, 2006). Fewer women earning doctoral degrees in engineering means that fewer women will serve as engineering faculty and role models for young women seeking to enter the field.

In addition, when female graduates have not developed the skills necessary to excel in the engineering field, disparities emerge in the accomplishments of men and women in engineering, discouraging future women from entering the engineering workforce. Engineering is one of the most lucrative fields of employment and, thus, is important not only in creating financial equity between the genders in the United States, but also in ensuring that women are included in decision-making roles in technological fields, which are fast reforming our country. Building females' academic performance in engineering and other STEM fields, and thus properly educating women, may help ensure that nearly half of the U.S. population will not be left out of the decision-making process. Additionally, with gender parity may come a "much needed

diversity in perspectives, creativity, and leadership to these fields" (Baum, 2000, cited in Zhao et al., 2005, p. 504).

Resources invested. If women leave the engineering program before receiving their degrees, individual, institutional, and federal resources will have been mis-invested by parents, students, and administrators. Female students extend their time-to-degree by spending time in rigidly prescribed course requirements and then transferring to another program. Extending time-to-degree adds to the costs normally incurred by students on their college education, on average at least $5,836 (average tuition and fees at four-year public college in 2006–07) to $22,218 (average tuition and fees at four-year private institutions in 2006–07) (College Board, 2006a). In addition, students absorb the opportunity costs of the extra time spent in college without an income. The longer students stay in college without earning their degrees, the greater the increase in these costs. Students who began their studies in 1999–2000, at four-year public institutions, took an average of 6.2 years to complete their degrees, and students at four-year private institutions, 5.3 years (College Board, 2006c). On average, women spend an additional eighteen months in college when they begin in engineering and then transfer into another major (National Center for Education Statistics, 2000).

Administrators, faculty, and advisors at higher education institutions also invest resources in students who may drop out, and programs spend money on students who may ultimately choose another field. These resources include the time faculty and advisors spend with students that could be spent with other students. Each additional year that an engineering student spends in college costs an institution on average $34,079 (this includes administrative costs, faculty costs, and aid given to students) (National Center for Education Statistics, 2005).

Finally, the federal government also invests funds in the additional time that female engineering students spend in higher education. Federal funds are spent to give students grants, loans, and tax credits. Just over 60 percent of full-time students receive college money from the government in the form of grants. Millions of students also receive tax credits for attending college to help them afford their time there. During the 2005–06 year, college students were awarded a total of $134.8 billion in student aid from the federal and state governments, colleges and universities, and other private sources (College Board, 2006b).

Legal obligations. Title IX of the 1972 Education Amendments to the Higher Education Act specifies 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 educational program or activity receiving federal financial assistance" (Feminist Majority Foundation, 2007). Thus, policies that discourage female students from becoming engineers are potentially illegal (Feminist Majority Foundation, 2006). The Committee on Maximizing the Potential of Women in Academic Science and Engineering (2006) found that the gender bias in engineering creates a "chilly climate" for women. Recommendations to improve the climate are required to help engineering programs become compliant with Title IX.

Global competitiveness. Undergraduate engineering programs cannot keep up with the need for engineering talent. "Enrollments are down for the second year running" (Grose, 2006, p. 28). Grose (2006) pointed out two major talent pools not being successfully recruited by engineering programs: women (56% of the U.S. population) and African-Americans and Hispanic-Americans (25% of the population). As the need for engineers increases, not only do undergraduate programs need to attract and retain female students, but they also need to teach females the skills needed to succeed in the profession and ensure their confidence in those skills,

so that they remain in engineering. The talent pool in engineering is reduced by the under-representation of women. Women's ideas may differ from men's because women do not think the same way as men do. Carey (2005) found that women use different parts of their brains than do men. Thus, men are more able to focus on tasks like mathematics, while women because of their talent for integration solve solving them from a more holistic perspective (Carey, 2005). This is not to suggest that one sex is more intelligent or has the ability to solve engineering problems more effectively, but that each sex has something to add to the field. Leaving women out of the engineering field means that creativity and ingenuity are restricted to the male perspective. Women make unique contributions to any field (Astin, 1993b; Fennema, 1998; Greene, 1998; Johnson, 1993; Moskal, 2000; Moskal, Knecht, & Lasich, 2002; Terenzini, Pascarella, & Blimling, 1996). Engineering programs in the United States cannot allow their graduates entering the engineering profession to be limited to only one group of citizens.

Including these factors in studies of women in engineering increases our opportunities to understand why women who graduate in engineering may not rate their engineering skills in the same manner as do men. The research questions asked here were designed to investigate whether certain student experiences are more or less important for female students than for male students, controlling for a comprehensive list of possible in- and out-of-class student experiences. For example, one study found that while participation in design competitions improved learning outcomes in models that include all students, a model that included only female students showed that team projects actually increase the chilly climate for women (Colbeck, Cabrera, & Terenzini, 2000). The results from this study will lead to recommendations to engineering departments about the experiences that may best serve female students.

The succeeding chapters reveal how this study answers the questions asked here and how it builds on the current literature. The next chapter explores the current literature on how women learn and differences between male and female students' development of their engineering related skills. This includes possible differences in the ways in which research has shown that instructional factors, faculty activities, and student experiences can contribute to female and male students' learning. Chapter three explains the methodology used to answer the study's five questions. Then, chapter four presents the results of the analyses run for this study. Finally, chapter five recaps the previous chapters and discusses the theoretical, practical, and policy implications of the findings.

Chapter 2

Literature Review

Several theories explore the reasons for the lack of women in engineering careers. Theories have explained early childhood development as the cause (Hernandez ,1993; Keynes, 1989; LeBold, n.d.; Lever, 1978; McLeod & Almazan, 2003). Others have considered girls' socialization and preparation in elementary and secondary school (Alexander, Eckland, & Griffin, 1975; Conklin & Daily, 1981; Duncan, Featherman, & Duncan, 1972; Kandel & Lesser, 1969; Wilson & Portes, 1975; Woelfel & Haller, 1971; Woo, Barnhard, & Beasley, 2005). Still others have suggested that if women overcome barriers in early life and enter engineering as undergraduate majors, they are on the way to being engineers and scientists (Ambrose, Lazarus, & Nair, 1998; Hawks & Spade, 1998).

In the present study the focus was on female engineering students' experiences in college and their influence on learning. Many studies point to the treatment of female students in college as the problem (Bjorklund, Parente, & Sathianathan, 2004; Colbeck, Cabrera, & Terenzini, 2000; Haines, Wallace, & Cannon, 2001; Kardash & Wallace, 2001; Laughlin, 1996; Monasterky, 2005; Seymour & Hewitt, 1997; Terenzini, Cabrera, & Colbeck, 2000; Zhao et al., 2005). Engineering classes are often taught by the lecture method, which has been found to be more conducive to male learning than to female learning (Felder & Brent, 2004a ; Kardash & Wallace, 2001; Lawal, 2007; Seymour & Hewitt, 1997; Zhao et al., 2005). Female students "pick up a new disadvantage in university – low engineering self-efficacy" (Haines, Wallace, & Cannon, 2001, p. 682).

Absence of Women

Engineering is arguably the leading example of a male-dominated field. In 1995, women earned 17.3% of the B.S. degrees in engineering (National Science Foundation (NSF), 2006). By 1999, women earned nearly 20% of the B.S. degrees, but still comprised only 10% of the engineers in the workforce and earned a lower salary than their male counterparts (National Science Board, 2004). Between 2000 and 2004, the percentage of females earning B.S. degrees in engineering remained above 20%. In 2006, females received only 19.5% of the engineering degrees awarded, down from 20.3% the previous year. Even more troubling is the fact that the female graduates in the six largest engineering disciplines (mechanical, aerospace, computer, computer science, electrical, and electrical/computer) comprised as little as 11.3% of the graduates (Grose, 2006).

The low percentage of female graduates in engineering is not seen in other higher education fields. When compared to other fields and the overall population of college students, there are fewer female graduates in engineering. In the 1995 overall population of college graduates, 54.8% were female; that percentage steadily increased to 57.6% by 2004 (NSF, 2006). Even other fields, such as mathematics and statistics, previously regarded as male-dominated fields, had by 2004 awarded 45.9% of their baccalaureate degrees to women (NSF, 2006). Agricultural sciences, which as recently as 1995 awarded only 38.7% of bachelor's degrees to female students, increased the number of these degrees to 52.2% by 2004. In 2004, the only other field to have fewer than 40% female baccalaureate graduates was computer sciences, with only 25.1% female. Engineering remains one of the few largely male-dominated fields in undergraduate education.

There are two basic reasons for fewer women graduates in engineering. First, fewer women enroll in engineering compared to other fields. In 2002, only 1.6% of women who earned degrees at four-year institutions received their degrees in engineering compared to 8.6% for men, and women comprised only 20% of all engineering degree graduates (National Science Foundation, 2006). In addition, women leave the engineering field at nearly twice the rate of men (Bix, 2004; Kardash & Wallace, 2001; Michel, 1988).

Even those women who successfully graduate with engineering degrees are twice as likely as male graduates to be unemployed (Iversen & Douglas, 2004). Of the 2001 and 2002 engineering bachelor's degree recipients, 9.2% of female graduates, who did not continue their education as full-time graduate students, were not employed in engineering, compared to 5.8% of male graduates (NSF, 2006). Male graduates in 2001 and 2002 were also more six times more likely to be employed in science and engineering occupations (NSF, 2006).

Those females continuing their education in engineering comprised 21.1% of master's degrees and 17.6% of doctoral degrees awarded in 2004, compared to only 16.2% and 12.3% of degrees in 1997. For doctoral engineering degree graduates in 2001 and 2002, women seemed just as likely to be employed. The median salary for full-time employed engineering graduates is higher for female graduates by $6,000 when compared to men (NSF, 2006). Male engineering doctoral degree graduates are one and one-half times more likely to work in industry and nearly half as likely to enter academic employment compared to female graduates. Even though female engineering graduates may have a greater propensity to enter academia, due to the greater number of male doctoral degree graduates, the number of male engineering faculty still outnumbers the female engineering faculty 4 to 1 (NSF, 2006).

Gender Gap

In addition to the lower levels of female educational attainment in engineering, a disagreement has been found in the literature over the past few decades about whether the gender gap between male and female engineering students' academic achievement still exists. Several single-institution studies (Greenfield, 1982; Mbarika, Sankar, & Raju, 2003; Orabi, 2007; Whigham, 1988) and one multi-institution study (Takahira, Goodings, & Byrnes, 1998) found no significant difference in the academic performances of male and female students. In contrast, other studies indicate the continued existence of a gender difference (Felder et al., 1995; Haines, Wallace, & Cannon, 2001; Sax, 1994; Sax & Harper, in press). These inconsistencies are discussed in the next sections.

No differences found. Several studies found no gender gap in grade-point average or class performance in engineering and related fields (Bannerot, 2006; Greenfield, 1982; Kardash and Wallace, 2001; Marra, Palmer, & Litzinger, 2000; Mcarika et al., 2003; Orabi, 2007; Takahira et al., 1998; Whigham, 1988). Bannerot (2006), Greenfield (1982), Marra et al. (2000), Mbarika et al. (2003), Orabi (2007), and Whigham (1988) were all single-institution studies in which overall grades were used as the measure of academic performance. The analyses from all six studies revealed no significant difference in academic performance between male and female students. Orabi (2007) compared the performance of 52 male students and 49 female students in four introduction to engineering courses taught by the same professor and found no differences in the coursework and examination performances between the male and female students. On a final course project that required the use of mechanical devices and problem-solving skills, females, who originally reported little knowledge of such mechanics, by the end of the project scored just as well as their male counterparts (Bannerot, 2006). Marra, Palmer, and Litzinger (2000)

discovered that design experiences coupled with collaborative learning in several project-based courses at Penn State had a positive influence on male and female students' intellectual development, with no significant difference between the genders. Male and female engineering students in this study also had approximately the same cumulative grade-point averages. Marra and her colleagues suggested that their study's findings indicate that female and male engineering students are performing at the same level intellectually after their first year.

Several multi-institution studies also suggest no differences between the sexes in academic performance. Takahira et al. (1998) found no significant difference in the final course grade between male and female students in 48 sections of statistics at 17 institutions. Kardash and Wallace (2001) and Seymour and Hewitt (1997) found that female engineering students have just as high or higher grades in their collegiate classes.

All of these studies suggest that female students are, on average, learning just as much as male students. However, even if all other studies were consistent with these, this would not suggest that women and men get to these levels of learning in the same manner. Some experiences might still be more helpful or harmful for female development than male.

Differences found. While grades may be an easily quantifiable and readily available measure of academic performance, three studies that used only grades and several studies that employed grades and other measures report gender differences among engineering students (Bannerot, 2006; Felder, Felder, Mauney, Hamrin, & Dietz, 1995; Felder, Felder, & Dietz, 2002; French, Immekus, & Oakes, 2005; Haines, Wallace, & Cannon, 2001; Hecht et al., 1995; Kaufman, Felder, & Fuller, 2000; Kilgore et al., 2007; Knight et al., 2002; Peters, Chisholm, & Laeng, 1995; Sax, 1994; Sax & Harper, in press; Whitt, Pascarella, Elkins Nesheim, Marth, & Peirson, 2003). Felder et al. (1995) conducted a single-institution study of engineering and found

that females did not gain the same level of skills as men. This study used grades in engineering courses as the measure of academic performance. Felder et al. (1995) found that women on average enter college with stronger academic credentials than men, but by the end of their college career have grades that are equal to or significantly lower than those of males. Felder, Felder, and Dietz (2002) found that males outscored females in their grades in five chemical engineering courses. Kaufman, Felder, and Fuller found that in two chemical engineering courses, male students had significantly higher test scores and final grades than their female peers (Kaufman, Felder, & Fuller, 2000). Peters, Chisholm, and Laeng (1995) used an objective test to measure students' spatial ability at a single institution. They found that males in engineering scored significantly higher than females.

Felder et al. (1995) also found that females did not rate themselves as highly on their development of problem-solving skills as did men. Knight et al. (2002) found significant differences between male and female engineering students on several learning outcomes. Male students reported higher levels of design skills and ability to use engineering methodology. Haines, Wallace, and Cannon's (2001) multi-institution study concluded that male students have greater self-perceived abilities than females after graduation. According to Haines, Wallace, and Cannon (2001), females "pick up a new disadvantage in university – low engineering self-efficacy" (p. 682).

The results from these studies, all of which relied on self-reports of engineering abilities, must be considered with caution. Several studies have found that females in science, technology, math, and engineering often rate themselves as less confident of their technical abilities than their male counterparts (Besterfield-Sacre, Moreno, Shuman, & Atman, 2001; Felder et al., 1995; Hawks & Spade, 1998; Orabi, 2007; Seymour & Hewitt, 1997). Felder et al. (1995) found that

women tended to under-predict their grades, while men's predictions were more accurate. In this study, women's performance and self-confidence were not correlated. Light et al. (2007) also found that although first-year female students performed just as well as their male counterparts on an engineering task, they reported significantly lower levels of confidence in their engineering abilities. Thus, the self-reports may be presenting a biased picture of student learning.

Another multi-institution study found that mathematical self-concept is higher among men than any women and that college reinforces the gap (Sax, 1994). Sax and Harper (in press) used a multi-institutional dataset of all disciplines to explore 19 outcomes with gender gaps. The gender gap in five of the outcomes disappeared after controlling for pre-college characteristics. Two other gender gaps were also no longer significant after controlling for pre-college characteristics and student experiences and institutional characteristics. For the remaining 12 outcomes, the gender gaps remained significant even after controlling for all other variables. Three of these twelve outcomes were academic outcomes. Gender-related differences in mathematical ability and competitiveness remained significant even with all controls, with female students being below male students in self-ratings. The gender gap for GPA was also significant, with females having the advantage (Sax & Harper, in press).

Whitt, Pascarella, Elkins Nesheim, Marth, and Peirson (2003) analyzed survey data from 3,331 students across disciplines at 18 institutions to calculate the net effects of gender on cognitive outcomes. They used blocked procedures to understand "how the net impact of sex on the dependent variable changed in magnitude in the presence of different sets of control variables" (p. 593). The results of their study indicated that females' learning outcomes in college differed significantly from men's even after they controlled for the students' pre-college characteristics and experiences during college. Since Whitt et al. (2003) were unable to pinpoint

the reasons for the gender gap, they suggested a study that future studies include additional student experiences and a larger sample.

Five studies found that female engineering students might be better prepared than their male counterparts in certain areas for the engineering workforce (Bannerot, 2006; French, Immekus, & Oakes, 2005; Hecht et al., 1995; Kilgore et al., 2007; Knight et al., 2002). When analyzing data from two cohorts of engineering students at a large U.S. midwestern university, French, Immekus, and Oakes (2005) discovered that females had higher GPAs than their male counterparts. In a sophomore-level design course, Bannerot (2006) compared the performance of male and female students on two individual design projects. On the first project, which required creativity, females outscored male students by a considerable margin. While male and female students began their engineering program reporting the same level of communication skills, women ended up scoring higher than men after their engineering education experiences (Hecht et al., 1995; Knight et al., 2002). Hecht et al. (1995) suggested this difference may stem from female engineering students' use of interpersonal resources to build their engineering abilities because they place a higher value on learning through communication with others. Kilgore et al. (2007), in a multiple-institution and longitudinal study, found that female engineering students seem to be more aligned with the ABET goals for the Engineer of 2020, which include education on a broad spectrum, awareness of cultural contexts, and self-motivated learning. Female engineering students tend to consider the context for which an item is being designed and not just the functional details.

The multitude of studies that suggest that male and female engineering students do not develop the same level of engineering skills also suggest that women and men may not learn in

the same manner. In addition, the experiences necessary to develop their skills might also differ by gender. In the next section we consider some of these possible learning differences.

How Women Learn and Develop

Running throughout every experience in and out of the classroom that influences students' development of engineering skills are differences in men's and women's responses to these stimuli. When women do not fit into the development patterns and stages suggested by psychologists, the interpretation could be that there is something "wrong" with women. Many theories have considered the different gender patterns within development (Baxter Magolda, 1992; Baxter Magolda, 2001; Belenky, Clinchy, Goldberger, & Tarule, 1986; Gilligan, 1982; Josselson, 1987; Kegan, 1982). The differences among these theories fall along a spectrum. The differences among women and men are found within the same stage on the development path, in the amount of time spent in certain stages, or in completely different pathways.

Different patterns within the same stage. Baxter Magolda found that the differences between men and women fall within the stages of intellectual development (1992) and identity and interpersonal development (2001). Baxter Magolda (1992) followed an entering cohort of 101 students at Miami University of Ohio to track their intellectual development over five years. At the end of five years, she had data for 70 students. These students were both male and female students, a noteworthy consideration because Perry's work (1970) had only included men and Belenky et al. (1986) only incorporated women. While Baxter Magolda's stages were not rigid stages and instead used the term patterns of ways of knowing, her ways of knowing followed a stage-like hierarchy. Women and men were separate groupings within these patterns.

Baxter Magolda (1992) defined the first way of knowing in intellectual development as absolute knowing**,** in which knowledge is considered to exist as a certainty. Within this stage,

females primarily adopt a “receiving” pattern, believing their responsibility is to learn the knowledge given to them without questioning it critically. In this stage, women also rely on peers for support. Men in this stage primarily use the pattern of mastery, which means they expect teachers to share knowledge in interesting ways but question information that deviates from their form of truth. Males use peers to demonstrate and test knowledge. While Baxter Magolda placed these gender patterns in the same way of knowing, other development models would suggest that male students are further along the development scale (Perry, 1970). Females rely on peers throughout the stages to resolve uncertainties, while male students tend to consider their own thinking and opinions to determine knowledge (Baxter Magolda, 1992). By the final way of knowing, contextual knowing, Baxter Magolda (1992) found that the separate gender-patterns integrate into one pattern.

*Different amounts of time in stages***.** Kegan (1982) did not stress differences between genders, but he did suggest that women and men tend toward certain places of equilibrium. Rather than progressing as a hierarchy, Kegan’s model is a pendulum swinging between individuality/independency and community/integration. Each stage in Kegan’s psychological development scale is the momentary equilibrium on one side of the continuum. Males are more likely to desire distinctiveness, while women tend to want inclusion. “Women can be expected to have more difficulty emerging from embeddedness in the interpersonal, and men more difficulty emerging from the embeddedness in the institutional” (Kegan, 1982, p. 210). Kegan did not suggest that these levels are a hierarchy or that one builds on the other, so he did not suggest that women are constantly at a lower level of development than men.

Different pathways to development. Belenky et al. (1986), Gilligan (1982), and Josselson (1987) argued that the pathways to development differ completely for males and females. The

theme that seems to run through these theories is that females develop through connections with others. These theories take the idea of differences to the furthest level, with Josselson even suggesting that models of development for women need to include more than one pathway.

Belenky, Clinchy, Goldberger, and Tarule (1986) interviewed 135 women, 90 from nine academic institutions and 45 from agencies, on parenting. The authors compared their theory to that of Perry (1970), who included only men in his study, developed a theory and framework, and then all students followed the same pattern. In Perry's theory, there was no separate consideration of women's complexities. Belenky, Clinchy, Goldberger, and Tarule (1986) theorized that women come to "know" something in five ways. Theses stages build on Perry's (1970) scheme. Their stages of development begin with women thinking of themselves as being without their own minds and voices and range to the end of the spectrum with women seeing all knowledge as contextual and see themselves as creators of knowledge.

Josselson (1987) expanded the idea by questioning whether even a pathway developed specifically from studying the experiences of women is enough to capture all of their different possible experiences. Any one set pathway to development is not capable of capturing the full spectrum of women's experiences. To build her theory, Josselson examined identity development in a representative sample of college-educated women. Longitudinal interviews revealed four diverging paths for women's identity development. While identity development is only one of the three aspects discussed by Baxter Magolda (2001) in self-authorship, it only highlights the importance of understanding the complexity of all components of development.

Gilligan (1982) also argued that women are not inferior to men in their personal or moral development. Women simply develop differently than men. Gilligan studied how people make judgments about what is "right" or "moral." Gilligan considered other theories available about

development and believed that the flaw in these theories is that they put women in a second-class citizen position. She focused in particular on Kohlberg's (1969) stages of moral development and questioned women's tendency to be classified as less developed than men on his scale. She also questioned Freud's (1961) idea that women's moral sense was stunted due to their continued attachment to their mother. Erikson (1950) also said that development stemmed from separation from the familial unit. Gilligan broke away from all of these beliefs to create her own stages of moral development for women. In Gilligan's study, women thought more about the caring thing to do rather than the action that would be sanctioned by the current rules. Women developed in a way that focused on connections rather than separation. In contrast with men, the ethical decisions made by women tended to be influenced by the people they were connected with rather than to be based on social justice.

All things considered. The pattern of knowing for the sexes may help explain why female students achieve at different levels in engineering than do male students. Female students rely on their peers to receive the learning support they need to feel comfortable with new information (Bock, 1999). According to feminist theorists, the practices used to teach mathematics and engineering result in a gender gap. The differences in learning between the sexes suggest that the in-class and out-of-class student experiences that are best for female students might not be the same as those for male students. Thus, identifying experiences that are particularly effective for women and encouraging women to take part in those experiences might reduce some of the gender inequity in the levels of engineering skills learned while in college.

In the past, women were not included in the development of engineering curricula (Grayson, 1977). "You can't just add women and stir," is the adage—the presence of women in classes does not mean that female students are being included and encouraged in the same

manner as male students and in the way needed to succeed (Minnich, 1990). In order to create a educational change, engineering faculty, advisors, and administrators, along with parents and peers, need to challenge these universal claims to truth (Nussbaum, 1997).

Learning Patterns Applied to Engineering

Elshorbagy and Nwetter (2002) applied Kolb's (1984) learning model to engineering education and suggest that engineering students not only receive information, but ask questions, go through trial-and-error stages, and then develop their own version of the material. This type of learning encourages students to take ownership of their own learning and to continue with engineering careers (Colbeck, Cabrera, & Terenzini, 2000). Felder, Felder, and Dietz (2002) continued the study by Felder et al. (1995) and examined type of learner as well as gender in skills differences among engineering students. Learning type was found to moderate grades in five chemical engineering courses between the genders. Male thinkers ("thinkers" tend to make decisions objectively) earned only slightly higher grades than female thinkers. Male feelers ("feelers" tend to make decisions subjectively and respond well to active and collaborative learning) received considerably higher grades than female feelers. Female feelers were the most disadvantaged and were outperformed by all three other groups. "The implication is that women with a preference for feeling may be particularly vulnerable in engineering school, perhaps suggesting the need for a better balance in the curriculum between technical and social aspects of engineering" (Felder, Felder, & Dietz, 2002, p. 10).

Pedagogies and techniques suitable to each learning style could be used to encourage effective student learning (Finelli, Klinger, & Bundy, 2001). The traditional pedagogies used by engineering professors do not match the predominant learning styles of engineering students (Felder & Silverman, 1988). Most engineering courses use lectures as the primary mode of

instruction (Felder & Silverman, 1988). Dunn and Carbo (1981) found that engineering students are more active than reflective learners. Active learners do not learn in situations that require passivity, such as lectures, but active learners flourish in environments where they can learn collectively with others (Felder & Silverman, 1988).

In addition, the lecture method might be even more inappropriate for female engineering students' development of engineering skills. Baxter Magolda (1992) and Belenky et al. (1997) have suggested that men and women have different developmental patterns. Wise et al. (2004) observed eight male and eight female engineering students in a first-year design course and found separate patterns between the genders. Three other single-institution studies also suggest differences in the learning patterns of female and male engineering students (Dee & Livesay, 2004; Rosati, 1997; Rosati, 1999). The learning style of many women inclines them to prefer small, more interactive courses (Knight, Sullivan, Poole, & Carlson, 2002).

"Gender, age, learning styles and educational background are all understood to have considerable effects on how students react to teaching methodologies" (Dunbar, Gordan, & Seery, 2007, p. 4). Female engineering students more frequently report a desire to be in collaborative rather than competitive classes than their male counterparts (Knight, Sullivan, Poole, & Carlson, 2002). The competitive nature of engineering has been suggested as one reason for the belief among female students that they cannot succeed (Baker, Krause, Yasar, Roberts, & Robinson-Kurpius, 2007; Brainard, Metz, & Gillmore, 1998; Hathaway, Davis, Sharp, 2000; Sonnert, 1995). In a qualitative study of a design course that enrolled nine students (5 males and 4 females), Baker et al. (2007) found that females reported increased levels of self-confidence in their technical abilities when working in a non-competitive environment. Engineering tends toward competitive pedagogies based on male learning styles and not those of

females (Lawal, 2007). Thus, early engineering courses that relied more heavily on lectures and student competition fostered higher levels of intellectual development among male students than among female students (Felder & Brent, 2004a).

Conceptual Framework

Understanding that background literature that suggests females may be learning differently from males, and particularly in engineering, the focus on the rest of the chapter is the student learning process in college. Figure 2.1 illustrates the hypothesized relationships for student learning in the *Engineering Change* study (Lattuca, Terenzini, & Volkwein, 2006). This framework shaped the design of the current study and was the framework used in the formation of the dataset used for this study as well. The first stage of the conceptual framework implies that the new EC2000 accreditation standards will require a variety of program changes, including the curriculum and instructional practices in engineering programs. In addition, under the assumption that EC2000 is making an impact, one might expect to see changes in the faculty culture. For example, faculty members might be expected to increase their involvement in activities, such as professional development, that help educate faculty members on how to assist students to develop the new skills set forth in the EC2000 standards. Programs might also make changes to administrative policies in response to the new accreditation standards. For example, programs might increase the emphasis on teaching and learning during hiring, promotion, and tenure decisions. The alterations to curriculum, instruction, culture, practices, and policies then might lead to a shift in student experiences both in and outside of the classroom. Finally, the model suggests that these differences in students' experiences influence differences in student learning.

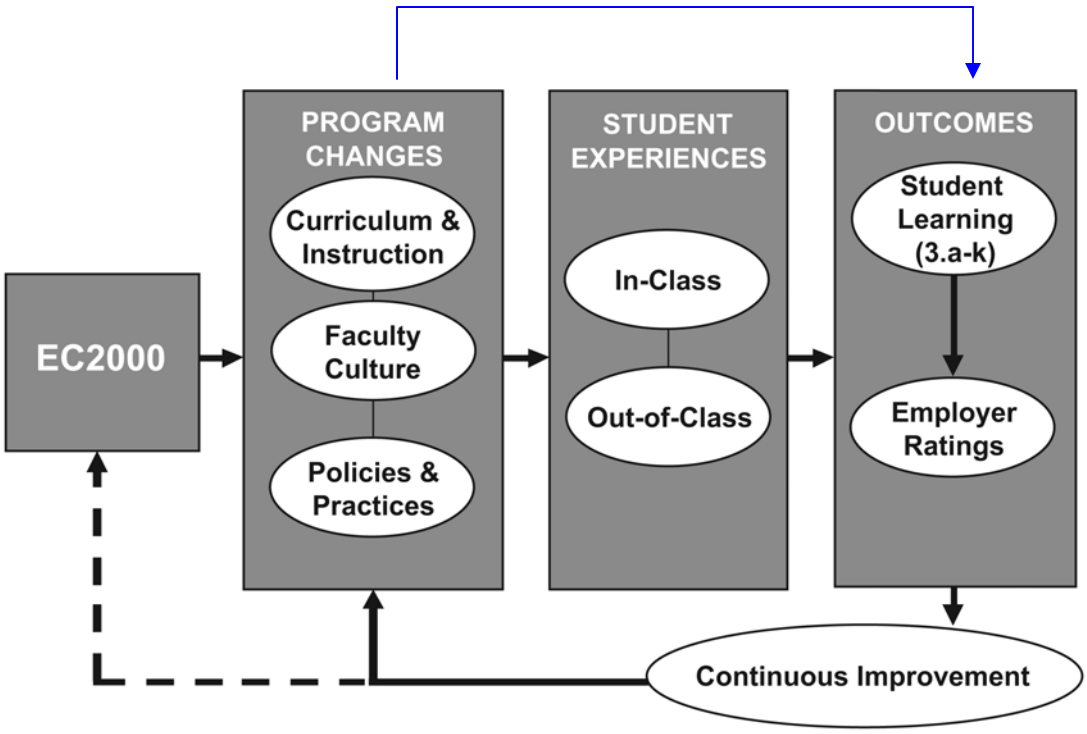

Figure 2.1. Conceptual Framework for the Engineering Change Study

This present study took this framework and then paid particular attention on conditional effects by examining whether certain student experiences implied in the model have the same effects on women as on men. In addition to the change in focus to gender conditional effects, the current study also explored the conditional effects of program changes on student learning (illustrated by the blue line in Figure 2.1). For example, while participation in design competitions has been shown to improve learning outcomes in analyses that include all students, a model that includes only female students suggests that team projects may also increase the chilly climate for women (Colbeck, Cabrera, & Terenzini, 2000). This present study examined differences between male and female students' experiences and, ultimately, the effects of those experiences on the development of students' design and analytical skills, their ability to function in a group, and their awareness of societal and global issues.

Program Attributes and Faculty Activities

As mentioned in the last section, the first links in the causal chain leading to students learning are the effects of program attributes and faculty activities on students' experiences. Curricular changes can also have substantial influences on student learning. Busch-Vishniac and. Jarosz's (2004) study of engineering programs found that curricula need to retain technical materials, but also clarify the link between fundamentals and applications, reduce the rigidity in course requirements, incorporate the use of teamwork in all classes, and create an environment that promotes inclusion. The next sections explore some of the program changes and faculty activities that have occurred in response to the new accreditation standards of EC2000.

Curricular flexibility. Generally speaking, women tend to prefer a more flexible curriculum. The flexibility to take courses outside of their major and explore other interests affects female students' persistence and academic success in engineering (Laughlin, 1996; Monasterky, 2005; Seymour & Hewitt, 1997; Xie & Shauman, 2003). Monasterky (2005) and indirectly Seymour and Hewitt (1997) found that the most common reason for female students' decision to switch out of engineering, math, and science fields was due to interest in other majors. Students who display high levels of mathematical ability along with high verbal skills are less likely to major or follow a career in mathematics and math-related fields (Monastersky, 2005). Laughlin (1996) found that curricular flexibility was one of the two most important factors to ensure female achievement and success. Lack of flexibility in choosing courses was the most popular answer from female graduates in 1994, 1995, and 1996 when reporting the worst aspects of their engineering education (Laughlin, 1996). Despite female students' interest in other fields, engineering programs are not very flexible. Most engineering programs are highly prescribed and allow very few electives (Kardash & Wallace, 2001; Seymour & Hewitt, 1997;

Zhao et al., 2005). Programs that include continuous curriculum planning allow faculty and administrators to regularly consider such curricular attributes as flexibility and adjustment.

Pedagogy. As suggested by the *Engineering Change* framework (Lattuca, Terenzini, & Volkwein, 2006), pedagogy has a lot to do with student experiences. The results from a few studies in engineering suggest that collaborative and active learning techniques are good for engineering students overall (Morell et al., 2001; Pimmel, 2001; Prince, 2004). Morell et al. (2001) examined STEM faculty perceptions of the effectiveness of collaborative learning when used in their classroom at institutions participating in the Puerto Rico Louis Stokes Alliance for Minority Participation (PR-LSAMP). The results of the study indicated that faculty perceived more positive than negative changes in their students' performance in such areas as class participation, study habits, performance on tests and quizzes, comprehension of concepts, development of leadership and teamwork abilities, and attrition. Pimmel (2001) explored the benefits of active and collaborative education in his capstone design course. He surveyed both the students and the other faculty who came into contact with these students. The students reported that active and collaborative education activities were effective and important to their own development. The faculty supported this finding and cited increased team skills for the students in the course. The overwhelming support for collaborative learning also questions the traditional assumption that individual work and competition best promote achievement in engineering (Prince, 2004).

According to some theorists, women in particular tend to learn best in an engaging environment in which they discuss information and interact with peers (Baxter Magolda, 1999; Belenky, Clinchy, Rule Goldberger, & Mattuck Tarule, 1997; Bock, 1999; Cross, 1998). Engineering classes are often taught via the lecture method, stressing memorization of facts and

disconnected information rather than collaborative learning projects or students' self-discovery of concepts, and they are highly competitive (Kardash & Wallace, 2001; Seymour & Hewitt, 1997; Zhao et al., 2005). Such classroom techniques are often antithetical to women's learning preferences. Many women in engineering, whether or not they leave, report that professors do not adequately explain information, allow them to build upon previously learned concepts, or provide in-class hands-on experience, self-discovery of knowledge, or connections to their lives (Kardash & Wallace, 2001; Seymour & Hewitt, 1997). Participation in a freshman design courses has also been shown to foster confidence in female engineering students (Courter, Millar, & Lyons, 1998).

An additional area related to pedagogy is the level of participation exhibited by engineering students. Participation in this context refers specifically to active involvement in class. Zhao et al. (2005) also found that women were less engaged in engineering classes than their male peers. Steele (1997) suggests that female hesitance to speak in class may be related to a fear of confirming a negative stereotype about women's deficiencies in engineering. Lower levels of participation may also be ascribed to an atmosphere in which "stereotypical" male jocularity and lack of inhibition in asking questions or making off-handed comments is accepted, if not rewarded, and the quieter, more passive traits often characteristic of women go unnoticed (Steele, 1997).

Engineering has a history of being industry-driven. After World War II, the government funded engineering programs by increasing research dollars. To win research grants, engineering programs hired faculty with skills in research rather than practical engineering (Prados, Peterson, & Lattuca, 2005). Thus, between 1950 and 1960, what was taught in the classrooms shifted from a practical to a theoretical focus (Prados, 1992). By the 1980s, educators and employers began to

realize that students needed to be taught practical skills to be globally competitive (Prados, Peterson, & Lattuca, 2005). By 1993, the science focus in engineering accreditation produced graduates with high technical skills, but according to employers the graduates lacked the more creative and "softer skills", such as communication and teamwork skills (Todd et al., 1993). In response to the needs of employers and society, engineering programs now include more professional skills in the undergraduate curriculum (ABET, 1997).

Despite what we know about how women learn, engineering does not seem to use a pedagogy that is coordinated with that learning style. While engineering is traditionally lecture-based, after EC2000, the use of more active learning pedagogies has increased. This shift might increase women's learning but the use of lectures is still predominant in engineering. In *Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States* (ABET, 1997), the Accreditation Board for Engineering and Technology (ABET) altered the accreditation standards. When ABET encouraged changing the focus of engineering programs from technical engineering skills to include "soft" skills, the new standards may have changed the learning environment in engineering as well. The accreditation changes increased the demand for collaboration, and so students may be more likely to develop communication and group skills (Kedrowicz & Nelson, 2007; Laeser, Moskal, Knecht, & Lasich, 2003). As previously discussed, female students tend to excel under the softer skills and collaborative pedagogies, so one might ask whether this shift to the soft skills in engineering may have created an environment that could potentially create more opportunities for the experiences that are more important for women in engineering. "Although there may be a tendency to assume that the content of engineering precludes the use of alternative pedagogical practices, our findings show that is a misconception" (Lord & Camacho, 2007, p. 13). A program incorporating reflection,

collaboration, and presentation of concepts from multiple perspectives and contexts significantly increases students' analytic problem solving, conceptual understanding, and drawing and modeling ability (McKenna & Agogino, 2002).

Undergraduate education projects. Faculty who participate in projects that improve undergraduate education and in activities that enhance content knowledge in their courses, are more likely to create course atmospheres that demonstrate to students their dedication to teaching. The amount of energy and dedication that students see professors putting into their courses is important to engineering students' academic success (Cordova-Wentling & Camacho, 2006). Female engineering students' academic success, in particular, has been found to be positively influenced by faculty members who emphasize course improvement, support and motivate their students, and show their belief in female students' engineering abilities (Anderson, 2002; Brainard & Carlin, 1998; Cohoon, 2001; Henes et al., 1995; Sheahan & White, 1990; Wentling & Thomas, 2005; Zeldin & Pajares, 2000).

Precollege Characteristics

While many college departure or student learning models (e.g., Astin, 1993a; Tinto, 1993) include pre-college characteristics that are mainly demographic in nature, such as gender, ethnicity, socioeconomic status, or family background, factors such as pre-college ability and preparation in math and science also need to be considered when thinking about engineering. Foundational knowledge and precollege characteristics may affect subsequent experiences and academic performances. The research literature on women's preparation for and ability in math, science, and overall high school grades or test scores is mixed. Seymour & Hewitt (1997), Harris et al. (2004), and Huang et al. (2000, as cited in Zhao et al., 2005) found that women's preparation in math and science, high school GPAs, and SAT scores are as good as or better than

their male counterparts in engineering. According to Felder, Felder, Mauney, Hamrin, and Dietz (1995), on average, women enter college with stronger credentials than men. Bogue (2006) found that in the past women had not taken as many high-level math courses in high school as their male counterparts, but today more women are taking the advanced math and science courses (with the exception of physics). Xie and Shauman (2003) gathered data from seventeen nationally representative datasets. Their findings suggest that the preparation gap between male and female students is small and closing. They also dispute the idea that females are less likely to pursue and succeed in science and engineering because of these differences.

On the other hand, however, Smyth and McArdle (2004) reported that gender differences in science, math, and engineering persistence that favor males are often accounted for, though not fully, by differences in academic preparation and grades. Additionally, Smyth and McArdle postulated that boys take higher-level math and science courses than do girls in high school, so even if grades are the same, they are not really "the same" because the grades "are disproportionately comprised of more challenging SME-relevant courses, which could account for an easier time in college classes" (p. 375).

In-class Experiences

Although pedagogy is important, it takes more than just a change in pedagogy to make engineering appealing and rewarding for female students (Du & Kolmos, 2007). The next set of links in the causal chain leading to students learning (portrayed by Figure 2.1) are the effects of students' experiences on their learning. This section looks at the in-class one of the two subsets of those experiences. Astin (1993a) studied 27,000 students and found that college environments and students' college experiences reinforce and even strengthen "stereotypical differences between men and women in behavior, personality, aspiration, and achievement" (p. 406). In-

class experiences, such as collaborative learning, interactions with faculty, and instructor clarity, can be critical in the development of engineering abilities (Bjorklund, Parente, & Sathianathan, 2004; Colbeck, Cabrera, & Terenzini, 2000; Terenzini, Cabrera, & Colbeck, 2000). These three in-class experiences are discussed in the following sections.

Collaborative learning. According to Cross (1998), the most important factor affecting learning by female students is that their way of knowing involves their being "connected learners" (p. 6). As suggested by Bock (1999), women learn more effectively with their peers. Pedagogy, which allows students in engineering courses to interact primarily with professors, supports the male students in the class and puts the female students at a disadvantage. Engineering professors who use a more collaborative learning method in their teaching styles are more likely to reach the women in engineering. Several studies found that gender gaps in engineering and science students' learning close when a more collaborative and welcoming environment is created for women (Astin & Astin, 1993; Davis et al., 1996; Knight, Sullivan, Poole, & Carlson, 2002; Lantz, 1982; Rosser, 1991; Tobias, 1990; Ware, Steckler, & Leserman, 1985).

In the 1980s and 1990s, the cooperative learning model entered engineering (Smith et al., 2005). At the 1981 IEEE/ASEE Frontiers in Education (FIE) conference, Smith, Johnson, and Johnson first introduced the concept of cooperative education to the engineering field. By the mid-1990s, cooperative learning was considered part of the best practices in engineering education (Smith et al., 2005). Because the terms cooperative education and collaborative learning are often used interchangeably by researchers (Barkley, Cross, & Major, 2004; Bruffee, 1999; Smith et al., 2005), research on either is included in this review. Both pedagogies rely on small groups of students working together to maximize the learning of all students (Bruffee,

1999; Johnson et al., 1991; Smith, Johnson, & Johnson, 1981; Smith et al., 2005). The main difference is that cooperative learning creates structured individual student accountability while collaborative learning does not (Smith et al., 2005). Since the literature on female students in engineering discusses about collaborative learning and the term cooperative was also used when talking about internships and cooperative education, this study used the collaborative learning terminology.

Engineering students seem to develop their engineering abilities more in collaborative and interactive learning environments than other environments (Haller et al., 2000; Taraban et al., 2007). More than 168 rigorous research studies conducted between 1924 and 1997 compared the effectiveness of collaborative, competitive, and individualistic learning on students' learning. These studies suggest that collaborative learning fosters greater student academic achievement than competitive or individual approaches (Cartwright, 1998; McKeachie, 1988; Prince, 2004; Qin et al., 1995; Smith et al., 2005). Springer, Stanne, and Donovan (1999) selected 383 reports published after 1980 of small-group learning in STEM courses and conducted a meta-analysis of 39 studies that met their inclusion criteria. The effects of participation in small-group learning on STEM undergraduates were significant and positive. The effects size for the influence of small-group learning on student achievement was .51, for persistence, .46, and for attitudes, .55 (Springer, Stanne, & Donovan, 1999).

Seery, Waldmann, and Gaughran (2006) found that all students who were exposed to active learning pedagogies, such as collaborative learning, showed a measurable increase in their performance, unlike those students who had traditional instructional methods. Johnson and Johnson (1989) reported a larger increase in social skills within collaborative rather than competitive or individual situations. Terenzini et al. (2001) studied 480 engineering students at

six engineering schools, who were enrolled in either 17 collaborative learning courses or six traditional lecture courses. The results suggest that using collaborative methods produces both statistically significant and substantially greater gains in students' development of their engineering design, problem-solving, communication, and group participation skills, than those associated with more traditional instructional methods (Terenzini et al., 2001).

The study by Randolph (2000) asked students to discuss their experiences in an information systems class that used a fully collaborative learning approach. Students worked as a team on in-class assignments, edited each other's work, and collaborated on examinations. Students indicated learning more in this setting, and reported that the examinations became learning experiences because they were allowed to brainstorm and discuss the problems (Randolph, 2000). For the courses in which faculty in the College of Engineering at San Jose State University adopted collaborative learning as a teaching methodology, the positive effect on student attitudes and learning has been significant. Students reported that collaborative learning improved their interpersonal, team, communication, problem-solving, and design skills (Mourtos & Allen, 2001).

The use of collaboration in the classroom has the advantage of being purportedly more "women-friendly" than traditional methods (Pawley, 2004). Collaborative learning techniques are especially well suited to female engineers because they emphasize group efforts and active learning, which are gender- and race-friendly learning styles (Cartwright, 1998). Female students prefer collaborative language in the classroom, which requires participants to continually interact, to those that foster competitive interactions among students, which has students competing for turns (Edelsky, 1981; Haller et al., 2000; Tannen, 1990). Hartman and Hartman (2002) studied the engineering students at Rowan University. This then five-year-old engineering

program incorporated many of the factors associated with the retention and academic success of women in engineering, such as hands-on lab work, collaborative teamwork, and interdisciplinarity. The study compared gender differences in students' satisfaction with various program activities. Females were more satisfied with the applied and collaborative aspects of the Rowan program than were male students. Their findings support the perception that collaborative learning is particularly women-friendly. In contrast, Terenzini et al. (2001) found that students, in courses with collaborative learning pedagogies, reported "unequal treatment" by gender more often than students in traditional pedagogies. They suggested that these findings were a function of the settings created by the two methods. Collaborative learning settings give students many more opportunities to interact with faculty and peers than traditional classrooms. Thus, more frequent interactions mean more opportunities for conflict. While this study suggests that collaborative learning might have negative impacts on female students' development of their engineering skills, the majority of studies disagrees and points out the strengths of collaborative learning.

Engineering education as currently offered may be better suited to the learning styles of men in institutions of higher education. Rather than relying on lectures to disseminate knowledge, if learning pedagogies were used that allowed students to work in small groups, women could build understating of the concepts and theories in engineering (Willis, 1990). Many researchers, such as Eccles (1992), Koehler (1990), and Peterson and Fennema (1985), have found that increasing the use of small group discussion, collaborative learning, and practical problem-solving activities improve the involvement and performance of female students in science and technology courses. Observational studies show that the motivation of female students to follow their aspirations in science fields increases when collaborative learning

methods are used in science courses (Davis et al., 1996). Braxton, Milem, and Sullivan's (2000) study of 718 students discovered that active learning experiences (such as collaborative learning) had a positive influence on students' persistence through college. Females were significantly more likely than men to say that they felt they learned more in groups than alone (Felder et al., 1995).

While collaborative learning might be more influential in female learning, it is a positive experience for both female and male students (Bjorklund, Parente, & Sathianathan, 2004; Bruffee, 1999; Cross, 1998; Henes et al., 1995; Palmer, 1998; Terenzini, Cabrera, & Colbeck, 2000; Worley, 2002). A study of both male and female engineering students found that collaborative learning activities have positive effects on group skills, problem-solving skills, and occupational awareness (Bjorklund, Parente, & Sathianathan, 2004). The increase in use of collaborative learning may affect female students' development of their skills more, but it does not hurt the male students' development of the same skills.

Interactions with faculty. Student-faculty interactions have a positive influence on student development of engineering design and professional skills (Bjorklund, Parente, & Sathianathan, 2004; Colbeck, Cabrera, & Terenzini, 2000; Terenzini, Cabrera, & Colbeck, 2000). Constructive feedback on high-level tasks from faculty to students in engineering is important (Felder & Brent, 2004b). Bjorklund, Parente, and Sathianathan (2004) found that faculty who interact with students and provide them with feedback was the only factor significantly related to all four of the student learning outcomes. They studied: group skills, problem-solving skills, occupational awareness, and engineering competence).

Interaction with faculty may be even more influential for women engineers than male engineers (Robinson & Reilly, 1993; Seymour & Hewitt, 1997; Zeldin & Pajares, 2000; Zhao,

Carini, & Kuh, 2005). In a study of 500 female engineering alumnae, female engineers described their relationships with faculty either as the most beneficial or the most detrimental experience while in college (Robinson & Reilly, 1993). When faculty responded positively to female students, those students gained confidence in their skills (Seymour & Hewitt, 1997). Zeldin and Pajares (2000) also found that supportive faculty members had a positive effect on female students' development of self-worth in math-related abilities, which are critical for engineering.

The industrial engineering program at the University of Oklahoma has had unexpected success in recruiting and graduating female students. Lancaster et al. (2005) interviewed 41 students from this program to find out what might be producing these results. Without prompting, female students were twice as likely to mention interactions with faculty during office hours as having a positive impact. Thus, the researchers suggested that high-quality faculty-student interactions are particularly important for female engineering students (Lancaster et al., 2005).

For female students, a professional relationship with their professor helps them feel connected to that course and the engineering major (Margolis & Fisher, 2002; Seymour & Hewitt, 1997). The type of relationships sought by female engineering students from their faculty advisors differs from that of their male counterparts. Female students say that they want advisors to get to know them as people and establish a personal relationship, while their male peers just want their advisors to give them the facts (Vesilind, 2001). Having a supportive mentor is particularly important to female engineering students, because of their need for inclusion in the engineering field (Bova, 1995; Chesler & Chesler, 2002; Noe, 1988; Single et al., 2000; Wadia-Fascetti & Leventman, 2000). Murphy et al. (2007) interviewed 185 students and 12 faculty

members at four institutions and identified the importance of strong role models to female engineering students' success.

While faculty support is positive for female students, dismissive comments from faculty have a harmful effect on their academic confidence and development (Sax, 1994; Sax, Bryant, & Harper, 2005). Discouraging comments might be more devastating to a female's success in engineering than lack of encouragement. The sense that faculty did not take their comments seriously causes a decline in females' self-rating of mathematical ability (Sax, Bryant, & Harper, 2005). When assessing their own performances, female students tended to relate failure in engineering to a lack of ability, while boys related failure to lack of effort (Burton, 1986). Male students see responsibility for learning as being split between themselves and the instructor (Bock, 1999). Thus, female students, even more so than male students, need reassurance about their abilities from their faculty members. The influence of discouragement ties back into the idea that social interactions are critical to the persistence of females in engineering.

Even through Krause (2006) used race as a backdrop to examine whether discrimination and prejudice affect the quality of the relationships individuals have with others, the findings may be applied to women in a male-dominated field. African Americans have more negative relationships due to discrimination and prejudice. African Americans were found to be subjected to more discrimination and prejudice because so much of their time is spent with white people, who are the majority in society (Krause, 2006). Females in the engineering field are surrounded by males, who make up the majority of students and faculty, and so most of their time is spent with males. Thus, when the findings from Krause's study are applied to the experiences of females in engineering, the perception may be that females in engineering are subjected to more discrimination and prejudice. This exposure to discrimination and prejudice creates opportunities

for negative social interactions and leads to poor levels of persistence and confidence among females in engineering (Seymour & Hewitt, 1997).

In in-depth interviews with 150 computer engineering students from a Minority Serving institution, Varma and Hahn (2007) found that female students were significantly more negative in reporting their experiences in class and with program teachers and advisors, than were male students. The results from Vogt (2008) indicate that unapproachable faculty members decrease students' self-efficacy, academic confidence, and GPA. Seymour and Hewitt (1997) found that poor advising was a key concern for women who switched out of engineering. The advisors would discourage female engineers from continuing their engineering education because the female students did not have a 4.0 grade-point average or might think they are struggling in mathematics. Even females, who successfully completed engineering degrees and stayed in the engineering field, when asked about their learning experiences, said that poor advising hindered their learning because they did not take the classes necessary to develop their skills fully (Robinson & Reilly, 1993).

While the interactions between students and faculty seem to be critical to female students' development, Zhao, Carini, and Kuh (2005) found that females are less likely than male students to interact with their faculty in science, technology, engineering, and mathematics fields. Women had fewer opportunities for valuable informal exchanges with faculty and women are less likely to ask questions in engineering classes than their male peers (Zhao, Carini, & Kuh, 2005). In contrast, in a study of 17,637 students across all college disciplines, women reported more frequent interaction with faculty than men (Sax, Bryant, & Harper, 2005). Although the findings with respect to the frequency of female students' interactions with faculty are

contradictory, both studies found that interactions with faculty increased learning outcomes in both male and female students.

Clarity and organization of instructor. Studies have shown that instructor clarity can have a positive influence on students' development of engineering skills (Colbeck, Cabrera, & Terenzini, 2000; Lambert, Terenzini, & Lattuca, 2007; Lattuca, Terenzini, & Volkwein, 2006; Terenzini, Cabrera, & Colbeck, 2000). Terenzini, Cabrera, and Colbeck (2000) surveyed 1,258 engineering students enrolled at seven institutions. The findings from the self-reported learning gains revealed that both professional skill development and an understanding of jobs in engineering can be enhanced through clear instruction and course structure. In addition, Colbeck, Cabrera, and Terenzini (2000), using the same database, found that instructor clarity and organization were significantly and positively related to increases in students' motivation to become engineers, sense of responsibility for their own learning, expected grades, and likelihood of persisting in engineering. Instructor clarity and organization also had a statistically positive influence on all nine of the engineering learning outcomes in the *Engineering Change* study (Lattuca, Terenzini, & Volkwein, 2006).

Teamwork in Engineering

While teamwork falls under the category of a student experience, it does not fit in either subsection of in-class of out-of-class but instead incorporates both. A new emphasis on teamwork in the engineering classroom room and industry has increased the use of team projects inside and outside of the classroom (Kedrowicz & Nelson, 2007). While males and females may have had different experiences in teams, both genders note the importance of teamwork (Karanian & Okudan, 2006). Working in teams is, in particular, a good match for female students because it requires a collaborative rather than a competitive environment (Rosser,

2001). Learning with peers helps build confidence in engineering students who are unsure of their skills. Thus, it has been suggested that incorporating teamwork into the classroom makes engineering friendlier to female students (Mead, Rosenfeld, & Bigio, 1996; Rosser, 1991, 2001; Tobias, 1990).

Much of the research considering gender in teamwork focused on the gender composition of the team (Cordero, DiTomaso, & Farris, 1996; Herschel, 1994; Johnson & Schulman, 1989; Laeser et al., 2003; Lee, 1993; Rogelberg & Rumery, 1996; Wheelan, 1996; Wheelan & Verdi, 1992). While a few studies indicated that gender composition might not influence teams' performances (Herschel, 1994; Johnson & Schulman, 1989; Kichuk & Wiesner, 1997; Wheelan, 1996), the majority disagreed. Trytten (2001) found in her engineering course that the group of all-female students outperformed all other groups. Okudan, Horner, Bogue, and Devon (2002) measured team performances on two design projects in a semester-long engineering course using team quizzes, scores on design demonstrations, peer evaluations, and blind evaluation of team reports. They discovered that all-male and all-female teams slightly outperformed heterogeneous teams (Okudan et al., 2002). Using a scoring rubric to evaluate the final reports of engineering design teams over two semesters, Moskal, Knecht, and Lasich (2002) also considered the effects of team gender composition on their final product. In the first-semester design course, the highest scores belonged to the all-male teams. In the second-semester course, all-female teams outperformed all other teams (Laeser et al., 2003; Moskal et al., 2002). The female teams also showed the most improvement over the two semesters (Knecht & Carlon, 2002). Putting under-represented students in small groups together has been shown to increase their performance (Tonso, 1996b; Trytten, 2001).

A conversation with a female student revealed that being in a group in which women were the majority was the most significant experience in her engineering education (Trytten, 2001). Women who had at least one other female on their team became more positive about group work than when they entered their program (Hartman & Hartman, 2006). The all-female team said that they did not want to work with male students because the male students were too competitive and did not like to let the women use the equipment (Baker et al., 2007). Many other studies also support the importance of not isolating a female in an otherwise all-male group. When a single female engineering student is in a group of male students, she is less likely to be a full participator in the group (Felder & Brent, 1994; Felder et al., 1995; Haller et al., 2000; Natishan, Schmidt, & Mead, 2000; Rosser, 1997b; Tonso, 1996b). Females reported being more satisfied with their group when they were in all-female and female-majority teams (Knecht & Carlon, 2002). Females' satisfaction also increased with an increase in the proportion of females in the group (Cordero, DiTomaso, & Farris, 1996).

The quantitative and qualitative data collected by Caso et al. (2002) showed positive influences for all students who participated in collaborative learning activities on student persistence and learning. While female engineering students seem to learn more in collaborative teams (Agogino & Linn, 1992; Felder et al., 1995), gender bias in those teams can diminish their effectiveness (Baker et al., 2007; Colbeck, Cabrera, & Terenzini, 2000; Felder et al., 1995; Guzzetti & Williams, 1995; Tonso, Miller, & Olds, 1994). Okudan and Bilen (2003), in a study of 16 design teams in two introduction engineering design courses at the Pennsylvania State University, discovered that when the number of females on a design team increased, the design team's performance decreased. Research has suggested the presence of gender bias on project teams (Halterman, Dutkiewisz, & Halterman, 1991). Males assumed that their female

counterparts could not do the actual work and forced them to write the report instead (Caso et al., 2002). The students who were interviewed were not interested in this stereotypical role and felt that they had to constantly prove themselves to their male teammates. The result of this need to prove their worth caused females to feel less free to ask questions because doing so meant they risked being labeled “the dumb girl.”

Some of these biases might stem from differences in female and male communication in groups (Andrews, 1992) and in the differences in the types of questions asked by females than by males in those same teams (Hawkins & Power, 1999). Several studies provided evidence that suggests that teamwork may be a negative experience for female students in engineering, because the large number of males in the discipline makes female students feel isolated and under-valued (Hartman & Hartman, 2006; Kaufman, Felder, & Fuller, 2000; Light, 1990; Moskal, Knecht, & Lasich, 2002; Okudan & Mohammed, 2007; Tannen, 1993). Some female engineering students indicated a preference for working alone because their contributions in small mixed-sex groups were not valued (Light, 1990). Hartman and Hartman (2006) followed a group of students at Rowan University over two semesters of design courses. When female engineering students entered their program, they showed a greater preference for group work than did their male counterparts. By the end of the first year of teamwork, female students who were in groups with all males were less enthusiastic about group work. This decline in preference for group work was due to negative experiences in these groups (Hartman & Hartman, 2006). Moskal, Knecht, and Lasich (2002) found that mixed-gender teams had the lowest performances across both semesters. The researchers suggested that because engineering has been a male-dominated field for so long, the ability to interact with female students has not been a skill taught in engineering (Moskal, Knecht, & Lasich, 2002). In two sophomore-level chemical engineering

courses, students rated their group experiences. Group averages were slightly higher for all-male and all-female groups in one course than for mixed-gender teams, while no differences were found in the other course (Kaufman, Felder, & Fuller, 2000).

Some disagreement exists about whether male and female students act differently in groups. Moskal, Knecht, and Lasich (2001) found no differences in behavior between male and female leaders of engineering design teams. In addition, no gender differences were found in the task and process roles taken by engineering students (MacDonell-Laeser et al., 2001; Okudan, 2004). However, differences in the behaviors of members on teams of different gender compositions were found in encouragement and goal-setting levels. Knecht and Carlon (2002) found gender differences in task and process roles when a team's gender composition was also considered. In heterogeneous teams, male members concentrated on the task functions and female team members had a more integrated approach that incorporated both task and team functions. All-male teams are more likely to encourage their fellow members to participate and to set goals for each team member (MacDonell-Laeser et al., 2001). Baker et al. (2007) observed engineering groups in the classroom and found that the teams that were all-female and mixed-gender were more collaborative but developed solutions more slowly than the all-male teams. Johnson and Schulman (1989) discovered that as the age of each gender decreased in a group, women were more likely to focus on process and males were more likely to be task-oriented, and while being the only male was advantageous for males, being the only female was not for females. Laeser, Moskal, Knecht, and Lasich (2003) observed team interactions and found that members of male majority teams were more likely to clarify and set standards during meetings than members of female majority teams.

Women also seem to have different reasons for appreciating teamwork. Female engineering students appear to like group work because it offers the opportunity for help and support from group members in understanding difficult material, while male students regarded teamwork as beneficial because of the opportunity it offers to reinforce learned material with their teammates (Felder et al., 1995; Hartman & Harman, 2006).

As Tonso (2006) pointed out, not all groups are created equal. Tonso conducted an ethnographic study of two teamwork cases to explore engineering students' interactions and gender hierarchies. He found a power differential between male and female engineering students in teamwork. Tonso argued that professors need to provide more guidance on effective teaming, because the research shows that instructing students in collaborative behaviors when they are working in teams has a positive impact on the learning experience of everyone on the team (Baker et al., 2007; Cohen, 1994; Lew et al., 1986). In order to improve functions within teams, Tonso (2006) suggested that faculty teach students how to respect one another and give students constant feedback. In addition, teams should either be all male and female teams or have balanced gender compositions in order to reduce conflict (Tonso, 2006).

Chilly Climate

As suggested by the causal chain in Figure 2.1, students' experiences affect their learning. The climate in engineering encompasses both in-class and out-of-class experiences, so it cannot be included in only one. Thus, climate and its effects on learning are discussed in this section. A great deal of the literature on women's persistence and academic performance in engineering focused on a "chilly climate" or an unwelcoming atmosphere. The climate has been suggested to play a significant role in both women's decisions to stay in the engineering major and their ability to academically succeed in engineering (Harris et al., 2004; Lee, 2002; Salter &

Persaud, 2003; Seymour & Hewitt, 1997; Whitt et al., 1999). “Male-normed classrooms, often dubbed ‘chilly’ climates for women, have generally been described in the literature as competitive, weed-out systems that are hierarchically structured with impersonal professors” (Vogt, Hocevar, & Hagedorn, 2007, p. 339). Women who were confident of their abilities when they entered college, after experiencing the engineering climate, questioned whether they fit in the engineering program at all (Bergvall, Sorby, & Worthen, 1994; Collins, Bayer, & Hirschfeld, 1996; Ginorio, 1995; Lawal, 2007; Nauta, Epperson, & Kahn, 1998; Rosser, 1995; Seymour, 1995; Seymour & Hewitt, 1997). This could be due to the fact that women are less effective in competitive environments (Gneezy, Niederle, & Rustichini, 2003), and engineering is a very competitive environment (Henes et al., 1995; Vogt, Hocevar, & Hagedorn, 2007; Sax, 1994).

In addition, some of the existing literature focused on the level of peer and faculty encouragement when discussing department climate and women’s decisions to leave engineering (Harris et al., 2004; Lee, 2002; Salter & Persaud, 2003; Seymour & Hewitt, 1997). Peer and faculty attitudes may be the most critical component in predicting discriminatory practices or perceptions (Harris et al., 2004). If women feel supported and encouraged by others in the department, they may be more likely to persist.

Some researchers wonder if the chilly climate still exists or if other factors contribute more to the departure decision than discrimination, however subtle, against women. Zhao et al. (2005) found that an inhospitable climate does exist but women find ways to deal with it. Harris et al. (2004) found that even in a department with gender equity in the number of female and male students, women still perceived a somewhat negative atmosphere. However, Steele, James, and Chait Barnett (2002) found students reported finding a less negative atmosphere than

expected, and Serex and Townsend (1999) reported finding no difference in men's and women's perceptions of the climate in engineering; both rated it low.

Out-of-Class Experiences

The final set of links in the causal chain leading to students learning is explored in this section. As suggested by Figure 2.1, out-of-class experiences may have effects on students' development of their engineering skills. Most of the research on how college affects students included either in-class or out-of-class experiences, but few incorporated both at the same time. There were some exceptions (see Kuh, 2001; Pascarella et al., 1996; Springer, Terenzini, Pascarella, & Nora, 1995; Terenzini, Springer, Pascarella, & Nora, 1995). Hagler and Marcy's study stressed the importance of out-of-class experiences on design development (1999). To understand the influences of college on engineering students' learning outcomes, both in and out-of-class experiences need to be included in any analysis.

Before the *Engineering Change* research project, much of the engineering education research left out these critical influences on students' skill development (Strauss & Terenzini, 2005). The *Engineering Change* research team decided on six out-of-class experiences that were directly related to engineering and believed to affect students' engineering development. The six out-of-class experiences chosen were: involvement in an internship or collaborative education programs, formal study abroad, informal international travel, participation in student engineering design competition(s), involvement in a student chapter of a professional society or association, and perceptions of the diversity climate in their program (Lattuca, Terenzini, & Volkwein, 2006). The literature in each of these areas is discussed below.

Internship/cooperative education. Several studies suggested that participating in internships and cooperative education experiences have positive impacts on engineering

students' learning (Blair, Millea, & Hammer, 2004; Gardner, Nixon, & Motschenbacker, 1992; Lattuca, Terenzini, & Volkwein, 2006; Lindenmeyer, 1967). In 1906, the University of Cincinnati instituted cooperative education as part of the curriculum for engineering students. Cooperative education continues to be part of the curriculum for engineering programs across the United States. Cooperative education gives students a chance to gain experience in the work world and then integrate it with coursework concepts (Blair, Millea, & Hammer, 2004). Several studies suggested that cooperative education results in higher GPAs and starting salaries for students (Blair, Millea, & Hammer, 2004; Gardner, Nixon, & Motschenbacker, 1992; Lindenmeyer, 1967). Blair, Millea, and Hammer (2004), when studying graduates from the Mississippi State University, found that students who participated in cooperative education took two semesters longer to complete their undergraduate degrees than students who did not. The particular conditional effects by gender of internships and cooperative education also need to be explored to ensure that female students' experiences in these opportunities are not deterring them from entering the engineering workforce (Blair, Millea, & Hammer, 2004; Seymour & Hewitt, 1997).

Design competitions. While participation in design competitions has been shown to have a positive influence on engineering outcomes for both male and female students (Colbeck, Cabrera, & Terenzini, 2000; Lambert, Terenzini, & Lattuca, 2007; Lattuca, Terenzini, & Volkwein, 2006), studies that included only women in their analysis found that involvement in these team projects can reinforce the negative effect of the chilly climate (Colbeck, Cabrera, & Terenzini, 2000). When considering 2004 male and female graduates in the *Engineering Change* study, even after controlling for all in-class experiences and precollege characteristics, involvement in a design competition had a positive statistically significant effect on six of the

nine learning outcomes, including both design and problem-solving-skills and group skills (Lattuca, Terenzini, & Volkwein, 2006). “While team-based design projects may lead to gains in students’ self-perceptions and professional competencies, team projects can also create a chilly climate for women due to increased potential for conflict during small group interactions” (Colbeck, Cabrera, & Terenzini, 2000, p. 5).

Professional society chapters. Participation in a professional society has been reported to increase students’ development of engineering learning outcomes (Lambert, Terenzini, & Lattuca, 2007; Lattuca, Terenzini, & Volkwein, 2006; Robin & Reilly, 1993). Robin and Reilly (1993) surveyed 500 female alumnae in professional careers in the engineering field. Seventy percent of these alumnae as undergraduates had been part of student professional societies and 20% held offices in the organizations. These female alumnae reported that holding these positions increased their skill levels and helped them prepare for their careers. Lattuca, Terenzini, and Volkwein (2006) found that involvement in professional society chapters had a significantly positive effect on six of nine learning outcomes, including both design and analytical skills and group skills. In an analysis of the same dataset, Lambert, Terenzini, and Lattuca (2007) found that involvement in a professional society was no longer a significant predictor of group skills, after controlling for program changes and faculty activities. Participating in a student chapter of a professional society, however, remained a significant influence on design and analytical skills even after controlling for program changes and faculty activities. Schulz et al. (1998) indicated that peer support systems and involvement in campus organizations positively influenced students’ academic success, especially for female engineering students. These studies suggest the importance of encouraging students to join a professional society chapter at their institution.

In addition to the professional society chapters created for all students, many institutions have incorporated societies specifically for women engineers. These societies are designed to create warmer climates for women and give them a forum for support and networking (Marra & Bogue, 2003). While these societies had the best intentions, some recent studies suggested that they may only be reinforcing the stereotype that female engineers need extra help and are not equal with their male counterparts (McLoughlin, 2005). McLoughlin (2005) studied 28 female engineering students in the Society of Women Engineers at nine large institutions and 13 small private institutions longitudinally over two years. She found that all but two of the women were unsupportive of the women in engineering programs and felt that their experience was negative. "Students targeted by these programs, the goal of which was to make them more comfortable and successful in their chosen field, instead felt less comfortable and more ostracized due to the implication that their gender defines their academic engineering ability and identities" (McLoughlin, 2005, p. 376). The author of this paper recommended eliminating programs that use demographics as their basis and make sure that support programs teach all students to be respectful and professional.

Implications for Higher Education

It is important to understand the differences in women's learning styles in order to find the best way to produce female graduates with the skills needed in the workplace. "Education and clinical services do not adequately serve women's needs" (Belenky, Clinchy, Goldberger, & Tarule, 1986, p. 8). Higher education administrators should realize that women learn in a different way and not at an inferior rate to men so that educators and programs do not belittle their skills development.

Responding to individual students' needs at each level of learning can strengthen the overall educational experience in and outside of the classroom (Baxter Magolda, 1992). After identifying the gender patterns in development and learning, significant differences are revealed that lead to the conclusion that males and females may need different challenges and support systems to ensure their future skill levels. Evidence points to learning as an activity that displays gender patterns based on peer relationships and learning styles. For females, the learning relationship with peers differs from the learning relationship with peers that male students seem to prefer. By gaining an understanding of the experiences that encourage women's learning and by expanding our definitions of that learning process, higher education administrators and educators can ensure that they do not marginalize female students.

Given the review of the current literature, this study focuses on the exploration of the conditional effects of program changes, faculty activities, and students' experiences in the male-dominated field of engineering. The next chapter summarizes the methods used to answer the five questions of this study:

1) Have the changes made by programs and faculty members in response to EC2000 produced gender-related differences in students' experiences?

2) Have gender gaps in design and problem-solving skills, group skills, and societal and global issues awareness closed?

3) Have the changes made by programs and faculty in response to EC2000 varied by gender in their effects on students' experiences while in college?

4) Have the changes in program curricula and faculty practices had a different effect on female engineering students' development of design and problem-solving skills, group skills, and societal and global issues awareness than that of men?

5) Do engineering students' in-class and out-of-class experiences have the same effects on female students' development of certain engineering abilities as on male students' development of the same abilities?

Chapter 3

Research Methods

The intricate and multi-faceted design of the *Engineering Change* study (Lattuca, Terenzini, & Volkwein, 2006) provides an excellent dataset for a 360-degree examination of engineering programs. In 2004, information was collected from graduates of engineering programs who received their degrees in 1994 and 2004, faculty, and program chairs in 147 programs at 39 different institutions. Thus, the dataset allows for an exploration of the possible differences in the effects of student experience on learning outcomes for female students compared to male students. Because this study is a secondary data analysis, unless otherwise noted, the description of the design, population, sample, data collection, and variables follows the depiction also found in chapter two of the *Engineering Change* study.

Conceptual Framework

The *Engineering Change* study assessed the changes in student learning associated with the implementation of the new *Engineering Criteria 2000* (EC2000) accreditation standards (ABET, 1997). In *Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States* (ABET, 1997), the Accreditation Board for Engineering and Technology (ABET) shifted the focus of engineering program review from resources, faculty, and facilities, to what students were learning in their programs. The new EC2000 standards specified 11 learning outcomes that continued to stress technical engineering skills while also emphasizing the more professional "soft" skills absent from earlier requirements. The technical skills included students' development of such learning outcomes as mathematical, scientific, and basic engineering knowledge. Professional skills included working in teams, understanding contemporary and ethical issues, and communicating effectively. The complete list of technical

and professional skills is given in Table 3.1 (Lattuca, Terenzini, & Volkwein, 2006). Expanding the intellectual skills of graduates of engineering programs is the definitive goal of EC2000 (Prados, Peterson, & Lattuca, 2005).

Table 3.1. *EC2000 Criterion 3 Learning Outcomes*

a. An ability to apply knowledge of mathematics, science, and engineering
b. An ability to design and conduct experiments, as well as to analyze and interpret data
c. An ability to design a system, component, or process to meet desired needs
d. An ability to function on multi-disciplinary teams
e. An ability to identify, formulate, and solve engineering problems
f. An understanding of professional and ethical responsibility
g. An ability to communicate effectively
h. The broad education necessary to understand the impact of engineering solutions in a global and societal context
i. A recognition of the need for, and an ability to engage in life-long learning
j. A knowledge of contemporary issues
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Source: Lattuca, Terenzini, & Volkwein (2006)

As discussed in chapter two, the conceptual framework used for this study was created using the hypothesized relationships for student learning in the *Engineering Change* study (Lattuca, Terenzini, & Volkwein, 2006). Figure 3.1 (the same as Figure 2.1) illustrates these relationships. First, the conceptual framework implies that the new EC2000 accreditation standards will influence the curriculum and instructional practices in engineering programs. Next, the alterations to curriculum, instruction, culture, practices, and policies then might lead to a shift in student experiences both in and outside of the classroom. Finally, the model suggests that these differences in students' experiences influence differences in student learning. The present study examined whether certain student experiences implied in the model have the same effects on women as on men. In addition to the change in focus to gender conditional effects, the current study also explored the conditional effects of program changes on student learning. In particular, the current study examined differences between male and female students'

experiences and, ultimately, in the development of their design and analytical skills, their ability to function in a group, and their awareness of societal and global issues. For a more detailed discussion of this framework, refer to chapter two.

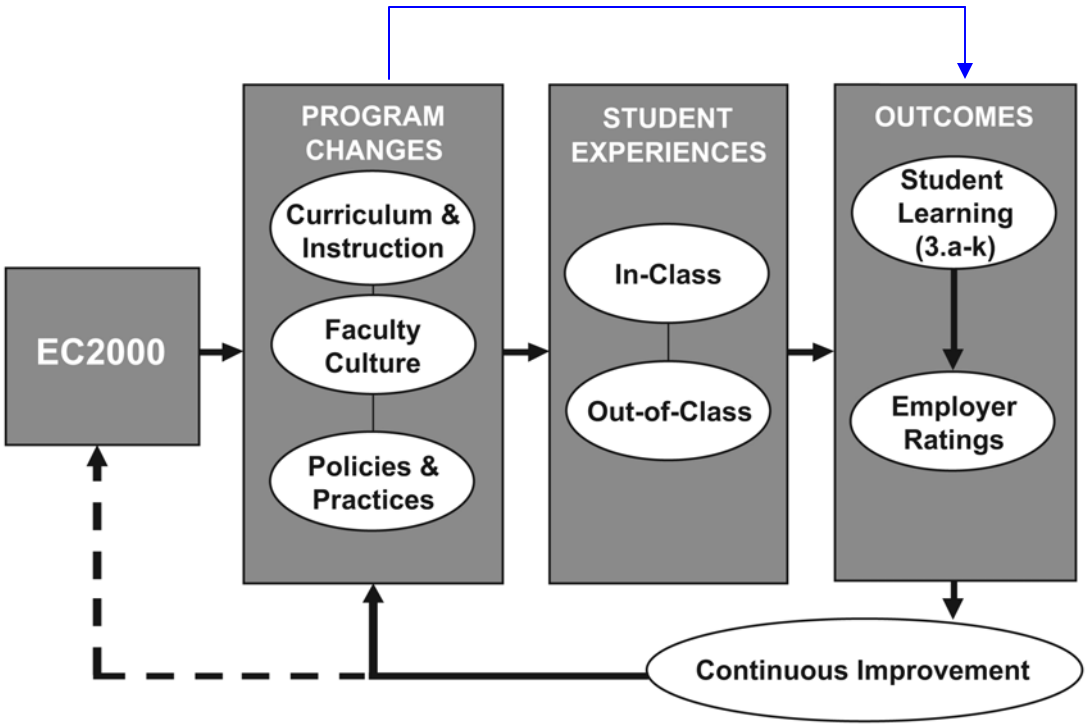

Figure 3.1. Conceptual Framework for the Engineering Change Study

Design

The *Engineering Change* study was a large, national examination of the effects of ABET's new accreditation standards for undergraduate engineering programs (Lattuca, Terenzini, & Volkwein, 2006). The research group adopted a quasi-pre-/post-test, cross-sectional, *ex post facto* design that involved surveys of engineering graduates in 1994 and 2004. The present study was a secondary data analysis of the *Engineering Change* database and used survey data from the *Engineering Change* study collected from the graduates in both years.

Population and Sample

The population for the *Engineering Change* study included all students who graduated in 1994 or 2004 from ABET-accredited undergraduate engineering programs that offer at least two of seven engineering disciplines: aerospace, chemical, civil, computer, electrical, industrial, and mechanical (Lattuca, Terenzini, & Volkwein, 2006). The target population included 1,241 ABET-accredited engineering programs, of which 1,024 offered at least two of the seven specified disciplines. Five of these seven disciplines produce 75% of the undergraduate engineering degrees in any given year (chemical, civil, electrical, industrial, and mechanical), and the remaining two (aerospace and computer) were included because of their strong links with industry sectors. According to the U.S. Department of Education (2006), two of these disciplines produce the largest amount of female engineering graduates by proportion (industrial and chemical), as well as disciplines that produce some of the smallest proportions of female engineering graduates (aerospace, electrical, and mechanical).

The *Engineering Change* study dataset was created using a two-stage, 7x3x2, disproportional, stratified random sample. The first stage entailed random selection of 40 institutions across the three strata. The first stratum was discipline. The second stratum was the EC2000 review cycle, which was included in the sampling design because of a belief that when the program adopted the new accreditation standards might influence the degree of change in faculty activities, program policies, and student learning. Three categories make up the EC2000 review cycle strata. The first category includes institutions that decided to be reviewed earlier than required. The second group contained programs that were undergoing a mandatory review under EC2000, and the third was those programs that deferred EC2000 review when they had that option. Finally, the third stratum included institutions that were in a National Science

Foundation Engineering Education Coalition. The NSF coalitions were an important factor because they were leaders in developing the ABET criteria. There was also a disproportional over-sampling of programs with fewer graduates (industrial and aerospace).

The sample also included four EC2000 pilot institutions, which were first reviewed in 1996 and 1997, several Historically Black Colleges and Universities (HBCUs), and Hispanic Serving Institutions (HSIs) to ensure that underserved populations were more numerous. After all data for the engineering change study had been collected, the final sample included 39 institutions with 147 programs.

Data Collection

The data collection for the *Engineering Change* study had multiple stages and sources. Surveys were sent to all graduates from both 1994 and 2004 in the sampled programs. For each program, the faculty and engineering program chair or chairs were surveyed and the dean was interviewed. Finally, engineering employers were surveyed as well. The data from the employers and the qualitative interview data from the deans were not used in this study. The graduates from 1994 and 2004, faculty, and program chair data collection are discussed next.

Students. The first source of data was the 1994 and 2004 engineering graduates at the participating institutions. Because part of the *Engineering Change* study was an interest in differences in learning outcomes between 1994 graduates and 2004 graduates, the study design required use of the same procedures with both groups of graduates (the only difference being some of the closing questions on the survey instrument, discussed later). The Survey Research Center (SRC) at Pennsylvania State University distributed and collected the surveys for both cohorts of graduates. In order to increase response rates, participants could choose to take the survey by paper-and-pencil or on-line. Personally addressed packets containing a cover letter

from the project directory, an explanation of their rights as participants, a paper survey, and a return envelope with prepaid postage were sent to each of the graduates. The cover letter provided a description of the study, the e-mail address and phone number to which to address questions, and the names of the project sponsors. Each packet also gave graduates the address of the web-based version of the survey and a $2.00 incentive to encourage their participation.

Following Dillman (2000), the survey dissemination progressed in three stages. The original packets were sent out in mid-February 2004. To ensure the likelihood of participation by students about to graduate in 2004, the deans of each of the campuses were asked to send emails to students encouraging them to complete the surveys. The survey instrument can be seen in Appendix A. After about two weeks, all sampled graduates received a postcard reminder. A month following the initial packet, the sample members who had not yet responded to the survey received a packet including the complete set of survey materials again. SRC gathered all of the paper surveys, scanned the responses, and merged those data with the on-line responses. SRC then removed all identifying information before releasing the dataset to the research team.

The student survey instrument collected information from the engineering graduating seniors for 1994 and 2004 on precollege characteristics (e.g., basic demographic information and preparation levels); students' in-class experiences, perceptions of program and class climate, involvement in out-of-class engineering-related activities; and self-reports of their learning on the 11 EC2000 3.a-k outcomes criteria. For this analysis, the self-reports of greatest interest are skill levels in engineering design and analysis, working in groups, and awareness of societal and global issues.

The 39 selected institutions identified 15,734 individuals as graduates in 1994 from the seven engineering programs in the *Engineering Change* study (Lattuca, Terenzini, & Volkwein,

2006). In the spring semester of 2004, the entire population of undergraduate graduates from 1994 received the student survey instrument. Of the graduates who were mailed survey forms, 5,494 1994 graduates responded, for a total of 5,336 usable cases and a usable response rate of 34%. The usable responses were those remaining after removing surveys missing more than 20% of the requested information. To avoid the use of listwise deletion and loss of other cases missing even one response, in the usable student and faculty cases expected maximization procedures were used to impute the missing data for the continuous items (Allison, 2001). Since gender was not imputed, 5,335 cases remained after removing those cases in which gender was missing. Of those cases, 928 were female graduates and 4,407 male graduates.

The 39 selected institutions identified 12,144 individuals as 2004 graduates from the seven engineering programs (Lattuca, Terenzini, & Volkwein, 2006). These graduating seniors were mailed survey forms in the spring semester of 2004 (Appendix B). Of the surveys mailed out, 4,543 graduating seniors completed the survey, with 4,330 usable cases and a usable response rate of 36%. The continuous items from the usable graduating senior cases were imputed using expected maximization procedures (Allison, 2001). Since gender was not imputed, 4,158 cases were remaining after removing those cases in which gender was missing. Female graduates composed 21.4% of the cases (888) and male graduates, 78.6% (3,270). Of the original 40 participating institutions, one did not return any student responses. This institution was removed from the study, thus reducing the institutional sample to 39 schools.

To test whether the graduate respondents were representative of the larger population in their corresponding graduating class, Chi-square goodness-of-fit tests were done. These statistical tests indicated that the 1994 graduating senior respondents were not biased with respect to the control (public or private) of the institutions attended, but were slightly

unrepresentative of the population with respect to gender (females were overrepresented) and engineering discipline. Weights were calculated to correct for both of these biases. The tests also unveiled an under-representation of students at research institutions, and an over-representation of students at baccalaureate and master's institutions. To correct for these biases, weights were derived to align the respondents' distributions with those of the national population for both the students' engineering disciplines and genders.

Chi-square goodness-of-fit tests also indicated that respondents from the 2004 graduating class were representative of that population with respect to the institutions' control (public or private), but there were slight gender and engineering discipline biases. The tests revealed that students at research institutions were over-represented, while students at master's institutions were under-represented. In order to correct for these biases, weights were derived to align the respondents' distributions with those of the national population for the students' engineering disciplines and genders.

Faculty. The study design also entailed surveying all the engineering faculty in any of the seven programs offered on a participating campus. As with the methods used in the student surveys, the SRC mailed packets to each of the faculty. Deans sent preliminary emails encouraging participation, follow-up postcards were sent two weeks after the initial survey, and then after another two weeks a complete packet was mailed to faculty members who had not completed the surveys. The packets sent to the faculty members consisted of a cover letter explaining the study's purpose, a respondent's rights, a copy of the survey instrument (Appendix C), a postage-paid return envelope, and the website where faculty could take the survey on-line if they preferred. The surveys were collected by the SRC. The data were cleaned, and all identifying information was removed before the dataset was released to the research team.

Faculty members reported on changes in their instructional approaches and other professional practices and development activities over the past decade. The first section of the survey collected information on faculty members' demographic and professional characteristics, such as their teaching experiences, academic title, tenure status, and engineering discipline. The following items on the questionnaire asked faculty to describe a course that they taught regularly. They were asked about enrollment in the course, 14 curricular topics related to the EC2000 standards, changes in the type of pedagogies they employed, and the influences causing them to make changes to their courses. The instrument also delved into faculty perceptions in several areas of student learning. The survey requested their perceptions of how their curricular and pedagogical changes had increased or decreased the EC2000 Criterion 3.a-k skills of graduating seniors over the graduates from the previous seven to ten years. This section also asked faculty about their professional development activities, changes in the faculty reward system, their emphasis on assessment and continuous improvement, and their current curricular planning.

During the fall 2003 semester, a total of 3,303 faculty members were identified by their institutions and contacted for the *Engineering Change* study. A total of 1,272 faculty members responded, providing 1,201 usable responses (36%). Usable responses were defined as those with less than 20% of the data missing. Finally, expected maximization procedures were used to impute all of the missing data on the continuous items (Allison, 2001).

As with the student data, the distribution of faculty respondents was compared with the distribution of the population using Chi-square goodness-of-fit indices. Tests indicated that faculty members were representative based on the type and control of institutions at which they taught. There was a slight bias with respect to gender (females were overrepresented), discipline,

and institutional membership in an NSF-Coalition (those in NSF were overrepresented). Weights were created to adjust for these biases.

Program Chairs. The data collection procedures used with the program chairs followed those for both cohorts of students and faculty. Participating institutions supplied the names and addresses for the program chairs of all sampled programs. The packets were also very similar to the previous packets, containing a cover letter on the purpose of the *Engineering Change* study, a letter explaining participants' rights, the paper survey, a return pre-paid envelope, and the website location of the on-line version of the survey instrument for those who preferred that format. After two weeks, a follow-up reminder e-mail was sent to those chairs who had not responded to the initial packet. A month after the initial mailing, the SRC sent a second complete packet to each of the program chairs who still not had responded. In addition, phone calls were made to each non-responding program chair. The SRC compiled the completed surveys and completed the data-cleaning of the responses before the dataset was released to the research team.

Respondents answered questions about a wide array of program characteristics and the changes made to the curriculum since the implementation of the EC2000 accreditation standards. The first section of the survey asked basic questions about the program, such as when students have to declare their major and policies about cooperative education. The section collected information about the changes made to the curriculum in the time following the new EC2000 standards. Chairs also answered questions on the impact of ABET accreditation on curriculum planning and course assessment. Next, the questionnaire gathered information on the extent of program chairs' knowledge of the EC2000 review and the EC2000 3.a-k outcomes criteria. The last section of the survey instrument asked about the demographic and professional

characteristics of the program chair, such as gender, teaching experience, and their engineering discipline. The full survey instrument is provided in Appendix D.

In November 2003, the SRC sent surveys to 203 engineering program chairs. Of the surveys mailed out, 147 (72%) on 39 campuses provided usable responses. None of the surveys had fewer than 20% percent of the questions with missing responses.

As with the student and faculty data, Chi-square goodness-of-fit tests were calculated to judge whether the responding program chairs were representative of the population. These tests suggested a slight imbalance in institutional type: respondents were over-representative of chairs at master's-level institutions and under-representative of chairs at research institutions and publicly controlled institutions when compared with the population. Weights were created to eliminate the response bias for institutional type and NSF Coalition membership.

Variables

Dependent variables. To operationalize the 11 learning outcomes criteria in the EC2000 accreditation standards, factor scales (Armor, 1974) were created from 36 survey questions that had been developed through lengthy discussion, student focus group testing, and consultation with engineering faculty and administrators at the Pennsylvania State University. The graduates from 1994 and 2004 were asked to rate their engineering abilities on items related to each of the 11 learning outcomes, using a 5-point scale in which 1 = "No Ability" and 5 = "High Ability." Principal components factor analyses with Varimax rotation produced nine factors. The nine-factor solution retained 75.3% of the overall item variance for the original 36 survey items. All of the factor components loaded above .40 on a single factor; none loaded above .45 on more than one factor (for the full factor structure and scale reliabilities, refer to Lattuca, Terenzini, & Volkwein, 2006).

Three of these nine factors were the dependent variables in this study. Table 3.2 portrays the item composition of these three scales and their internal consistency reliabilities (Cronbach's alpha). The three factors selected for this study dealt with students' group skills, their design and analytical skills, and their awareness of societal and global issues. The factor scale alpha for the "Design and Analytical Skills" scale was .92; for the "Group Skills" scale, .86; and for the "Societal and Global Issues Awareness" scale, .92. The factor scale scores were calculated by summing students' responses to each item loading above .45 on a component and dividing by the number of items in the scale (Armor, 1974).

The Design and Analytical Skills factor scale measures students' ability to solve engineering problems for which there is no single solution. The Group Skills factor scale reflects students' abilities to work successfully in a team with others to accomplish a goal. The Societal and Global Issues Awareness factor scale evaluates students' understanding of contemporary issues and engineering solutions' impacts on those society, in local and global contexts.

Table 3.2. *Factor Structure of Items Operationalizing Two Learning Outcomes Criteria*

Scale Label and Highest Loading Items	Number of Items	Factor Loadings	Scale Alpha
Design and Analytical Skills	6		.92
Design solutions to meet desired needs		.78	
Apply systematic design procedures to open-ended problems		.77	
Define key engineering problems		.76	
Formulate a range of solutions to an engineering problem		.75	
Understand essential aspects of the engineering design process		.66	
Apply discipline-specific engineering knowledge		.47	
Group Skills	3		.86
Work with others to accomplish team goals		.86	
Work in teams of people with a variety of skills and backgrounds		.84	
Work in teams where knowledge and ideas from multiple engineering disciplines must be applied		.67	
Societal and Global Issues Awareness	5		.92
Understand contemporary issues (economic, environmental, political, etc.)		.80	
Understand that engineering decisions and contemporary issues		.79	
Understand the impact of engineering solutions in a societal context		.77	
Use knowledge of contemporary issues to make engineering decisions		.76	
Understand the impact of engineering solutions in a global context		.76	

Source: Lattuca, Terenzini, & Volkwein (2006)

Independent variables. The predictor variables for this study fell into five categories. The first set of variables was the covariates and included students' precollege characteristics, such as sociodemographic traits, personal demographics, and the students' academic preparation. The second group of variables consisted of the institutional characteristics. These traits included such features as Carnegie classification, institutional size and wealth, and type of control. The third set consisted of four scales measuring changes in engineering program characteristics, such as

curricular emphases. The fourth area included the faculty variables, which was five scales measuring faculty members' changes in their instructional practices and attitudes, as well as the faculty culture, over the past five to seven years. The final group of variables was the student experience set, which consisted of ten items reflecting students' in- and out-of-class activities relevant to engineering education. With only three exceptions, the alpha reliabilities for all student, program, and faculty factor scales were greater than .70. Table 3.3 describes the operational form of these and all other variables used in the analysis. This table also has the variables divided into their location in the level of analysis. Level-one of the HLM analysis was at the student level and level-two was at the program level. The level-one model explains the within-institution variance, and the level-two model does the same for the between-institution variance.

For each of the five faculty scales, an aggregate score at the program level was created by averaging all faculty scores on each scale fro all faculty members in each program within a particular institution. Each of these program-level faculty composite scores was then assigned to each individual graduate within the same program and institution. Program-level factor scores were also matched with individual students within the particular program chair's program and institution. Thus, for each individual student case, corresponding faculty and program factor scale scores were assigned, so that each case contained graduate, faculty, and program data.

Table 3.3. *Variables to be Used in HLM Analyse*s

Level One[a] Variables

1. Students' Precollege Characteristics

Age: Actual years

Sex: 1 = male, 0 = female

Transfer status: 1 = native freshman on entry, 0 = transfer

Citizenship: 1 = U.S. citizen, 0 = not a U.S. citizen

Race/Ethnicity: Black/African American, Hispanic or Latino, Asian, American Indian/Alaskan Native, Hawaiian or Pacific Islander, and other, each coded as a dummy variable (1 or 0) with white used as the comparison group

Family income: 9-point scale, where 1 = below $20,000 and 9 = more than $150,000

Highest level of education attained by mother: 4-point scale, where 1 = high school diploma, GED, or less and 4 = advanced degree

Highest level of education attained by father: 4-point scale, where 1 = high school diploma, GED, or less and 4 = advanced degree

SAT scores: Actual scores on both the math and verbal sections of the SATs

Overall high school GPA: 6-point scale, where 1 = below 1.49 (below C-) and 6 = 3.5 to 4.0 (A to A-)

Preparation for basic science and math courses when entering college: An Individual's response to the question: How well prepared were you for basic science and math courses when you entered college? On a 4-point scale, where 1 = not at all and 4 = very well prepared

2. Student reports of in-class and out-of-class activities relevant to engineering

Clarity and Organization Scale: An individual student's score on a 3-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in their classes. Constituent items: "Assignments and class activities were clearly explained;" "Assignments, presentations, and learning activities were clearly related to one another;" "Instructors made clear what was expected of students in the way of activities and effort." (Alpha = .82)

Collaborative Learning Scale: An individual student's score on a 7-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in their classes. Constituent items: "I worked cooperatively with other students on course assignments;" "Students taught and learned from each other;" "We worked in groups;" "I discussed ideas with my classmates (individuals or groups);" "I got feedback on my work or ideas from my classmates;" "I interacted with other students in the course outside of class;" "We did things that required students to be active participants in the teaching and learning process." (Alpha = .90)

[a] Level-one, or the student level, includes the variables explaining the within-program variance.

Table 3.3 (cont'd.)

Instructor Interaction and Feedback Scale: An individual student's score on a 5-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in their classes. Constituent items: "Instructors gave me frequent feedback on my work;" "Instructors gave me detailed feedback on my work;" "Instructors guided students' learning activities rather than lecturing or demonstrating the course material;" "I interacted with instructors as part of the course;" "I interacted with instructors outside of class (including office hours, advising, socializing, etc.)." (Alpha = .87)
Program Encouragement for Openness: An individual student's score on a 4-item scale (where 4 = almost always, to 1 = almost never) assessing how often things happened in the program both in-class and out-of-class. Constituent items: "My engineering courses encouraged me to examine my beliefs and values;" "My engineering courses emphasized tolerance and respect for differences;" "My department emphasizes the importance of diversity in the engineering workplace;" "My engineering friends and I discussed diversity issues." (Alpha = .74)
Perceived Program Climate: An individual student's score on a 4-item scale assessing how often things happened in the program when out-of-class. Constituent items: "In my major, I observed the use of offensive words, behaviors, or gestures directed at students because of their identity" (4 = almost never, to 1 = almost always) rescaled to 5 points to become a scale with other items; "I was harassed or hassled by others in my major because of my identity" (4 = almost never, to 1 = almost always) rescaled to 5 points to become a scale with other items; "I know some students who feel like they don't fit in this department because of their identity" (5 = strongly disagree, to 1 = strongly agree); "The faculty in my department are committed to treating all students fairly (5 = strongly agree, to 1 = strongly disagree)." (Alpha = .57)
Internship/Cooperative Education Experience: A single item with a 5-point scale, measuring the months as an intern or cooperative education student, where 1 = none and 5 = more than 12 months
Study Abroad: A single, 5-point item, measuring the months in a study abroad program, where 1 = none and 5 = more than 12 months
International Travel: A single, 5-point item, measuring the months spent traveling internationally (not study abroad), where 1 = none and 5 = more than 12 months
Participation in Design Competition: A single, 5-point item, measuring the months spent in student design projects beyond classroom requirements, where 1 = none and 5 = more than 12 months
Involvement in Professional Society Chapter: A single, 4-point item, measuring the level of activity in a student chapter of a professional organization, where 1 = not at all and 4 = highly

Table 3.3 (cont'd.)

Level Two[b] Variables

3. Institutional Characteristics

Type of control: 1 = public, 0 = private

NSF Coalition participation: 1 = member of coalition, 0 = not a coalition member

EC2000 review schedule: early (1998-2000) and on-time (2001-2003) – each coded as a dummy variable (1 or 0) with late (2004-2006) used as the comparison group

Carnegie classification: Carnegie Research Extensive, Carnegie Research Intensive, and Carnegie Masters – each coded into dummy variables (1 or 0) with Carnegie Bachelors as the comparison group

Wealth: Average salary of full professors in engineering, converted to z-scores

Size: Number of undergraduate engineering degrees awarded in 2004, converted to z-scores

Engineering discipline: Industrial, Mechanical, Aerospace, Chemical, Civil, and Computer – each coded as dummy variables (1 or 0) with Electrical used as the comparison group

4. Program Changes

Continuous Curriculum Planning: The program chair's individual score on an 8-item scale (where 5 = strongly disagree, to 1 = strongly agree) that assesses the program curriculum planning and revision. Constituent items: "Faculty in my program periodically review the program mission and objectives;" "Faculty in my program generally resist new curricular ideas or experimentation;" "Faculty in my program collaborate on curriculum development and revision;" "The program curriculum is a frequent agenda item at program meetings;" "Curriculum revisions are typically made in response to some problem rather than through a periodic planning process;" "Curriculum planning in my program is systematic;" "Curriculum decisions are usually based on opinions rather than data;" "Faculty are knowledgeable about the program's curriculum beyond their own courses." (Alpha = .73)

Emphasis on Teaching in Faculty Personnel Decisions: The program chair's individual score on a 3-item scale (where 5 = significant increase, and 1 = significant decrease) that assesses the change in the emphasis on teaching in personnel matters. Constituent items: "Recruiting and hiring;" "Promotion and tenure;" and "Salary and merit increases." (Alpha = .89)

Emphasis on Foundational Knowledge: The program chair's individual score on a 5-item scale (5 = significant increase, to 1 = significant decrease) that assesses the approximate change in the program's emphasis on the following areas over the past decade. Constituent items: "Basic engineering science;" "Foundational math;" "Basic science;" "Experimental methods;" "Engineering problem solving." (Alpha = .74)

[b] Level-two, or the program level, includes the variables explaining the between-program variance.

Table 3.3 (cont'd.)

Faculty Support for EC2000: The program chair's individual score on a 5-item scale (where 5 = almost all, to 1 = almost all) that assesses the proportion of faculty in the program that support certain activities. Constituent items: "Ongoing, systematic efforts to improve program quality;" "Curriculum/course development and revision;" "Assessment of student learning;" "Greater emphasis on students' "soft" skills;" "Using assessment information in decision-making." (Alpha = .88)

5. Instructional Practices and Attitudes of Faculty Members

Professionalism and Societal Issues: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 4-item scale (5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Professional ethics;" "Engineering in global/social contexts;" "Professional responsibility;" "Knowledge of contemporary issues." (Alpha = .78)

Project Skills: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 4-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Verbal communication;" "Technical writing;" "Teamwork;" "Project management." (Alpha = .74)

Applied Skills: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 3-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Modern engineering tools;" "Experimental methods;" "Engineering design." (Alpha = .51)

Active Learning Pedagogies: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 7-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the approximate change in the emphasis on the following areas since the first time they taught the same course. Constituent items: "Design projects;" "Assignments or exercises focusing on application;" "Open-ended problems;" "Student presentations;" "Use of groups in class;" "Hands-on experiences;" "Case studies or real-world examples." (Alpha = .78)

Undergraduate Education Projects: An average of all the individual faculty member's scores in each program. Each individual faculty member score is a 5-item scale (where 5 = significant increase, to 1 = significant decrease) that asses the faculty member's participation compared to five years ago. Constituent items: "A project to improve undergraduate engineering education;" "Applying for external funding for an undergraduate engineering education project;" "Developing or teaching a course with someone in another engineering discipline;" "Conference or journal submission on undergraduate education;" "Activities to enhance content knowledge." (Alpha = .64)

Source: Lambert, Terenzini, & Lattuca (2007)

Six program factor scales measured changes in program practices and policies over the last decade. These factors were all derived using principal components analysis with Varimax rotation. Factor scales were created by summing the component survey items with loadings above .40 and dividing by the number of factor-scale components. One of the first two program scales tapped the change in curriculum planning and revision while the other examined the importance of teaching in calculating hiring, promotion, and tenure decisions. Next, a program scale measured the change over the last decade in curricular emphasis on foundational skills. The fourth scale assesses the proportion of faculty in the program that support EC2000 related activities, such as an emphasis on "softer skills." The components of these program scales can be found in section four of Table 3.3.

Five faculty scales reflected changes in faculty members' attitudes and instructional practices. Three of the factor scales assessed the changes in their emphasis on applied, professional, and project-related skills. One indicator tapped the faculty member's increased involvement in professional development and outcomes assessment projects to improve the undergraduate education offered at their program. The final factor indicated any shifts made by faculty members to active pedagogies used in the classroom. Like the previous variables, detailed components of these measures are described in Table 3.3 (only in section 5).

Independent variables of interest. Three factor scales measured students' in-class experiences. Principal components factor analysis with Varimax rotation identified three factors among the set of instructional practice variables. The individual scales and components are listed in section two of Table 3.3. Factor scales were created by summing the comprising survey items (with loadings above .40) and dividing by the number of factor-scale components. These factor scales were labeled "Clarity and Organization", "Collaborative Learning", and "Instructor

Interaction and Feedback" (Cabrera, Colbeck, & Terenzini, 2001; Lattuca, Terenzini, & Volkwein, 2006; Terenzini, Cabrera, Parente, & Bjorklund, 2001). The Clarity and Organization scale was the combination of three items on which students reported how clearly instructors explained and interrelated assignments, class activities, presentations, and learning activities in their courses. Collaborative Learning is a seven-item scale, assessing how often students worked in groups together, learned from each other, and took an active part in the learning process. The five-item Instructor Interaction and Feedback scale assessed the amount of feedback instructors gave students on assignments, interacted with students in the course, and guided students' learning rather than lecturing.

The five out-of-class experiences were operationalized by individual items on the student survey. These activities were measured as the amount of time spent participating in a design competition, professional society, internship/cooperative education experience, international travel, and study abroad. Responses were given on a 5-point scales reflecting the months spent participating in each of the activities, where 1 = "none" and 5 = "more than 12 months" (Lattuca, Terenzini, & Volkwein, 2006). Table 3.3 describes these five out-of-class experiences.

Two scales were also created to represent students' perceptions of their program's openness to new ideas and people and their program's diversity climate. The program openness to diversity scale consisted of four items with an alpha of .74. The items asked graduates about the extent to which their program encouraged respect for others, emphasized tolerance, and discussed diversity. Program diversity climate was a scale created from four indicators, which included items that examined how graduates felt other students had been treated due to their identity. Although the alpha for this factor (.57) fell below the conventional .70 standard, the

scale was retained because of its substantive interest. The individual component items for both of these factor scales along with the in-class student experience factor scales are given in Table 3.3.

Data Analysis

The preliminary analyses compared means for the variables in the model to assess any differences based on gender. The raw score means for seven different precollege characteristics were evaluated by gender using zero-order, one-way analyses of variance (ANOVAs) for graduates in 1994 and then 2004. The precollege characteristics of only the female graduates were then compared by year of graduation (1994 & 2004). The process was followed for the ten in-class and out-of-class student experiences. These gender differences over time were used to answer question number one (Have the changes made by programs and faculty members in response to EC2000 produced gender-related differences in students' experiences?). Finally, comparisons of the adjusted means for design and problem-solving skills, group skills, and awareness of global and societal issues between males and female graduates, as well as between female graduates in 1994 and 2004 were made using analyses of covariance (ANCOVAs). These comparisons were use to answer the second question in the present study (Have gender gaps in design and problem-solving skills, group skills, and societal and global issues awareness closed?). The means for each of the three learning outcomes were adjusted for student transfer status, age, U.S. citizenship, race/ethnicity, mother's education, father's education, family income, test scores, high school GPA, institutional control (public/private), NSF Coalition participation, EC2000 review schedule, Carnegie Classification, wealth, and size. For each set of variables effect sizes were calculated to assess the importance of any statistically significant differences. The formulas used to calculate each effect size were:

$$\text{Effect size} = (\text{Mean}_{\text{female}} - \text{Mean}_{\text{male}}) / \text{Standard deviation}_{\text{pooled}} \text{ or}$$

Effect size = (Mean $_{2004female}$ – Mean $_{1994female}$) / Standard deviation $_{pooled}$.

The nested nature of the program, faculty, and student data included in the analyses also suggested the need for a multi-level analytical technique, such as hierarchical linear modeling (HLM), to answer the last three questions of the present study. This procedure has advantages over the use of ordinary least-squares (OLS) regression. Burstein (1980) first suggested that models used in education are inadequate for estimating the influence of schooling on students. He pointed out that most of the literature used single-level techniques such as OLS. Because the OLS approach assumes independence of observations, the technique fails "to capture the positive intraclass correlations that result from the interdependencies among students within the same institutions, classes, majors, etc." (Ethington, 1997, p. 167). According to Burstein (1980), the nature of education does not lend itself to single-level analytical procedures. Students are nested in classrooms, and those classrooms are nested within schools. In order to examine the effects of schooling on students, the commonalities between students in the same classrooms are examined with techniques that take these nested levels into account.

While Burstein (1980) was writing about elementary and secondary schools, Ethington (1997) argued that the same methodological concerns should be considered in higher education. College students are nested within programs and programs within institutions. Research that focuses on the effects of both individual experiences and the structure and organizational nature of programs and institutions also needs to use a technique sensitive to the nested nature of the data (Ethington, 1997).

Hierarchical linear modeling (HLM) allows the calculation of more realistic effects for nested data. For example, a model that considers college students and the organizational or structural effects of their intuitions has two levels of data in the analysis. The within-institution,

or level-one model, is similar to the OLS model except that the within-institution regression coefficients are allowed to vary across institutions (Ethington, 1997; Raudenbush & Bryk, 2002).

Next, the estimates of the parameters in the equation calculated for each institution, and then the variance of those parameters were estimated across institutions. After those steps, a chi-square statistic was calculated to decide whether the estimates really differed across institutions or if the variability was due largely to chance. If the variability in the estimates was non-random, a between-institution, or level-2, model was estimated. In the between-institution model, institutional measures predicted the coefficients from the level-1 model. Given the variability in the mean of the dependent variable and the coefficients of the predictors across the institutions in the example with students in institutions, HLM could examine the possibility that the selectivity of the institution (or any other characteristics of the institution for which the research has data) might impact the average levels in the dependent variable (the intercept at level-1) and the coefficient of the predictor (the slopes at level-1) (Ethington, 1997; Raudenbush & Bryk, 2002).

Such complex procedures have their limitations as well (Ethington, 1997). As Ethington stated in her study, “with very large groups and small intraclass correlations, nothing is gained from the more complicated modeling since more traditional approaches perform equally well and are less sensitive to model assumptions” (p. 190). When performing the same analysis using both HLM and OLS, Pascarella et al. (2006) found that findings were similar. The HLM analysis is still worthwhile, however, because it allows examination of influences on student outcomes while taking into account the nested nature of students within-programs (Raudenbush & Bryk, 2002).

The baseline HLM model for each of the three learning outcomes (Design and Analytical Skills, Group Skills, and Societal and Global Issues Awareness) had no predictors and

determined the amount of between- and within-program variance for each of the learning outcomes. The between-program variance represents the degree to which programs vary from one another, and within-program variance is defined as the extent to which students' development of learning outcomes differs within a particular program (Raudenbush & Bryk, 2002). The fact there is significant between-program variance indicates that there are differences in the effects of the programs in which students are enrolled. Level-one of the HLM analysis was at the student level and level-two was the program data. Since both the between and within-program variance were significant, models including the program-level and student-level predictors were estimated to explain the variance attributable to each level for each learning outcome. The second set of models added the pre-college characteristics to level-one of the models for each of the learning outcomes. The third set of models added the in-class and out-of-class student experiences to level-one of the models. Next, the institutional characteristics were added to level-two of the models. Finally, the program and faculty activities were added to level-two of the models. By adding these sets of variables in stages, the additional variance explained by precollege characteristics, faculty and program changes, and students' in-class and out-of-class experiences.

The interaction between gender and program and faculty changes is assessed using HLM with the effects of program and faculty changes on the gender difference, represented by the effect of the dummy-coded variable for gender on level one (Preacher, Curran, & Bauer, 2006; Raudenbush & Bryk, 2002). The interaction between gender and student experiences, because they are both level-one variables, must be treated in the same way as in OLS (Preacher, Curran, & Bauer, 2006; Raudenbush & Bryk, 2002).

If the interaction terms explained a significant amount of within-program variance for each of the learning outcomes, the HLM software allows one to easily graph the effect of each student experience on each of the learning outcomes by gender. By comparing the slopes of the lines for female and male graduates, the conditional influences of the student experiences become clear. Because the coefficients of student experiences can be relatively small in magnitude but still statistically significant (Lambert, Terenzini, & Lattuca, 2007), the gender differences in the slopes of the lines might be difficult to detect in graphs. Thus, tables displaying the slopes for each of the ten student experiences for both the male and female models and presenting the statistical significance of the gender differences are included if the graphs were not definitive.

Chapter 4

Findings

This chapter contains the results of analyses of variance (ANOVAs), analyses of covariance (ANCOVAs), and hierarchical linear modeling (HLM). These methods were used to answer the study's questions about the general and conditional gender effects of program attributes, faculty activities, and students' in-class and out-of-class experiences on graduates' design and problem-solving skills, group skills, and societal and global issues awareness.

The first section contains a comparison of the preparation levels of female graduates and male graduates within the same year and the gender gaps between the two cohorts (1994 and 2004). The findings suggest that gender differences exist in students' precollege characteristics. For the most part female graduates reported they were more prepared than their male counterparts.

The second section explores the college experiences of male and female graduates in 1994 and 2004. Female graduates report involvement in more student experiences associated in the literature with developing engineering skills. While female students report they are more prepared than their male counterparts, are involved in the right experiences, and are increasing their preparation and experience advantages, female students still indicate they do not have engineering skills as high as their male counterparts when they graduate.

The third section discusses changes in the gender learning gap over the ten-year period of this study. The gender gap in design and problem-solving skills remained constant between 1994 and 2004, with females falling behind. Male graduates were closing what could be called an inverse gender gap in group skills at a much faster pace. Female graduates in 2004 still rated themselves significantly more competent in group skills than did their male counterparts, yet the

magnitude of that difference had dropped to about half that of the 1994 difference. For the final learning outcome, societal and global issues awareness, the male advantage over females nearly doubled between 1994 and 2004.

In section four, the changes made by programs and faculty members over the last ten years are examined to identify possible effects on students' learning through the influences of these program and faculty changes on students' experiences while in college. The first set of student experiences discussed were in-class experiences, includes the clarity of classroom instruction, the amount of interaction students have with their faculty, and the emphasis on collaborative learning. Next, student perceptions of climate and openness to difference are explored. Finally, the last two set subsections cover five of the experiences students have outside of the classroom. Many of the program and faculty changes had statistically significant effects on these student experiences. For three of the student experiences (program climate, study abroad, international travel), the effects of the program and faculty changes differed by gender.

The final section explores both the general and the conditional influences of student experiences on students' development of engineering skills. These results revealed that the changes made by programs and faculty members are much more influential on the student experiences of female and male students have in college than on students' learning outcomes. All of the analyses suggest that gender moderates the impact of program and faculty changes on at least three of ten student experiences, as well as the influence of program and faculty changes and student experiences on all three of the engineering learning outcomes.

Students' Precollege Characteristics

In all aspects other than high school GPA and mathematics SAT score, female graduates increased their preparation advantage over their male counterparts in the decade between 1994

and 2004. Females had even begun to close the gap in Mathematics SAT score. The exception, high school GPA, was still higher for female graduates of 2004 than male graduates of 2004 but the difference between the sexes had fallen in comparison to 1994. The following subsections describe gender and cohort differences in these preparation characteristics.

High school grade-point average. As shown in Figure 4.1, exploratory t-tests revealed that female students who graduated in 1994 entered their engineering programs with significantly higher high school GPAs than their male counterparts ($p < .001$). Female engineering graduates in 2004 entered college with significantly higher high school GPAs than their male counterparts as well ($p < .001$). The number found in parenthesis is the effect size of the gender differences in each cohort. An effect size measures the magnitude of the difference between two means (Lattuca, Terenzini, & Volkwein, 2006). The effect sizes reported here are in standard deviation (sd) units. Thus, the 1994 effect size of .34 means that females report high school grade-point averages that are on average one-third of a standard greater than those of their male counterparts. For the purposes of this study, an effect size of .20 or smaller will be considered small and probably trivial, between .20 and .35 as moderate, and greater than .35 as large or strong. As shown by the effect sizes, the gender differences in high school grade-point average are moderate to strong, and over the decade between 1994 (.34) and 2004 (.29) the gender gap narrowed slightly between the sexes.

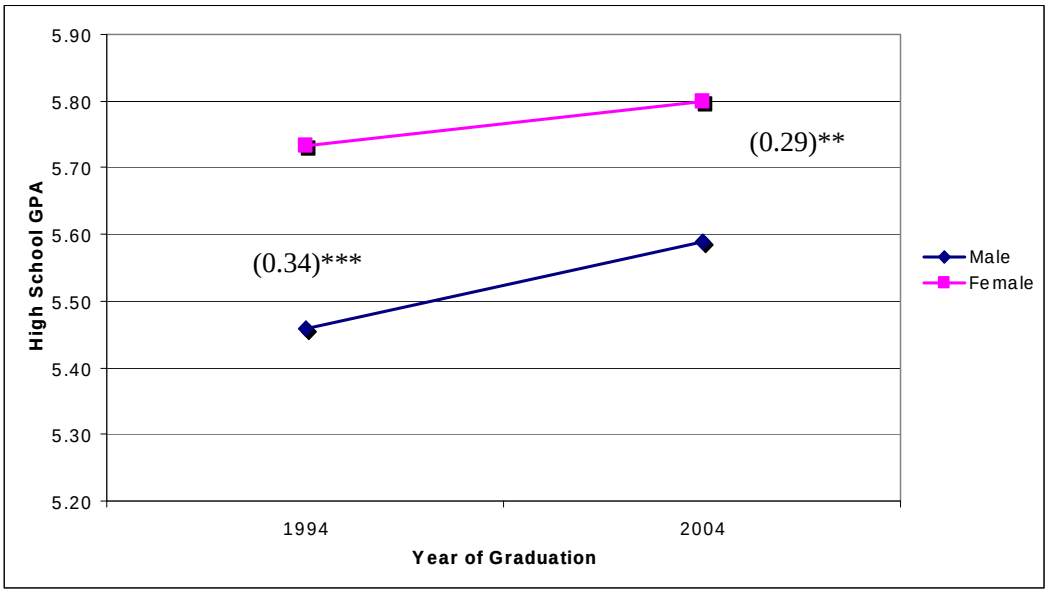

Figure 4.1 Graduates in 1994 and 2004: Gender differences in the means of the students' high school grade-point average when entering college.

**p < .01, ***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Preparation for math and science courses. Figure 4.2 displays a comparison of male and female students' reports of their secondary school preparation in math and science. Female and male graduates of 1994 felt equally well prepared in their math and science courses. Among graduates of 2004, female students reported being statistically significantly more prepared in basic math and science courses than did male students (p < .01). While the difference is statistically significant, the magnitude of the effect size (.10) represents only one-tenth of a standard deviation and is probably too trivial to give any conclusive power. The drop from 1994 to 2004 seems substantial in the figure, but it is only .13 and .22 points for women and men, respectively.

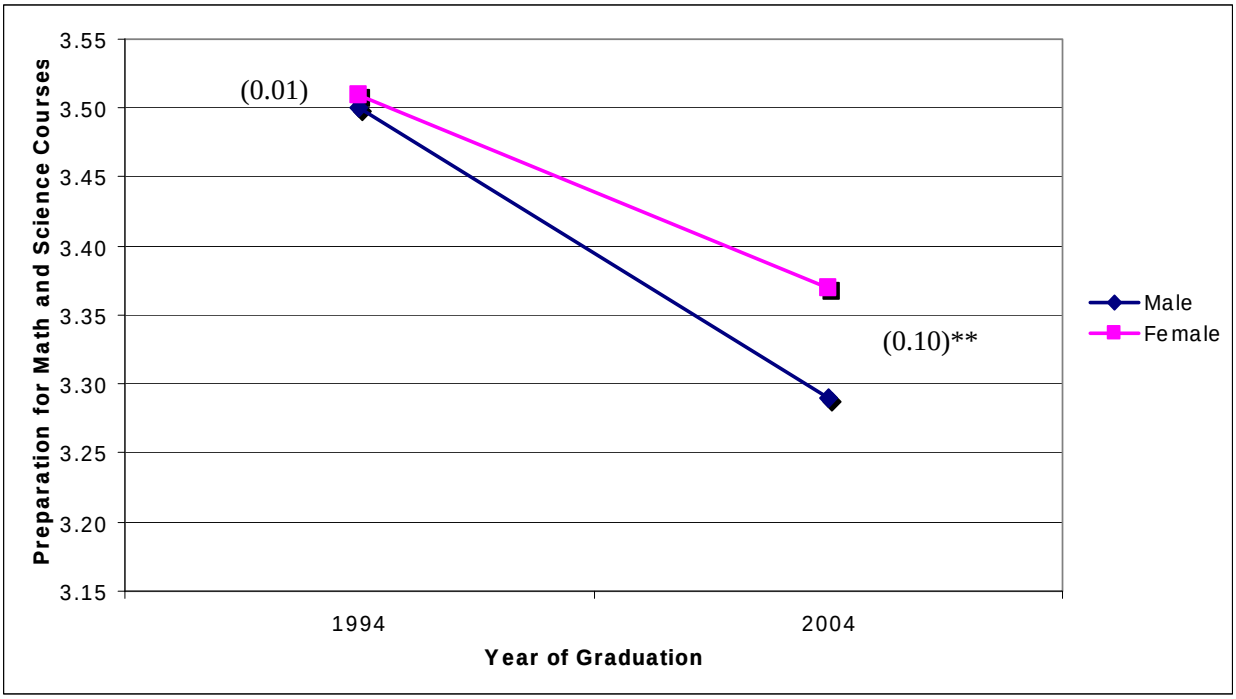

Figure 4.2. Graduates in 1994 and 2004: Gender differences in the means of the students' preparation for their math and science courses when entering college.

**p < .01

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

SAT verbal score. The SAT verbal scores of female and male graduates in 1994 and 2004 are illustrated in Figure 4.3. Female and male engineering students graduating in 1994 scored approximately the same on the verbal portion of the SAT. While the 2004 cohort shows a statistically significant ($p < .01$) gender difference in students' reported scores of their verbal portion of the SAT, the magnitude of that dissimilarity (.10) is probably not a substantively noteworthy difference. The reported verbal SAT scores have gone up over the last decade. This difference is 46 and 41 points for female and male students, respectively. These differences are both almost half a standard deviation in the magnitude of their effects sizes. Perhaps, this means engineering programs are trying to recruit students who are more likely to be well suited to develop the "softer" engineering skills, such written and oral communication.

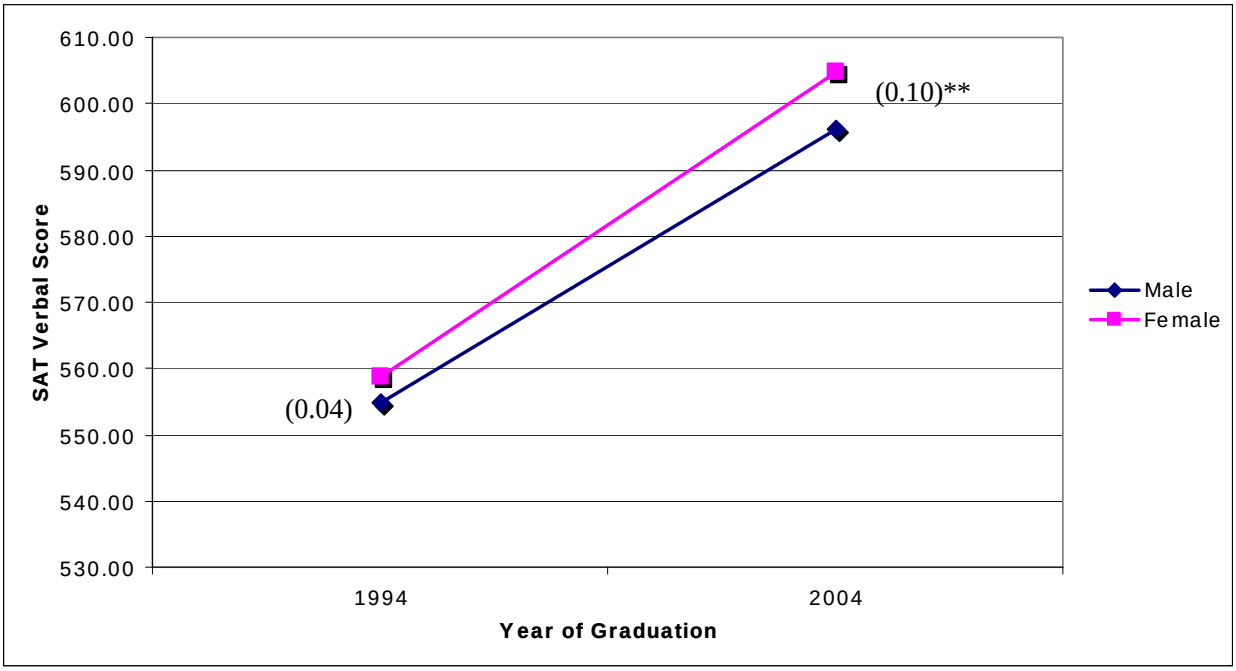

Figure 4.3. Graduates in 1994 and 2004: Gender differences in the means of the students' SAT verbal score when entering college.

**p < .01

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

SAT math score. As shown in Figure 4.4, male students who graduated in 1994 scored significantly higher than their female counterparts on the math portion of the SAT ($p < .001$). In contrast to the verbal portion of the SAT, male engineering graduates of the same year, as with their 1994 counterparts, scored significantly higher than females on the math portion of the SAT ($p < .001$).

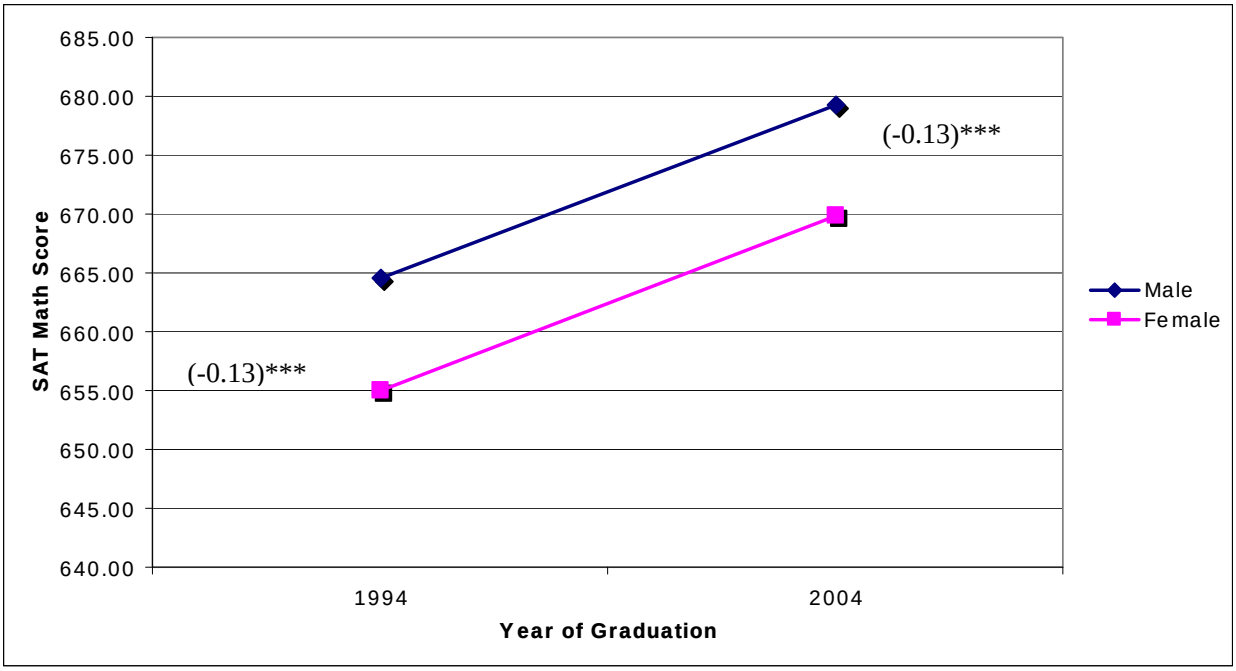

Figure 4.4. Graduates in 1994 and 2004: Gender differences in the means of the students' SAT math score when entering college.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Students' Experiences Inside and Outside of the Classroom

For the three in-class experiences, females' differences in level of clarity and organization, collaborative learning, and instructor interaction and feedback were greater than those of males in both 1994 and 2004, according to their self-reports. Outside of the classroom, the patterns in gender differences varied in students' participation in internships/cooperative education, design competitions, study aboard, international travel, and professional society chapters. Each of these experiences is discussed in individual sections below.

Clarity and organization of instructor. Figure 4.5 offers a comparison of male and female engineering graduates' self-reported perceptions of their instructors' clarity and organization. While female and male graduates in 1994 reported similar levels of instructor clarity and

organization in the classroom, by 2004 female graduates were reporting statistically significantly higher levels of instructor clarity and organization in the classroom than male students did ($p < .05$). However, the small magnitude of the effect size in 2004 (.09) suggests that the statistical significance could be due to the large number of participants in the study. Thus, the change between the 1994 and 2004 cohorts should not be considered noteworthy.

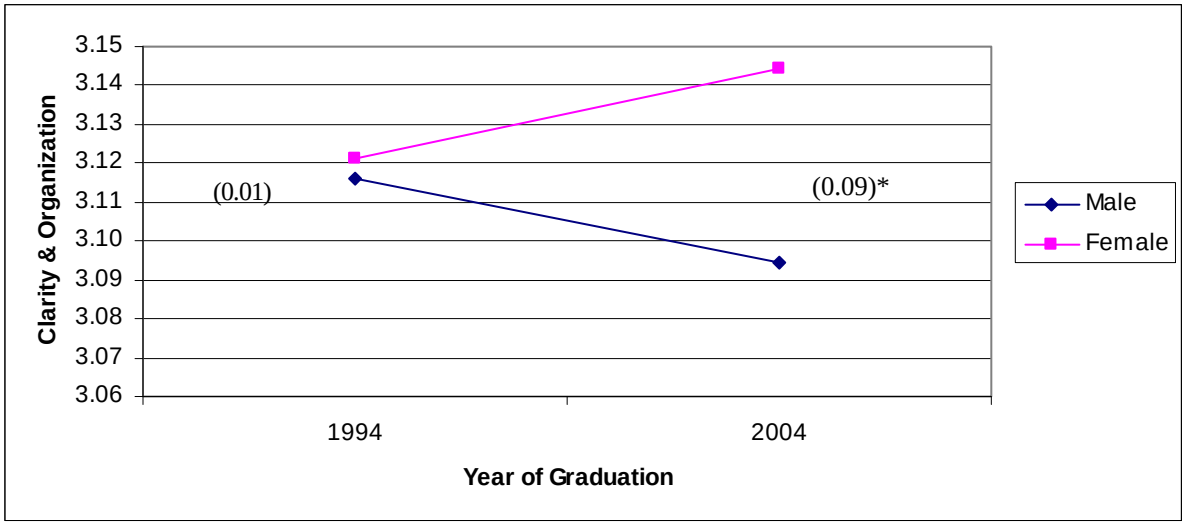

Figure 4.5. Graduates in 1994 and 2004: Gender differences in the means of the students' perceptions instructor clarity and organization.

*p < .05

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Collaborative learning. As illustrated in Figure 4.6, females graduating in 1994 reported significantly higher levels of collaborative learning in their classrooms than did male students ($p < .001$). By 2004, this gap had increased slightly but still suggested that female students were exposed to more collaborative learning in their classrooms than were their male counterparts ($p < .001$). In addition, the magnitudes of these differences (.25 and .38) are moderate to strong and substantively noteworthy. Perhaps these differences are due to the differences in disciplines chosen by each gender and the varied amounts of collaborative learning between the disciplines.

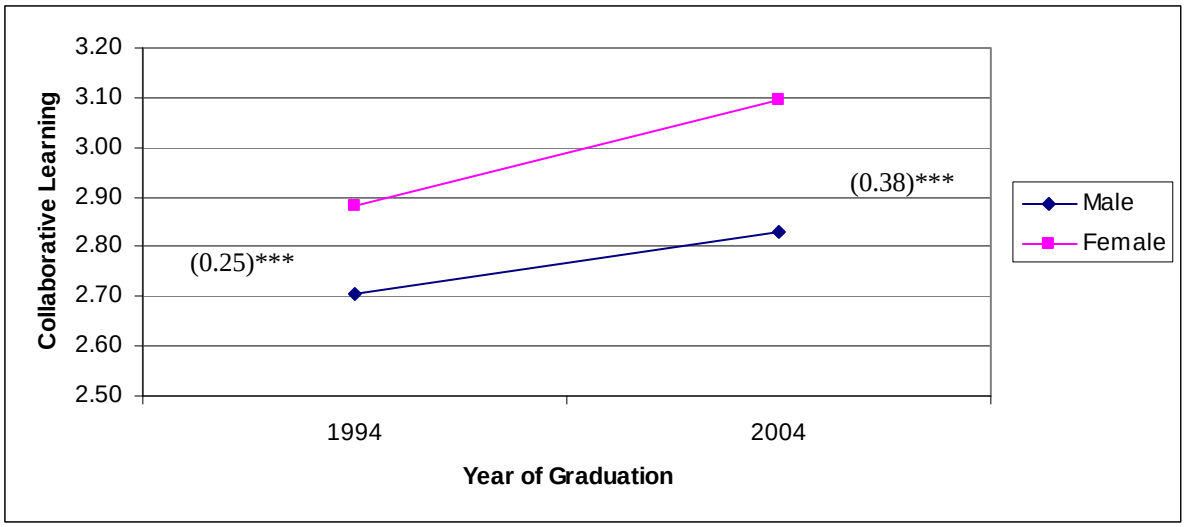

Figure 4.6. Graduates in 1994 and 2004: Gender differences in the means of the students' perceptions of the use of collaborative learning in their courses.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Instructor interaction and feedback. The lack of gender differences in student interaction and feedback with instructors for graduates in both 1994 (-.02) and 2004 (.06) is displayed in Figure 4.7. Female students graduating in 2004 reported the same levels of interaction with and feedback from their faculty members as their male counterparts.

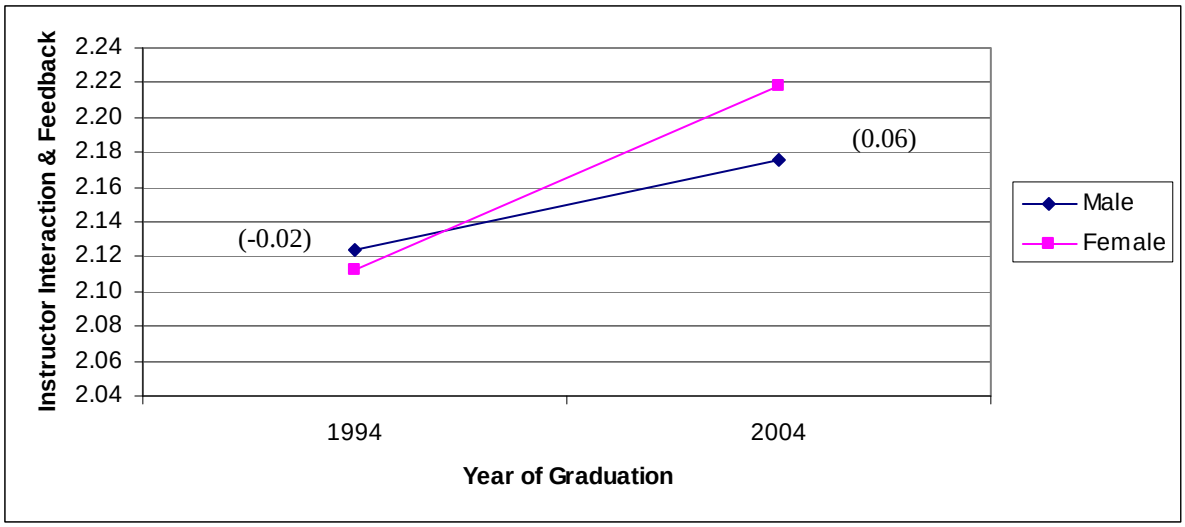

Figure 4.7. Graduates in 1994 and 2004: Gender differences in the means of the students' perceptions of their interaction with and feedback from their instructors.

The data for this analysis contained the female (n = 928) and male (n = 4,407) graduates of 1994 and the female (n = 888) and male (n = 3,270) graduates of 2004. The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Program openness to diversity. Figure 4.8 compares students' perceptions of their programs' openness to diversity. For the 1994 graduate cohort, females rated their programs' openness to diversity approximately the same as their male counterparts (.06). While the differences in 2004 did have statistical significance ($p < .01$), the magnitude of the effect size was not worthy of noting (.10).

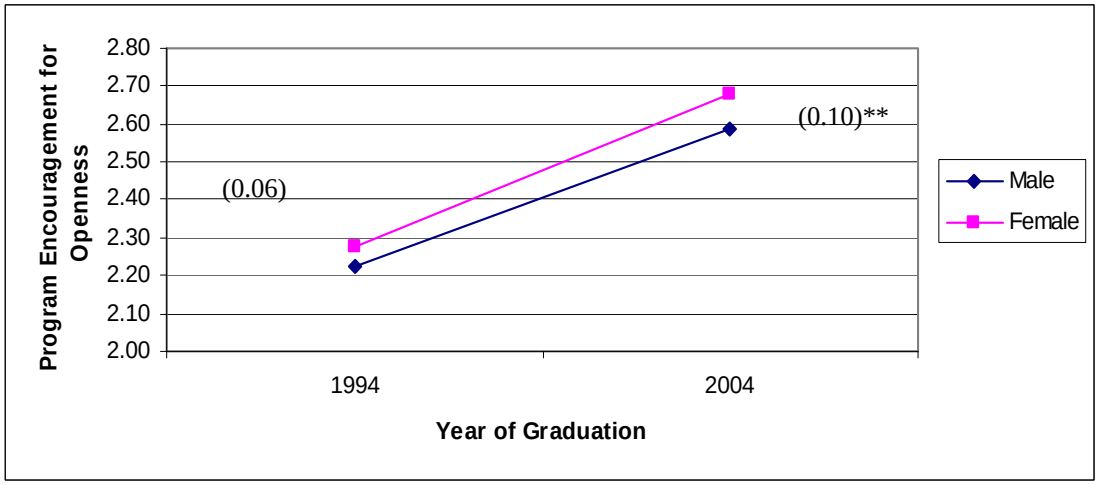

Figure 4.8. Graduates in 1994 and 2004: Gender differences in the means of the students' perceptions of their programs' openness to diversity.

**p < .01 The data for this analysis contained the female (n = 928) and male (n = 4,407) graduates of 1994 and the female (n = 888) and male (n = 3,270) graduates of 2004. The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Academic climate. Figure 4.9 suggests that in 1994 students' perceptions of their programs' perceived climate for engineering programs for women were significantly lower than those of men ($p < .001$). The magnitude of this difference is strong (-.37), but by the 2004 cohort this gender gap did seem to be closing. The magnitude had dwindled to less than one-fourth of that a decade earlier (-.08). This trend is noteworthy, because it raises the possibility that some of the faculty and program changes might be making the climate more equitable to the sexes.

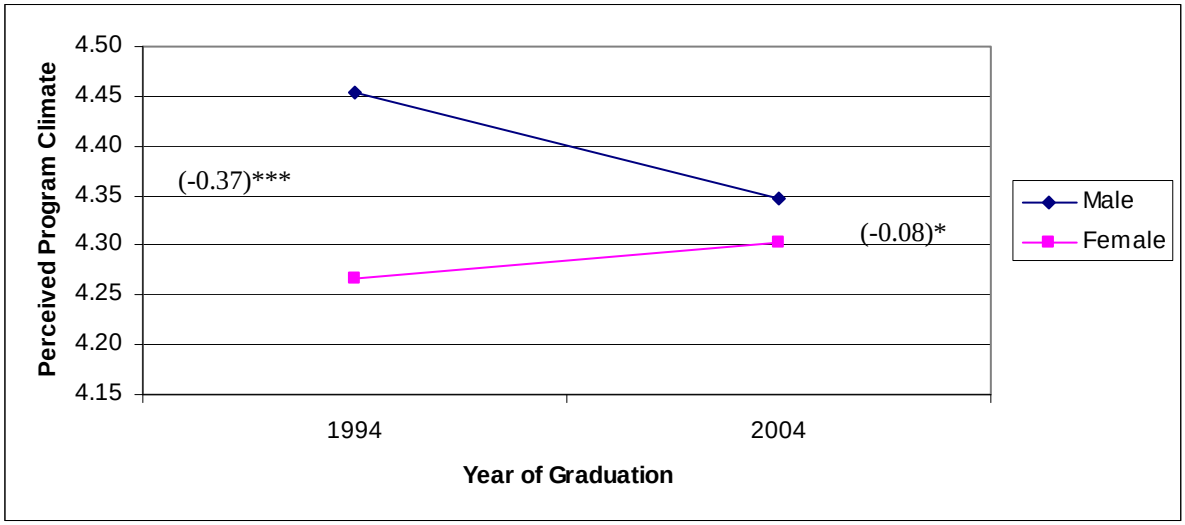

Figure 4.9. Graduates in 1994 and 2004: Gender differences in the means of the students' perceptions of their programs' climate.

*p < .05, ***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Internship/cooperative education. Comparisons of the time spent by female and male students in internships/cooperative education are displayed in Figure 4.10. On average, and compared to males, female engineering graduates in 1994 and 2004 reported significantly more participation in internships/cooperative education ($p < .001$). These differences were trivial in size though (.17 and .12).

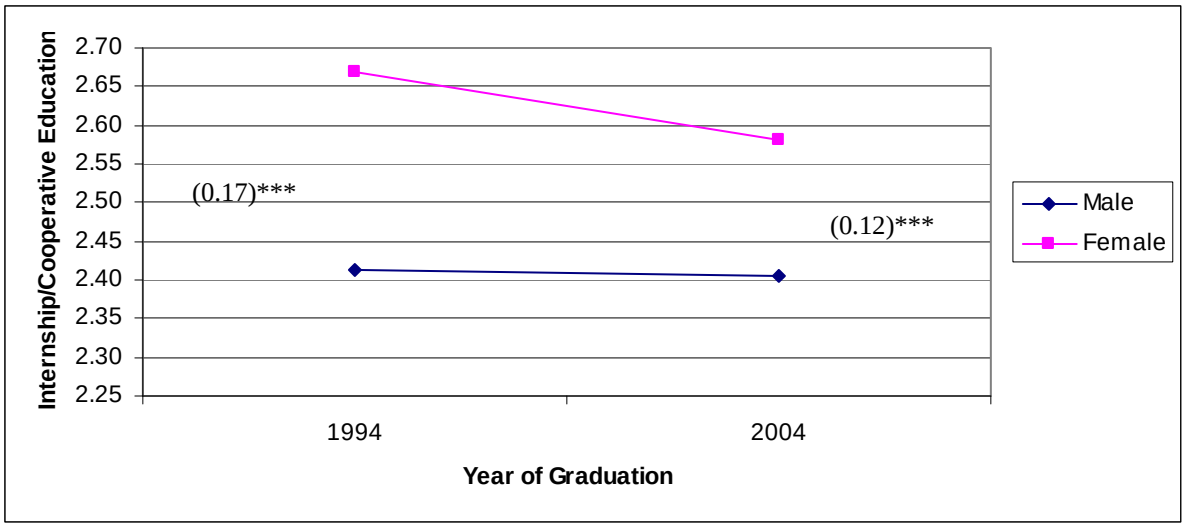

Figure 4.10. Graduates in 1994 and 2004: Gender differences in the means of the time that students spent in internships/cooperative education.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Study abroad. The gender differences in the time students spent studying abroad is depicted in Figure 4.11. On average, and compared to males, 1994 female engineering graduates reported significantly more participation in study abroad (p < .05). Female graduates in 2004 also indicated significantly (p < .001) more time studying abroad and the gap had more than doubled (.18). Even though the gap did double over the decade between 1994 and 2004, the difference in magnitude between the two cohorts (.11) is still probably trivial since it is only one-tenth of a standard deviation.

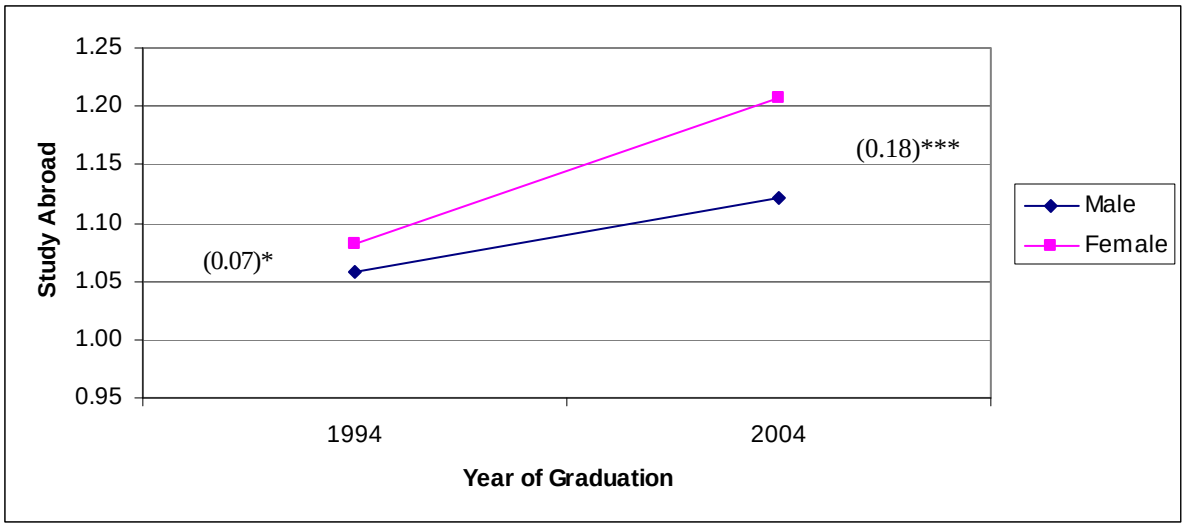

Figure 4.11. Graduates in 1994 and 2004: Gender differences in the means of the time that students spent studying abroad.

*p < .05, ***p < .001. The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004. The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

International travel. Figure 4.12 displays the gender differences in the international travel of graduates in 1994 and then a decade later. As with many of the other experiences, female engineering graduates in 1994 reported significantly more participation in international travel than their male counterparts (p < .01), but the magnitude of the effect size is small.

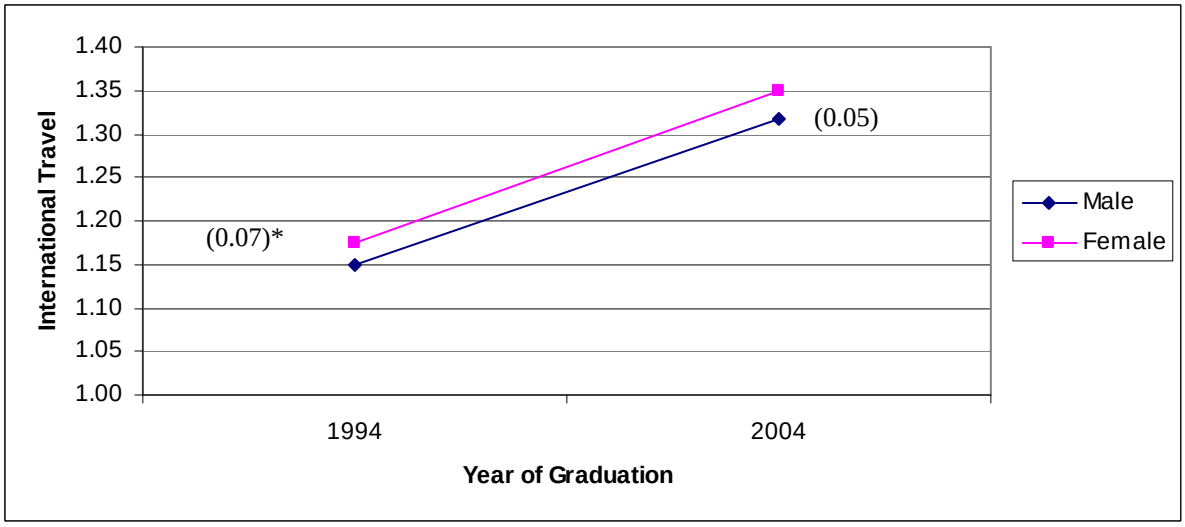

Figure 4.12. Graduates in 1994 and 2004: Gender differences in the means of the time that students spent traveling internationally.

*p < .05 The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004. The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Design competitions. Gender differences in design competition participation are shown in Figure 4.13. In contrast with the majority of experiences, 1994 female students were significantly less likely to spend time involved in design competitions than male students ($p < .001$). The same pattern was observed in the 2004 graduates ($p < .001$). Although there was statistical significance, the substantive differences in both cohorts were probably not worth reporting (-.13 and -.10)

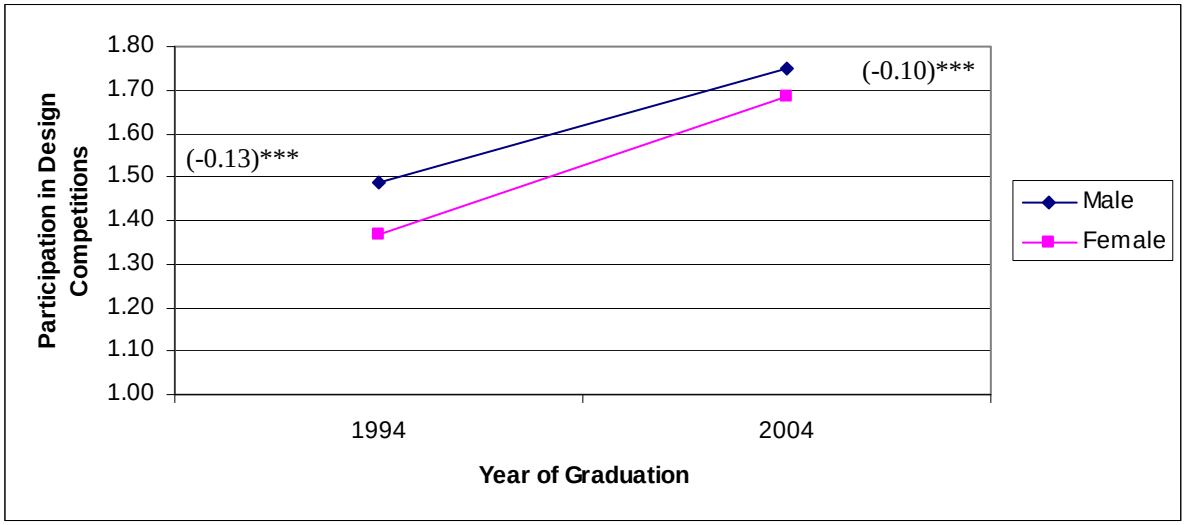

Figure 4.13. Graduates in 1994 and 2004: Gender differences in the means of the time that students spent participating in design competitions.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Professional society chapters. As shown in Figure 4.14, when compared to males, female engineering graduates in 1994 indicated significantly higher levels of involvement in professional society chapters ($p < .001$). The effect size of the gender gap for this experience is larger the effect sizes found for all the other experiences (.43). While the effects size of the gender gap for participation in professional society chapters was still more than that of the other out-of-class experiences (-.21), the gender gap had reversed. Female graduates in 2004 reported

being significantly less likely to spend time involved in professional society chapters ($p < .001$) than did male students.

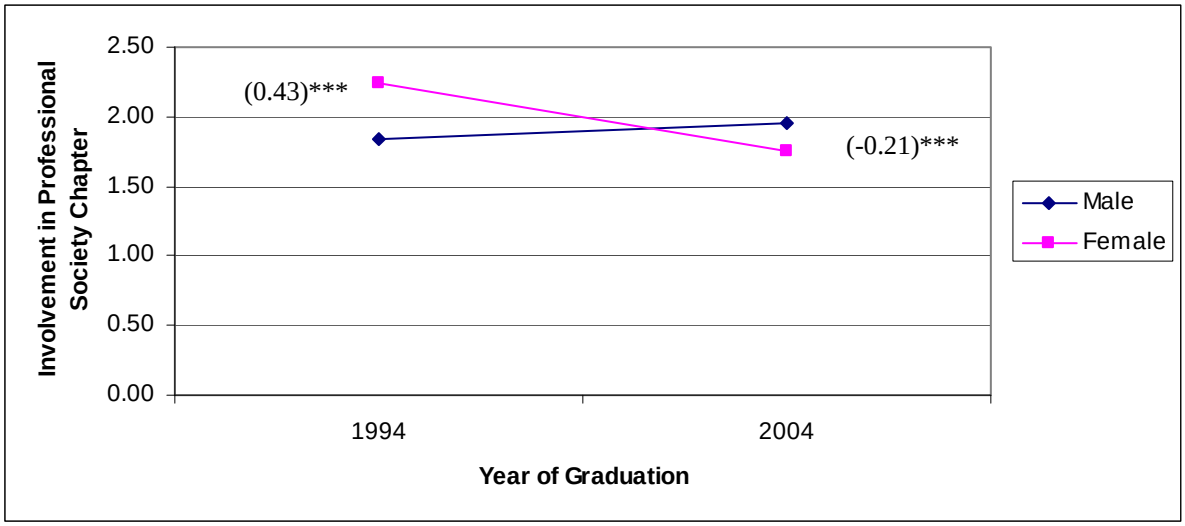

Figure 4.14. Graduates in 1994 and 2004: Gender differences in the means of the time that students spent involved in professional society chapters.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

Students' Learning Outcomes

The patterns across the three learning outcomes differed. Only the gender gap in design and problem-solving skills appeared to be substantively noteworthy.

Design and problem-solving skills. As shown in Figure 4.15, female 1994 graduates rated their ability to design solutions to problems significantly lower than did their male counterparts ($p < .001$). Female graduates from engineering programs in 2004 also reported significantly lower abilities to design solutions to problems than did their male counterparts ($p < .001$). Just as a reminder, the number found in parenthesis is the effect size of the gender differences in each cohort. An effect size measures the magnitude of the difference between two means after adjusting for differences in the variability of scores within groups (Lattuca, Terenzini, &

Volkwein, 2006). The effect sizes reported here are in standard deviation (sd) units. Thus, the 1994 effect size of -.28 means that male students report design and problem-solving skills that are on average more than one-fourth of a standard greater than those of their female counterparts. As shown by the effect sizes, the gender gaps in design and problem-solving skills were moderate (-.28 in 1994 and -.29 in 2004) and persisted between the sexes over the ten-year period.

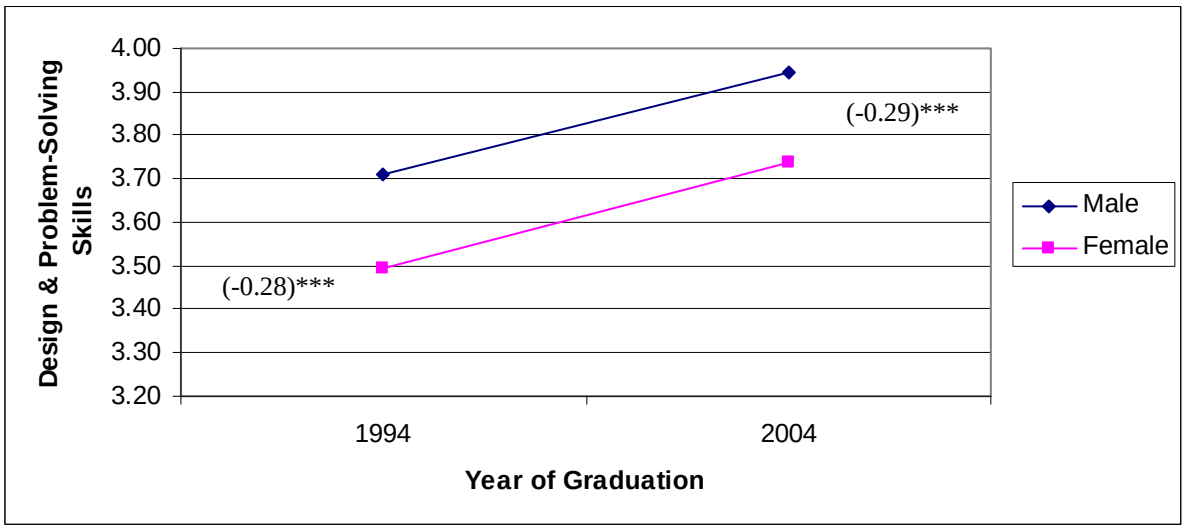

Figure 4.15. Graduates in 1994 and 2004: Gender differences in the adjusted[a] means of the students' design and problem-solving skills.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

[a] Adjusted for student transfer status, age, U S citizenship, race/ethnicity, mother's education, father's education, family income, test scores, and high school GPA, and for institutional control (public/private), NSF Coalition participation, EC2000 review schedule, Carnegie Classification, wealth, and size.

Group skills. Figure 4.16 indicates gender differences in reported group skills of engineering graduates in 1994 and a decade later. In contrast with the other two skills included in this study, female graduates in both 1994 and 2004 rated their group skills significantly higher than did males (p < .001). This gap had narrowed, however, as its effect size was more than half

the magnitude in 2004 (.08) than it was in 1994 (.17). The differences in either cohort were probably meaningless as they are both less than two tenths of a standard deviation.

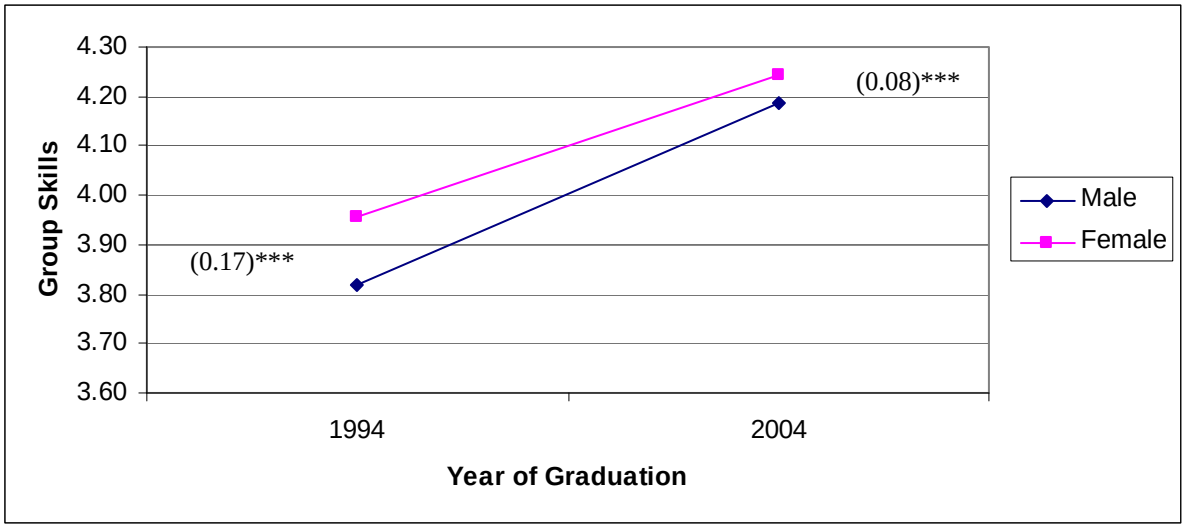

Figure 4.16. Graduates in 1994 and 2004: Gender differences in the adjusted[a] means of the students' group skills.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

[a] Adjusted for student transfer status, age, U S citizenship, race/ethnicity, mother's education, father's education, family income, test scores and, high school GPA, and for institutional control (public/private), NSF Coalition participation, EC2000 review schedule, Carnegie Classification, wealth, and size.

Societal and global awareness. As shown in Figure 4.17, female 1994 graduates reported significantly lower levels of awareness of societal and global issues than did male graduates ($p < .001$), although the magnitude of the difference (-.07) was much less dramatic than that associated with design and problem-solving skills (-.28). By 2004, the effect size of the gender gap in societal and global awareness had more than doubled (-.15), although it is still rather small.

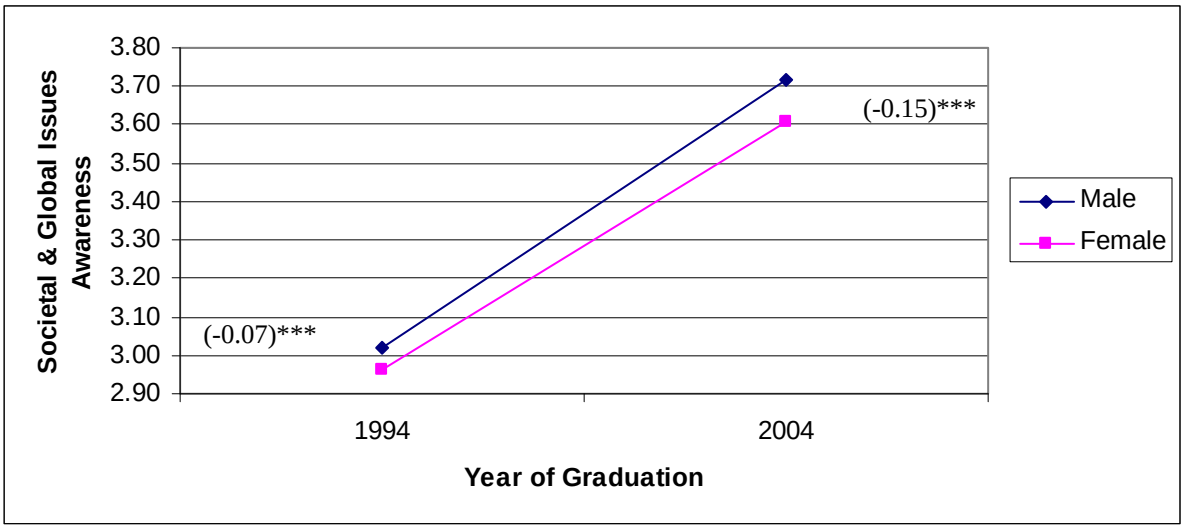

Figure 4.17. Graduates in 1994 and 2004: Gender differences in the adjusted[a] means of the students' societal and global issues awareness.

***p < .001

The data for this analysis contained the female (*n* = 928) and male (*n* = 4,407) graduates of 1994 and the female (*n* = 888) and male (*n* = 3,270) graduates of 2004.

The number in the parenthesis is the effect size and is calculated by using the formula Effect size = (Mean $_{female}$ – Mean $_{male}$) / Standard deviation $_{pooled}$.

[a] Adjusted for student transfer status, age, U S citizenship, race/ethnicity, mother's education, father's education, family income, test scores, and high school GPA, and for institutional control (public/private), NSF Coalition participation, EC2000 review schedule, Carnegie Classification, wealth, and size.

Since a male-advantaged gender gap still existed in students' reports of their design and problem-solving skills, which is arguably the most critical engineering skill, and awareness of global and societal issues, it will be helpful to administrators and faculty to understand what affects female students' abilities in these areas. This study suggests that over the decade between 1994 and 2004, some progress had been made in closing those gaps.

The general and conditional effects of the program changes, faculty activities, and student experiences on students' development of these skills are examined later in this chapter. The next section, however, explores the possible general and conditional influences that program changes and faculty activities have had on students' in-class and out-of-class experiences.

Effects of Program and Faculty Changes on Students' Experiences

As suggested by the model for this study (Figure 3.1), program and faculty changes may affect students' exposure to and participation in certain experiences while in college. As will be seen below, program and faculty changes have significant general effects on all ten of the in-class and out-of-class student experiences. In addition for three of those experiences, gender is a moderator for the impact of program and faculty changes on the student experience. The HLM models for the predictors for all ten student experiences are also found in this section.

In-class experiences. The variance components for each of the HLM models of the in-class student experiences are displayed in Table 4.1. The first HLM model for each of the in-class and out-of-class student experiences had no predictors and determined the amount of between- and within-program variance for each of the student experiences. These findings are in Table 4.1 on the first and fourth rows (which are bolded). The between-program variance represents the degree to which programs vary from one another and within-program variance is defined as the extent to which students' student experiences differ within a particular program (Raudenbush & Bryk, 2002). Level-one of the HLM analysis was at the student level and level-two was at the program level. The second set of models added the pre-college characteristics to level-one (explaining the within-program variance) of the models for each of the student experiences. The percentage that the pre-college characteristics explain is found in the fifth row. Next, the institutional characteristics were added to level-two (explaining the between-program variance) of the models. These numbers are found in the second row. Finally, the program and faculty activities were added to level-two of the models. The additional explained variance of these factors is found in the third row. Once all the sets of variables were added, the percentage

of between-program and within-program variance explained was calculated and can be found in the last two rows of Table 4.1.

The majority of the variance for all three of the in-class student experiences was attributable to the within-program differences. For clarity and organization in the classroom, 97.0% of the variance came from the within-program differences. The within-program difference accounted for 92.1% of the explained variance in collaborative learning and 89.7% in instructor interaction and feedback. While the between-program variance terms were much smaller (ranging from 3.0% to 10.3%), they did add a significant portion of variance ($p < .001$) to all three of the models for each of the in-class student experiences. The percentage of the between-program percentage is calculated by dividing the between-program variance by the total of the between-program and within-program variances and converting to a percentage. For example, for clarity and organization, the percentage of between-program variance would be .010/(.010+.320) = .03 = 3.0%. While statisticians have concluded 30% is an acceptable amount of total variance to be explained in a dependent measure, less than 5% between-major variance was not insubstantial (Porter & Swing, 2006). This evidence suggested that the data were indeed "nested" and the causes of the between-program variance should be explored.

Table 4.1. *HLM Models: Partitioning of Variance for Each of the In-class Student Experiences and Students' In-class Experiences*

	Instructor Clarity & Organization	**Collaborative Learning**	**Instructor Interaction & Feedback**
Variance Components:			
Total Between-Program Variance	**.010*** **	**.038*** **	**.046*** **
Percentage of Between-program Explained by:			
Institutional Characteristics	0.0%	20.9%	38.2%
Program Changes and Faculty Activities	4.0%	6.5%	3.8%
Total Within-Program Variance	**.320*** **	**.444*** **	**.400*** **
Percentage of Between-Program Explained by:			
Students' Precollege Characteristics	.7%	2.6%	1.0%
Percentage of Between-Program Variance Explained by the Final Complete Model	4.0%	27.4%	41.1%
Percentage of Within-Program Variance Explained by the Final Complete Model	1.1%	2.6%	1.4%

, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

All four program changes and all five of the faculty changes had significantly general effects on at least one of the three in-class student experiences. As shown in Table 4.2, the general effects of program and faculty changes on each of the in-class student experiences were listed under the intercept. The intercept represents the overall mean rating by students, both and male, across all programs on each of the three in-class student experiences. Programs that engaged in continuous curriculum planning had a significant ($p < .001$) influence on the overall mean of two of the three in-class experiences. Programs that had increased their emphasis on teaching in their faculty personnel decisions had a significant and positive effect on instructor interaction and feedback ($p < .05$). The amount of faculty support for EC2000 also had a positive influence on all three in-class experiences. All five of the faculty changes had significant effects on two of the three in-class experiences.

Table 4.2. *Significant Multilevel Effects*[a] *of Program Characteristics, Faculty Activities, and Student Experiences on Engineering Students' In-class Experiences*

	Instructor Clarity & Organization	**Collaborative Learning**	**Instructor Interaction & Feedback**
Intercept	***3.098****	***3.110****	***2.404****
Institutional Size	-.034**		-.028**
Institutional Wealth			-.086***
Program Scales (Change in emphasis on….)			
Continuous Curriculum Planning		1.109***	.998***
Emphasis on Teaching in Faculty Personnel Decisions			.556*
Emphasis on Foundational Knowledge		1.038**	
Faculty Support of EC2000	.361*	.778***	.435**
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues	1.234**	1.337***	
Project Skills	.686*		-.941*
Applied Skills		-3.167***	
Active Learning Pedagogies		2.094***-	1.172*
Undergraduate Education Projects	-3.997***	-3.387***	
Gender	***.053****	***-.143****	***-.046****
Institutional Size			
Institutional Wealth	.007*		
Faculty Scales (Change in emphasis on….)			
Project Skills	.177**		
Cohort	***-.026***	***.169****	***.100****
Institutional Wealth		***-.008****	
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues			.245**
Project Skills		.293**	
Applied Skills			-.241**

*p< .05, **p< .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

[a] Adjusted for student U S citizenship, minority status, parents' education, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional wealth, and size.

Conditional gender effects of the program and faculty changes on students' in-class experiences were measured by the joint influence of each of the level-2 (program level) program variables and the level-1 (student level) variable gender (also shown on Table 4.2). The number associated with gender was the gender difference in each of the student experiences. If the value

was negative that meant that females tended to report higher levels of that in-class experience, and if the value was positive that meant that males reported higher levels of the experience (the direction of these gaps resulted from the coding of gender, with female as “0” and male as “1”). Because both the slope for gender and the effect that faculty emphasis on project skills had on the gender slope were significant, the HLM analyses revealed a conditional gender effect for the curricular topics represented by this composite on instructor clarity and organization. Thus, when professors increased their emphasis on project skills topics in the classroom, such as verbal communication, teamwork, and technical writing, males were more likely than females to perceive their instructors’ teaching as clear and organized. No gender-related conditional effects were identified for the other two experiences studied here.

Program climate and openness. The variance components for both of the HLM models of program openness and climate are shown in Table 4.3. The majority of the variance for both student perceptions was attributable to the within-program differences. For program encouragement for openness, 92.1% of the variance came from the within-program differences. The within-program difference explained 97.7% of the variance for perceived program climate. While the between-program differences were much smaller (7.9% and 2.2%, respectively), they did add a significant portion of variance ($p < .001$) to both models.

Table 4.3. *HLM Models: Partitioning of Variance for Each of the In-class Student Experiences and Students' Perceptions of Program Climate and Openness*

	Program Encouragement for Openness	**Perceived Program Climate**
Variance Components:		
Total Between-Program Variance	**.053*** **	**.006*** **
Percentage of Between-Program Explained by:		
Institutional Characteristics	29.8%	2.9%
Program Changes and Faculty Activities	2.0%	36.9%
Total Within-Program Variance	**.611*** **	**.269*** **
Percentage of Between-Program Explained by:		
Students' Precollege Characteristics	4.6%	2.7%
Percentage of Between-Program Variance Explained by the Final Complete Model	31.9%	39.8%
Percentage of Within-Program Variance Explained by the Final Complete Model	5.0%	3.5%

*p< .05, **p < .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (*n* = 9,493).

Three of the four program changes and all five of the faculty changes significantly affected either program encouragement for openness and climate. Table 4.4 displays the magnitude of each of these general effects on the intercept. The strongest predictor of students' perceptions of their programs' openness to diversity, which included items such as a programs tolerance and respect for difference and emphasis on the importance of diversity in the workplace, was the degree of faculty emphasis on professionalism and societal issues. Professors who increased their attention to the topics of professionalism and problems in society contributed to an open atmosphere in their classrooms. Programs in which faculty members increased the use of active learning pedagogies had the strongest positive influence on students' perceptions of their programs' climate. In contrast, students in program where faculty participated in undergraduate education projects were more likely to report lower levels of perceived program climate. Two of the four program changes made a significant general impact on program

encouragement for openness and climate. All five of the faculty changes had significant effects on the perceived program climate ($p < .001$).

The program and faculty changes did not have significantly different conditional effects on students' perceptions of their program's encouragement for openness, but there were conditional gender effects of program and faculty change on students' perceptions of their programs' climate. Professors increasing the emphasis on project skills in the classroom and the program's emphasis on foundational knowledge was positively associated with the degree to which male graduates rated their programs' climate higher than that of their female counterparts ($p < .05$).

Table 4.4. *Significant Multilevel Effects*[a] *of Program Characteristics, Faculty Activities, and Student Experiences on Engineering Students' Perceptions of Program Climate and Openness*

	Program Encouragement for Openness	**Perceived Program Climate**
Intercept	***3.187****	***4.030****
Institutional Size	-.040***	
Institutional Wealth	-1.000***	.116***
Program Scales (Change in emphasis on….)		
Continuous Curriculum Planning	.658*	-1.005***
Emphasis on Foundational Knowledge	1.002*	-.853***
Faculty Support of EC2000		.595***
Faculty Scales (Change in emphasis on….)		
Professionalism and Societal Issues	2.343***	-1.445***
Project Skills	-1.0247**	1.051***
Applied Skills		-1.331***
Active Learning Pedagogies		2.386***
Undergraduate Education Projects	-1.869*	-5.989***
Gender	***-.071****	***.113****
Program Scales (Change in emphasis on….)		
Emphasis on Foundational Knowledge		.094*
Faculty Support of EC2000		-.051*
Faculty Scales (Change in emphasis on….)		
Project Skills		.156*
Cohort	***.415****	***-.032***
Institutional Size	.014***	
Program Scales (Change in emphasis on….)		
Emphasis on Teaching in Faculty Personnel Decisions	-.112**	
Emphasis on Foundational Knowledge	-.176*	.140**
Faculty Support of EC2000	.066*	.024**
Faculty Scales (Change in emphasis on….)		
Project Skills		.152*
Applied Skills	-.239*	
Active Learning Pedagogies	.254*	
Undergraduate Education Projects	-.347*	

*p< .05, **p< .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

[a] Adjusted for student U S citizenship, minority status, parents' education, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional wealth, and size.

Out-of-class experiences. Table 4.5 shows the variance components for each of the HLM models of the first three out-of-class student experiences. The vast majority of the variance for all three of the in-class student experiences was attributable to the within-program differences. For student time spent in an internship or cooperative education experience, 92.4% of the variance came from the within-program differences. In addition, the within-program differences explained 96.4% of the variance for participation in design competitions and 94.5% for involvement in professional society chapter. While the between-program differences were much smaller (ranging from 3.6% to 7.6%), they did add a significant portion of variance ($p < .001$) to all three of the models for each of the first three out-of-class student experiences.

Table 4.5. *HLM Models: Partitioning of Variance for Each of the Out-of-Class Student Experiences*

	Internship/ Cooperative Education	**Participation in Design Competitions**	**Involvement in Professional Society Chp.**
Variance Components:			
Total Between-Program Variance	**.174*** **	**.037*** **	**.054*** **
Percentage of Between-Program Explained by:			
Institutional Characteristics	17.7%	9.7%	46.9%
Program Changes and Faculty Activities	2.6%	0.0%	0.0%
Total Within-Program Variance	**2.115*** **	**.979*** **	**.914*** **
Percentage of Between-Program Explained by:			
Students' Precollege Characteristics	.8%	4.5%	2.8%
Percentage of Between-Program Variance Explained by the Final Complete Model	20.3%	9.7%	47.0%
Percentage of Within-Program Variance Explained by the Final Complete Model	1.7%	5.0%	3.4%

*p< .05, **p < .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

As shown in the first few rows of Table 4.6, all four program changes and four of the five faculty changes significantly affected at least one of the first three out-of-class student experiences. Faculty activities seemed to have the most noteworthy general influences on students' participation in internships and design competitions, although none of the faculty activities had any impact on students' involvement in a professional society chapter. Faculty members who increased their emphasis on project skills had significantly positive and strong effects on the mean time students spent participating in internships, cooperative education experiences, and design competitions ($p < .01$). The other program and faculty changes each had significant influences on only one of these three out-of-class experiences.

The HLM analyses revealed differences by gender on students' participation in internships (shown in Table 4.6). Programs that initiated continuous curriculum planning and whose faculty members increased their use of active learning pedagogies significantly increased the number of months students reported spending in internships by females over males ($p < .05$), while programs that emphasized foundational knowledge led to a significant decrease in the number of months spent in internships/cooperative experiences ($p < .05$).

Table 4.6. *Significant Multilevel Effects*[a] *of Program Characteristics, Faculty Activities, and Student Experiences on Engineering Students' Out-of-Class Experiences*

	Internship/ Cooperative Education	Participation in Design Competitions	Involvement in Professional Society Chp.
Intercept	***2.626****	***2.129****	***1.628****
Institutional Size	-.121***	-.100***	-.077***
Institutional Wealth	-.114***	-.088***	
Program Scales (Change in emphasis on….)			
Continuous Curriculum Planning		-1.410***	-1.348**
Emphasis on Teaching in Faculty Personnel Decisions		1.587***	
Emphasis on Foundational Knowledge			1.464*
Faculty Support of EC2000		.720***	
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues	3.300***		
Project Skills	3.062**	1.472**	
Applied Skills		-3.778**	
Undergraduate Education Projects		-2.264***	
Gender	***-.186****	***-.030***	***-.379****
Institutional Wealth			
Program Scales (Change in emphasis on….)			
Continuous Curriculum Planning	-.239*		
Emphasis on Teaching in Faculty Personnel Decisions			
Emphasis on Foundational Knowledge	.156*		
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues		-.235*	
Active Learning Pedagogies	-.350*		
Cohort	***.033***	***.320****	***.085****
Institutional Wealth			.0167**
Faculty Scales (Change in emphasis on….)			
Project Skills	.521*		.274*
Applied Skills	-.514**		

*p< .05, **p< .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

[a] Adjusted for student U S citizenship, minority status, parents' education, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional wealth, and size.

Study abroad and international travel. Table 4.7 displays the variance components for both of the HLM models of study abroad and international travel. The majority of the variance

for both student perceptions was attributable to within-program differences. For students' time spent studying abroad, 95.5% of the variance came from the within-program differences. The within-program difference explained nearly all (99.0%) of the variance for international travel. While the between-program differences were much smaller (4.5% and 1.0%, respectively), they did add a significant portion of variance ($p < .001$ and $p < .05$) to both models. Although these may have seemed small, according to Porter and Swing (2006), less than 5% between-major variance was not inconsequential.

Table 4.7. *HLM Models: Partitioning of Variance for the Time Students Spend Studying Abroad and Traveling Internationally.*

	Study Abroad	**International Travel**
Variance Components:		
Total Between-Program Variance	**.007*** **	**.002***
Percentage of Between-Program Explained by:		
Institutional Characteristics	26.0%	50.2%
Program Changes and Faculty Activities	1.8%	13.9%
Total Within-Program Variance	**.142*** **	**.213*** **
Percentage of Between-Program Explained by:		
Students' Precollege Characteristics	7.2%	5.2%
Percentage of Between-Program Variance Explained by the Final Complete Model	27.8%	64.1%
Percentage of Within-Program Variance Explained by the Final Complete Model	9.7%	5.9%

*p< .05, **p < .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

Two of the four program changes and four of the five faculty changes had significant general effects on either international travel or study abroad. These general effects (for all students) are displayed in Table 4.8. Programs that implemented continuous curriculum planning

and where faculty supported EC2000 had a significant positive effect on the average time students spent both in study abroad and international travel. The more programs' faculty stressed professionalism and societal issues, the less time students spent studying abroad ($p < .001$). Perhaps students felt the need to travel abroad less when they thought they understood the issues that they would face here and abroad as opposed to those presented in the classroom.

The HLM analysis also uncovered several conditional effects of program and faculty changes on international travel by gender. Women in programs that engaged in continuous curriculum planning and in which faculty participated in undergraduate education enhancement projects spent more time traveling internationally than did their male counterparts.

Table 4.8. *Significant Multilevel Effects*[a] *of Program Characteristics, Faculty Activities, and Student Experiences on Engineering Students' Travel and Study Abroad*

	Study Abroad	**International Travel**
Intercept	***1.411*****	***2.046******
Institutional Size	-.112***	-.067***
Institutional Wealth	-.118***	-.152***
Program Scales (Change in emphasis on….)		
Continuous Curriculum Planning	1.564***	1.192*
Faculty Support of EC2000	-1.714***	-1.224***
Faculty Scales (Change in emphasis on….)		
Professionalism and Societal Issues	-4.901***	
Gender	***-.026****	***-.031****
Program Scales (Change in emphasis on….)		
Continuous Curriculum Planning		-.091**
Faculty Scales (Change in emphasis on….)		
Project Skills		-.114*
Cohort	***.078******	***.102******
Institutional Wealth	.009***	
Program Scales (Change in emphasis on….)		
Emphasis on Teaching in Faculty Personnel Decisions	-.043**	-.044*
Emphasis on Foundational Knowledge	.079**	
Faculty Scales (Change in emphasis on….)		
Undergraduate Education Projects		.148*

*p< .05, **p< .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

[a] Adjusted for student U.S. citizenship, minority status, parents' education, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional wealth, and size.

Hierarchical Linear Models of the Effects on Learning Outcomes

All of the variance components for the three outcomes' HLM models are displayed in Table 4.9. The vast majority of the variance for all three outcomes was attributable to within-program differences. The between-program variance represents the degree to which programs vary from one another and within-program variance is defined as how much students' development of learning outcomes differs within a particular program (Raudenbush & Bryk, 2002). For design and problem-solving skills, 97.7% of the variance came from within-program

differences. The within-program difference explained 97.4% of the variance for group skills and 96.3% of the variance for societal and global issues awareness. While the between-program differences were much smaller (ranging from 2.3% to 3.7%), they did add a significant portion of variance ($p < .001$) to all three models.

Table 4.9. *HLM Models: Partitioning of Variance for Each of the Learning Outcomes*

	Design & Problem-Solving Skills	**Groups Skills**	**Societal & Global Issues Awareness**
Variance Components:			
Total Between-Program Variance	**.013*** **	**.017*** **	**.028*** **
Percentage of Between-Program Explained by:			
Institutional Characteristics	27.9%	54.5%	68.7%
Program Changes and Faculty Activities	14.3%	14.6%	5.6%
Total Within-Program Variance	**.558*** **	**.628*** **	**.729*** **
Percentage of Within-Program Explained by:			
Students' Precollege Characteristics	5.7%	6.1%	15.6%
Student Experiences	13.2%	13.6%	11.3%
Interaction Terms	2.2%	8.6%	1.1%
Percentage of Between-Program Variance Explained by the Final Complete Model	41.6%	72.4%	73.2%
Percentage of Within-Program Variance Explained by the Final Complete Model	21.3%	20.7%	27.9%

*p< .05, **p < .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

Table 4.10 shows the level-one effects of the hierarchal model before program and faculty changes are taken into account at the second level. The gender differences in design and problem-solving skills, as well as societal and global issues awareness, are significant, with males rating themselves higher than their female counterparts ($p < .001$). The gender difference in group skills, with females outscoring males, is also significant ($p < .01$). Table 4.11 displays the same factors once program and faculty changes are taken into account.

Table 4.10. *Level-one Effects of Student Characteristics and Experiences on Engineering Students' Development of Design and Problem-solving Skills, Group Skills, and Societal and Global Issues Awareness*

	Design & Problem-Solving Skills	**Groups Skills**	**Societal & Global Issues Awareness**
Intercept	***3.616****	***3.644****	***2.790****
Student Characteristics			
Cohort	.145***	.272***	.549***
Gender	.234***	-.051**	.110***
Citizenship	-.110	.281	.193
Minority	-.014	.063	.075**
High School GPA	-.009	.030*	-.036*
SAT Scores	.001***	.000	.001***
Preparation for Basic Math & Science Courses	.035**	.002	.017
Parents' Education	.001	.004	.008
Student Experiences			
In-Class			
Collaboration	.104***	.034***	.129***
Instructor Interaction and Feedback	.126***	-.009	.121***
Clarity	.189***	.087***	.093***
Climate	.049**	.074***	
Program Openness	.071***	.085***	.216***
Out-of-Class			
Internship/Cooperative Education Experience	.029***	.019**	.002
Study Abroad	-.022	-.009	
International Travel	.010	.057**	.076***
Participation in Design Competition	.074***	.030**	-.003
Involvement in Professional Society Chapter	.045***	.020	.016

*p< .05, **p< .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

As shown in Table 4.11, all four of the program changes and all five of the faculty changes significantly affected at least one of the three learning outcomes. One program change and two faculty changes significantly influenced the overall mean of design and problem-solving skills and societal and global issues awareness. Two of the four program changes and two of the five faculty changes made a significant impact on the average rating of group skills. Five of the

student experiences were influenced by at least one of the program changes. All ten of the student experiences were affected by at least one faculty change. Seven of the ten experiences students had while they are in school were impacted by at least two faculty changes.

Unlike what was seen in the same models in Table 4.10, the gender difference shown in Table 4.11 was non-significant in both the design and problem-solving and the group skills models. Once the level-two predictors, program and faculty changes, were put into the model, the gender differences for these two learning outcomes was explained. The model did still show an unexplained gender difference in societal and global issues awareness.

Table 4.11. *Significant Multilevel Effects[a] of Program Characteristics, Faculty Activities, and Student Experiences on Engineering Students' Development of Design and Problem-solving Skills, Group Skills, and Societal and Global Issues Awareness*

	Design & Problem-Solving Skills	**Groups Skills**	**Societal & Global Issues Awareness**
Intercept	***3.986****	***3.605****	***2.763****
Program Scales (Change in emphasis on….)			
Emphasis on Foundational Knowledge		2.73*	
Faculty Support of EC2000	-1.651*		1.377*
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues		7.31**	
Applied Skills	-8.507**	-5.95*	-6.323*
Active Learning Pedagogies	3.953**		
Gender	***.273***	***.021***	***.547****
Faculty Scales (Change in emphasis on….)			
Applied Skills	-1.800**		
Undergraduate Education Projects	-2.273**	-2.357**	
Cohort	***.069***	***.115****	***.410****
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues	-.566**		
Student In-Class Experiences:			
Collaboration	***.101****	***.319****	***.113****
Faculty Scales (Change in emphasis on….)			
Applied Skills	.319*		
Active Learning Pedagogies	-.288*		

Table 4.11 (cont'd.)	**Design & Problem-Solving Skills**	**Groups Skills**	**Societal & Global Issues Awareness**
Instructor Interaction and Feedback	***.119*** **	***-.005***	***.136*** **
Faculty Scales (Change in emphasis on….)			
Project Skills	-.391**		
Applied Skills	.402*		.370**
Clarity	***.215*** ***	***.123****	***.193*** ***
Program Scales (Change in emphasis on….)			
Emphasis on Teaching in Faculty Personnel Decisions		-.181**	-.167*
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues		.373*	
Active Learning Pedagogies	.396*	.409*	
Undergraduate Education Projects	-.614**		
Climate	***-.024***	***.023***	***-.107****
Faculty Scales (Change in emphasis on….)			
Active Learning Pedagogies	-.378*		
Undergraduate Education Projects			-.455*
Program Openness	***.086*** **	***.078****	***.260*** ***
Institutional Size			-.015***
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues		.347**	
Applied Skills	-.290*		
Student Out-of-Class Experiences:			
Internship/Cooperative Education Experience	***.020***		***.029***
Institutional Wealth	.008*		
Program Scales (Change in emphasis on….)			
Continuous Curriculum Planning			
Faculty Scales (Change in emphasis on….)			
Professionalism and Societal Issues		-.138*	
Study Abroad	***.145****	***.003***	***.136***
Program Scales (Change in emphasis on….)			
Continuous Curriculum Planning			-.309*
Faculty Support of EC2000	.175*		
Faculty Scales (Change in emphasis on….)			
Active Learning Pedagogies			.777*
International Travel	***.086***	***.199*** ***	***.166*** **
Institutional Size	-.025***		
Institutional Wealth			.025*
Faculty Scales (Change in emphasis on….)			
Active Learning Pedagogies	-.547**		
Undergraduate Education Projects	-.480*		

Table 4.11 (cont'd.)	**Design & Problem-Solving Skills**	**Groups Skills**	**Societal & Global Issues Awareness**
Participation in Design Competition	***.069***	***.036***	***-.004***
Program Scales (Change in emphasis on….)			
Emphasis on Teaching in Faculty Personnel Decisions	-.087**		-.106**
Faculty Scales (Change in emphasis on….)			
Project Skills	.187*	.178*	
Involvement in Professional Society Chapter	***.047****	***.026***	***-.005***
Program Scales (Change in emphasis on….)			
Emphasis on Teaching in Faculty Personnel Decisions	.084**	.097**	.122***
Faculty Scales (Change in emphasis on….)			
Applied Skills	-.255**		-.194*

*p< .05, **p< .01, ***p < .001

The data for this analysis contained the female and male graduates of 1994 and 2004 (n = 9,493).

[a] Adjusted for student U S citizenship, minority status, parents' education, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional wealth, and size.

Gender Conditional Effects of Student Experiences on Learning Outcomes

Design and problem-solving skills. The HLM software allows researchers to easily graph the effect of each student experience on each of the learning outcomes by gender. By comparing the slopes of the lines for female and male graduates, the conditional influences of the student experiences become clear. Unfortunately, the differences in impact might be significant but not always large and readily apparent graphically. For this reason, the next three tables report the slopes for each of the ten student experiences for both the male and female models and then the differences between the slopes. Finally, the tables show whether those gender differences are statistically significant.

Table 4.12 reports the slopes for each of the ten student experiences by gender and thus their impact on the overall mean of students' design and problem-solving skills. For both the female and male models, all four of the in-class experiences had significant effects on the development of design and problem-solving skills. In-class experiences are significant and

positive for both male and female students. For the female model, four of the six out-of-class student experiences were significant predictors, while for the male model only three of them were significant. The strongest predictor of design and problem-solving skills for both the male and female models was an instructor's clarity and organization in the classroom.

Differences also existed in the impact of some student experiences on the overall student mean of their reported design skills. The effect of the time students spent studying abroad was much more influential for female graduates than it was for male graduates (difference = .199). Collaboration in the classroom had almost twice the impact on female graduates' development of the ability to design solutions (.121) than it had on male graduates' development of the same skills (.072). The clarity and organization of the instructor was significantly more influential for male graduates than female graduates. Perhaps this means the pedagogies and teaching techniques currently used by faculty are not reaching women. Overall, the effects of two in-class experiences and four out-of-class student experiences differed by gender in their effects on students' ability to design solutions and solve problems.

Table 4.12. *Graduates in 2004: Comparing the HLM Slopes of Effects[a] of Student Experiences on Students' Development of Design and Problem-Solving Skills by Gender*

	Female Student Model (*n* = 888)	**Male Student Model (*n* = 3,270)**	**Difference Between Models**
Student Experiences			
In-Class			
Collaboration	.121**	.072**	.049**
Instructor Interaction and Feedback	.110*	.057*	.052
Clarity	.181***	.220***	-.038*
Program Openness	.072*	.079***	-.007
Out-of-Class			
Climate	.005	.040	-.036**
Internship/Cooperative Education Experience	.041*	.027**	.014
Study Abroad	.097*	-.102**	.199***
International Travel	.074	-.006	.081***
Participation in Design Competition	.067**	.092***	-.025*
Involvement in Professional Society Chapter	.032	.020	.012

*p< .05, **p< .01, ***p < .001

[a] Adjusted for student discipline, U S citizenship, minority status, parents' education, family income, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional control (public/private), Carnegie Classification, wealth, and size, for program use of continuous curriculum planning, emphasis on teaching in faculty personnel decisions, emphasis on foundational knowledge, overall faculty support of EC2000, and faculty emphasis on professionalism and Societal Issues, project skills, and applied skills, use of active learning pedagogies, and participation in undergraduate education projects.

Group skills. As can be seen in Table 4.13, the slopes for each of the ten student experiences differed by gender and thus their impact on the overall mean of students' group skills. For the female model, two of the four in-class experiences had significant effects on the development of group skills. For the male model, three of the in-class experiences' slopes were significant. For the female model, three of the six out-of-class student experiences were significant predictors, while for the male model only two of them were significant. The strongest impact on the group skills for both the male and female models was the extent of collaborative and active learning pedagogies experienced in the classroom.

The slopes that were least similar between the male and female models (indicating a gender-related conditional effect) were the effects of the time students spent traveling internationally, which had a much more positive influence on female graduates (.136) than on

male graduates (.022; non-significant). Participation in internships and international travel both positively impacted the overall average of female students' reports of their group skills, while it had no apparent effect for male students.

Table 4.13. *Graduates in 2004: Comparing the HLM Slopes of Effects[a] of Student Experiences on Students' Development of Group Skills by Gender*

	Female Student Model (*n* = 888)	**Male Student Model (*n* = 3,270)**	**Difference Between Models**
Student Experiences			
In-Class			
Collaboration	.319***	.268***	.051***
Instructor Interaction and Feedback	-.053	-.014	-.038***
Clarity	.066	.094**	-.029
Program Openness	.071*	.073***	-.003
Out-of-Class			
Climate	.047	.067*	-.020
Internship/Cooperative Education Experience	.055***	.015	.040***
Study Abroad	-.006	.001	-.007*
International Travel	.136***	.022	.114***
Participation in Design Competition	.038*	.033	.005*
Involvement in Professional Society Chapter	.026	-.010	.035***

*p< .05, **p< .01, ***p < .001

[a] Adjusted for student discipline, U S citizenship, minority status, parents' education, family income, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional control (public/private), Carnegie Classification, wealth, and size, for program use of continuous curriculum planning, emphasis on teaching in faculty personnel decisions, emphasis on foundational knowledge, overall faculty support of EC2000, faculty emphasis of professionalism and Societal Issues, project skills, applied skills, use of active learning pedagogies, and participation in undergraduate education projects.

Societal and global issues awareness. Table 4.14 displays the slopes for each of the ten student experiences by gender and thus their impact on the overall mean of students' societal and global issues awareness. For both the female and male models, all four of the in-class experiences had significant general effects on the development of societal and global issues awareness. For the female model, four of the six out-of-class student experiences were significant predictors, while for the male model only one of them was significant. The strongest influence on societal and global issues awareness for both the male and female models was their programs' encouragement of openness.

In all, the effects of two in-class experiences and all six out-of-class student experiences on the development of societal and global issues awareness seemed to differ by gender. The greatest difference between the male and female models was the effect of the time students spent studying abroad. Studying abroad had a large and more positive influence on female graduates' average self-rating of awareness of societal and global issues (.131 vs. .006 for males). The same pattern was seen in the effects of participation in internships and international travel. Program climate had strong and negative effects on female graduates' average self-rating of this awareness, but no apparent influence for male graduates.

Table 4.14. *Graduates in 2004: Comparing the HLM Slopes of Effects[a] of Student Experiences on Students' Development of Societal and Global Issues Awareness By Gender*

	Female Student Model (*n* = 888)	**Male Student Model (*n* = 3,270)**	**Difference Between Models**
Student Experiences			
In-Class			
Collaboration	.160***	.082**	.078***
Instructor Interaction and Feedback	.098*	.073**	.026
Clarity	.173***	.103***	.070***
Program Openness	.201***	.175***	.026
Out-of-Class			
Climate	-.118**	-.010	-.108***
Internship/Cooperative Education Experience	.054**	-.003	.057***
Study Abroad	.131***	.006	.125***
International Travel	.179***	.109***	.070***
Participation in Design Competition	.025	.010	.015*
Involvement in Professional Society Chapter	.030	-.018	.048***

*p< .05, **p< .01, ***p < .001

[a] Adjusted for student discipline, U S citizenship, minority status, parents' education, family income, SAT test scores, high school GPA, preparation for basic math and science courses when entering college, institutional control (public/private), Carnegie Classification, wealth, and size, for program use of continuous curriculum planning, emphasis on teaching in faculty personnel decisions, emphasis on foundational knowledge, overall faculty support of EC2000, faculty emphasis of professionalism and Societal Issues, project skills, applied skills, use of active learning pedagogies, and participation in undergraduate education projects.

Study Limitations

Students. This study has many of the same limitations as the *Engineering Change* study (Lattuca, Terenzini, & Volkwein, 2006). First, the three learning outcomes used as the dependent

variables (Design and Analytical Skills, Group Skills, and Societal and Global Issues Awareness) are very complex constructs. While several items and current practices were used to create the factors, the measures can only partially mirror the range of proficiencies needed in order to have these two skills. The only way to capture these skills would be to travel to all 39 institutions and directly observe each of the 4,000 students in and out of the classrooms.

Second, these constructs are measured as self-reports of student learning, which might have weakness. While most studies including students in higher education overall suggest that self-confidence and actual ability are positively related (Anaya, 1999; Bradburn & Sudman, 1988; Converse & Presser, 1989; Hayek, Carini, O'Day, & Kuh, 2002; Laing, Sawyer, & Noble, 1988; Pace, 1985; Pike, 1995), there are slightly more mixed findings in engineering education studies. Studies have indicated that there are no gender differences among engineering students concerning confidence in their abilities (Kaufman, Felder, & Fuller, 2000; Marra et al., 2004; Shaefers, 1993; Schaefers, Epperson, & Nauta, 1997), while some studies have also found statistically significant gender differences in confidence (Besterfield-Sacre et al., 1997; Besterfield-Sacre et al., 2001; Bradburn, 1995; Brainard & Carlin, 1998; Felder et al., 1995; Light et al., 2007; Marra et al., 2004; O'Hare, 1995; Orabi, 2007; Seymour & Hewitt, 1997; Turns et al., 2007; Zeldin & Pajares, 2000). Kaufman, Felder, and Fuller (2000) found that self-ratings did not differ significantly from actual course grades for male, female, minority, and non-minority students in two chemical engineering courses. Studies of the self-efficacy of engineering students have shown a positive correlation between self-efficacy and academic achievement (Marra et al., 2004).

Besterfield-Sacre et al. (1997) discovered that students departing engineering in good standing had lower confidence in their engineering skills than those students who left in poor

standing. Zeldin and Pajares (2000) also found that these gender differences in self-confidence affected the men and women who had entered into and continued to succeed in their professional careers. Engineering educators are aware that female students are less confident in their abilities than their male counterparts (Turns et al., 2007). Women enter engineering programs with high levels of self-confidence and self-esteem, but while in college something happens and those levels actually drop and are never as high again, even for females who successfully graduate from their engineering programs (Brainard & Carlin, 1998; Marra et al., 2004; O'Hare, 1995). Possibly females compare themselves unfavorably to their male counterparts and judge themselves more harshly than do their male peers (Hawks & Spade, 1998). In addition, women in science, technology, math, and engineering are less confident of their technical abilities than their male counterparts (Besterfield-Sacre, Moreno, Shuman, & Atman, 2001; Felder et al., 1995; Hawks & Spade, 1998; Orabi, 2007; Seymour & Hewitt, 1997). Felder et al. (1995) found that women tended to under-predict their grades, while men's predictions were more accurate. In this study, women's performance and self-confidence were not positively correlated. Light et al. (2007) also found that although first-year female students performed just as well as their male counterparts on an engineering task, they reported significantly lower levels of confidence in their engineering abilities. Although the use of self-reports for the three learning outcome measures do have their limitations, when compared with other options, such as standardized tests or direct observations, the latter have their own limitation, including cost, personnel, and length of the study.

Third, only engineering programs were included in the *Engineering Change* study. While the respondents were representative of the undergraduate engineering graduate population,

generalizing the results from this study to other academic areas is probably not possible because engineering is a specialized and technical field of study.

Fourth, characteristics of the students in this study are based on the responses of students in only seven engineering disciplines. While the seven disciplines that are included in this study have produced three-fourths of all the engineering degrees awarded since 2000, students in the disciplines not included here might show different conditional effects of program changes, faculty activities, and student experiences on students' development of their engineering skills.

Finally, caution must be used when trying to make inferences to all female engineering students from this study's findings. The women in the data set are graduates of engineering programs, so they are self-selected "survivors." The women are representative of the graduates of the included programs and are much more homogeneous than those female students who began their engineering studies four or five years prior to 1994 and 2004. Thus, the heterogeneity of the women students in the study is restricted. While the findings might not indicate to faculty and administrators which methods work best for all female engineering students, in light of potential gender differences in the development of students' engineering skills, it is still important to determine what worked for the women who made it to the end of their engineering program.

Faculty. The faculty survey data are limited in several respects. First, program chairs are asked to look retrospectively rather than asking faculty these questions longitudinally. The design constraints did not a pre-/post-EC2000 study of programmatic impacts of the new accreditation criteria, because surveys had not been done ten years prior to the new accreditation criteria as at that time the criteria could not be predicted.

Second, faculty members were asked to think about one course and not the broad spectrum of the curriculum when reporting on curricular and pedagogical changes (or lack of changes). After taking the responses of each faculty together in a larger context the responses should provide a valid and reliable window on engineering education nationally.

Third, most faculty members chose to respond to the survey with comments on one of their upper-division courses. Thus, the changes that faculty reported might not be representative of the lower-division courses respondents teach.

Finally, this study chose a subset of the possible changes faculty made to their courses and pedagogies so there could be other changes that have conditional effects as well. The choice of these particular changes was chosen based on the literature of what might have gender conditional effects on student experiences and students' development of their engineering skills.

Program chairs. The data provided by program chairs are also limited in certain ways. First, there is a possibility that program chairs inflated their descriptions of their program's practices, policies, and conditions. Some of the program chairs might have wanted to make their programs seem more positive then they were. To try and alleviate some of this bias, chairs were repeatedly told that their responses were confidential and their institutions would not be mentioned by name in any report or article.

Second, much like faculty and students, the reports of their program were retrospective. Again constraints in the possible design stopped any genuine pre-/post-EC2000 study of programmatic impacts of the new accreditation criteria. For the chairs that had not been in their post for the full ten-years, their responses might underestimate the amount of change that the program had undergone. The probability of this underestimation is low though, because nearly 80 percent of the program chairs have been at their institutions for more than 10 years.

Finally, the results from this study can only be generalized to the types of programs included in the sampling design. Programs had to be in one of the seven focal disciplines and been ABET-accredited in 1990 or earlier. Thus, newer programs (some of which may be more innovative) are not included in this study. There could be different student experiences that have gender conditional effects. When reviewing results this limitation must be kept in mind.

After taking these limitations into account and reviewing the previous sections, significant evidence exists to support the proposition that gender is a moderator for both program and faculty changes and students' experiences in and outside of the classroom. In addition, while females in 2004 were doing significantly better than they were in 1994, a gender gap was still evident, with males having the advantage in students' perceived learning while in their engineering programs. Female graduates still rated themselves significantly lower on both design and problem-solving skills and societal and global issues awareness than did male graduates. The analyses also revealed that certain program changes (such as emphasis on foundational knowledge), faculty changes (such as emphasis on applied skills), in-class student experiences (such as collaboration and instructor interaction and feedback), and out-of-class experiences (such as internships, international travel, and study abroad) appear to have a larger impact on learning among women than among men, even after controlling for students' precollege characteristics and preparation. For example, programs in which faculty emphasize applied skills not only directly affect female graduates' development of design and problem-solving skills (while having non-significant effects for their male counterparts), but also influence female graduates' perceptions of their programs' climates. The practical and policy implications of these findings are discussed in chapter 5.

Chapter 5

Summary and Conclusions

Women leave the engineering field at nearly twice the rate of men (Bix, 2004; Kardash & Wallace, 2001; Michel, 1988). In addition, the problem of undergraduate women's persistence in engineering is particularly troubling because women enroll in engineering at a lower rate than in other fields (National Science Foundation, 2006). Even those women who successfully graduate with engineering degrees are twice as likely as male graduates to be unemployed (Iversen & Douglas, 2004).

The alarming gender gap in unemployment for engineering graduates has been linked to the possibility of a gender gap between male and female students' academic achievement. There is some debate in the literature, however, over whether this gap in achievement still exists. Several single institution studies (Bannerot, 2006; Greenfield, 1982; Marra, Palmer, & Litzinger, 2000; Mbarika, Sankar, & Raju, 2003; Orabi, 2007; Whigham, 1988) and one multi-institution study (Takahira, Goodings, & Byrnes, 1998) found no significant difference in the academic performances of male and female students. In contrast, according to Felder, Felder, Mauney, Hamrin, and Dietz (1995), women on average enter college with stronger credentials than men, but by the end of their college careers they have grades that are equal to or significantly lower than those of males. In addition, three studies using only grades and numerous studies that employ grades and other measures discovered gender differences did exist (Bannerot, 2006; Felder, Felder, Mauney, Hamrin, & Dietz, 1995; Felder, Felder, & Dietz, 2002; French, Immekus, & Oakes, 2005; Haines, Wallace, & Cannon, 2001; Hecht et al., 1995; Kaufman, Felder, & Fuller, 2000; Kilgore et al., 2007; Knight et al., 2002; Peters, Chisholm, & Laeng,

1995; Sax, 1994; Sax & Harper, in press; Whitt, Pascarella, Elkins Nesheim, Marth, & Peirson, 2003).

Women as Learners

In order to understand why these gender gaps in persistence and development of engineering abilities may exist, studies of women in engineering tend to consider the effects of program and faculty activities, such as curriculum and pedagogy, and student experiences, such as perceptions of academic climate and participation in design competitions. For years, the literature has suggested that the climate in engineering is not conducive to female students' persistence or learning (Harris et al., 2004; Lee, 2002; Salter & Persaud, 2003; Seymour & Hewitt, 1997). Women who were confident of their abilities in high school, after exposure to the engineering climate, questioned whether they fit in the engineering program at all (Nauta, Epperson, & Kahn, 1998; Seymour, 1995; Seymour & Hewitt, 1997). Today, researchers question whether the chilly climate still exists or if other factors contribute more to women's departure decision than discrimination, however subtle, against women (Harris et al., 2004; Serex & Townsend, 1999; Steele, James, & Chait Barnett, 2002; Zhao, 2005).

Most theorists seem to agree that women tend more than men to learn through their interactions with others (Baxter Magolda, 2001; Belenky, Clinchy, Goldberger, & Tarule, 1986; Cross, 1998; Gilligan, 1982; Josselson, 1987). Within engineering, the literature supports the proposition that female students may learn differently than male students (Dee & Livesay, 2004; Dunbar, Gordan, & Seery, 2007; Knight, Sullivan, Poole, & Carlson, 2002; Rosati, 1997; Rosati, 1999; Wise et al., 2004). Thus, faculty use of active learning techniques, such as collaboration, may be more conducive to female learning than more traditional methods, such as lecturing (Baker, Krause, Yasar, Roberts, & Robinson-Kurpius, 2007; Brainard, Metz, & Gillmore, 1998;

Felder & Brent, 2004a; Hathaway, Davis, Sharp, 2000; Sonnert, 1995). Traditionally, lecturing has dominated engineering pedagogies (Lawal, 2007; Prados, Peterson, and Lattuca, 2005). Employers have stressed the need to develop skills, such as communication and the ability to work in groups, in graduates to ensure their success in the workforce. In response to this push and the changes to accreditation, engineering programs have had to change their curriculum to adopt more collaborative pedagogies. Because of these changes, some of the classroom experiences of students have been altered as well (Lattuca, Terenzini, & Volkwein, 2006).

Most of the research on how college affects students has included either in-class or out-of-class experiences, but few have explored both at the same time. A few exceptions exist (see Kuh, 2001; Lambert, Terenzini, & Lattuca, 2007; Lattuca et al., 2006; Pascarella et al., 1996; Reason et al., 2006; Springer, Terenzini, Pascarella, & Nora, 1995; Terenzini, Springer, Pascarella, & Nora, 1995). Studies exploring the differential effects of students' experiences on female students often consider a small subset of either the in-class or the out-of-class experiences (Eccles, 1992; Felder & Brent, 2005; Koehler, 1990; Laeser et al., 2003; Peterson & Fennema, 1985; Vogt, Hocevar, & Hagedorn, 2007). For example, interaction with faculty and advisors is shown to be more positively influential for women than men (Robinson & Reilly, 1993).

Out-of-class experiences may also account for differences in female and male students' learning. Involvement in a professional society has been found to be more influential on females' student learning than men's, providing female students the support and confidence they need to succeed (Chubin, May, & Babco, 2005; McLoughlin, 2005). Studies have had mixed results, however, when considering the differential effects of participation in design competitions. Design competitions integrate ideas and skills, and some studies suggest that women in a design competition develop higher levels of skills than their male counterparts (Laeser et al., 2003),

while another study suggests that women engaged in a design competition are at a disadvantage because design competitions reinforce the competitive nature of engineering (Colbeck, Cabrera, & Terenzini, 2000; Tonso, 1996a). For all these reasons, a comprehensive model of students' in-class and out-of-class experiences should be used to understand how different experiences affect women's student learning.

The Accreditation Board for Engineering and Technology (ABET) initiated alterations to its accreditation standards in *Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States* (EC2000) (ABET, 1997). These changes shifted the focus of engineering programs away from an exclusive concentration on technical engineering skills to include the more professional skills. The move toward "soft" skills in the engineering education field suggests that the learning environment of engineering might have shifted as well. The new accreditation criteria place greater emphasis on collaboration and development of students' communication and group skills (Laeser, Moskal, Knecht, & Lasich, 2003). Since female students tend to excel in the softer skills and to learn more readily from collaborative pedagogies, the curricular and instructional changes could potentially affect the learning of women in engineering differently than that of their male counterparts.

Learning Outcomes

Arguably, design skills are the central proficiency required to be a successful engineer (Simon, 1996). Design skills include the ability to devise a system, component, or process to fulfill desired needs and are linked with spatial abilities and being capable of solving unstructured questions. Thus, in order for females to be competent engineers, it is critical that they develop their design abilities. In comparison with male students, females report significantly lower levels of this skill (Felder et al., 1995).

Not until recently did the engineering education community seem to consider students' group skills a core skill. In response to employers' desires to have engineers with professional abilities such as group skills, the *Engineering Criteria 2000's* accreditation standards expanded the focus of engineering programs somewhat beyond the technical engineering skills to include soft skills (ABET, 1997). Since group skills are often considered a soft skill and "more feminine," group skills might be an ability in which the self-reported academic development gap will be small, if significant at all, between male and female students.

In addition to group skills, understanding the impact of engineering on society and the global community is a skill that has been added to the list of core skills required to be an engineer and is often cited as what is needed for future engineers' success (National Academy of Engineering, 2004). In addition to the importance of societal and global issues awareness for engineers for industry, females tend to be more concerned than males with the "social good" of their career choice (Hayes & Flannery, 2000; Sax, 1994). Thus, development of this skill might be more important for female graduates than male graduates in their interest and success in the engineering field.

The Research Problem

This study examined the proposition that changes in programs' organizational structures, practices, and policies, along with the experiences that students have while in college, affect female students' learning differently than that of male students. The three learning outcomes chosen for this study were students' development of design skills, group skills, and awareness of societal and global issues. Changes in program and faculty activities, made in response to the EC2000 new accreditation standards, possibly had conditional effects by gender on both the experiences that students had during their engineering education and on their learning outcomes.

For the learning that happens in engineering programs, and perhaps many other professional and academic fields, gender might be a moderator for the effects of programmatic and faculty activities, as well as the influences of students' undergraduate experiences.

This study sought to answer the following:

1) Have the changes made by programs and faculty members in response to EC2000 produced gender-related differences in students' experiences?

2) Have gender gaps in design and problem-solving skills, group skills, and societal and global issues awareness closed?

3) Have the changes made by programs and faculty in response to EC2000 varied by gender in their effects on students' experiences while in college?

4) Have the changes in program curricula and faculty practices had a different effect on female engineering students' development of design and problem-solving skills, group skills, and societal and global issues awareness than that of men?

5) Do engineering students' in-class and out-of-class experiences have the same effects on female students' development of certain engineering abilities as on male students' development of the same abilities?

The Significance of the Study

The substantial underrepresentation of females in the engineering field is a problem for several reasons, including social equity, misspent resources, equity in public funding, and global economic competitiveness. These reasons are discussed in the following subsections.

Social equity. Female graduates in six of the engineering disciplines (mechanical, aerospace, computer, computer science, electrical, and electrical/computer) comprise as little as 11.3% of all engineering graduates (Grose, 2006). In addition to the lack of females in engineering, if the women students who do earn their bachelor's degrees have not developed the skills necessary to excel in the engineering field, this creates disparities among the accomplishments of men and women in the field of engineering. Females also enter the

engineering workforce at lower rates than men. Since engineering is one of the most lucrative fields, females' ability to actively participate in engineering is important in creating not only financial equity between the genders in the United States, but also ensuring that women are included in decision-making roles in the technological fields, which are fast transforming our country. With gender parity in engineering may come a "much needed diversity in perspectives, creativity, and leadership to these fields" (Baum, 2000 as cited in Zhao et al., 2005, p. 504).

Resources invested. If women leave the engineering program before receiving their degrees, individual, institutional, and even federal resources will have been mis-invested by parents, students, and administrators. Female students extend their time-to-degree by spending time in rigidly prescribed course requirements and then transferring to another program. On average, women spend an additional year and one-half in college when they start in engineering and then transfer into another major (National Center for Education Statistics, 2000). Administrators, faculty, and advisors at higher education institutions also invest resources in students who may drop out, and programs spend money on students who may ultimately choose another field. Finally, the federal government also invests money in the form of student grants, loans, and tax credits in the additional time that female engineering students spend in higher education, which could have been avoided by understanding what women need to learn in the engineering disciplines.

Legal obligations. Title IX of the 1972 Education Amendments to the Higher Education Act specifies 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 educational program or activity receiving federal financial assistance" (Feminist Majority Foundation, 2007, p. 2). Thus, policies or practices that discourage female students from being engineers are

potentially illegal (Feminist Majority Foundation, 2006). The Committee on Maximizing the Potential of Women in Academic Science and Engineering (2006) made recommendations on the changes needed to help engineering programs comply with Title IX.

Global competitiveness. Undergraduate engineering programs cannot keep up with the need for engineering talent. “Enrollments are down for the second year running” (Grose, 2006, p. 28). Grose pointed out that one of the two major talent pools that are not successfully recruited by engineering programs is women (56% of the U.S. population). As the need for engineers increases, not only do undergraduate programs need to attract and retain female students, they also need to teach females the skills needed to succeed and stay in the engineering profession. Leaving women out of the engineering field means that creativity and ingenuity are restricted to what males bring. Engineering programs in the United States cannot allow their graduates entering the engineering profession to be limited to only one group of citizens.

The Methodology

The *Engineering Change* study’s intricate and multi-faceted design provides an excellent dataset for a 360-degree examination of engineering programs (Lattuca, Terenzini, & Volkwein, 2006). The *Engineering Change* study assessed the changes in student learning associated with the implementation of the new *Engineering Criteria 2000* (EC2000) accreditation standards (ABET, 1997). In 2004, information was collected from graduates of engineering programs who received their degrees in 1994 and 2004, faculty numbers, and program chairs in 147 programs at 39 different institutions. In particular, because the dataset contains large number of female graduates, it provided an excellent source for exploring gender-conditional effects of certain program, faculty, and in-class and out-of-class experiences. This study is a secondary data

analysis. Thus, unless otherwise noted, the description of the design, population, sample, data collection, and variables follows the depiction in *Engineering Change* (Lattuca et al., 2006).

Conceptual framework. The first stage of the conceptual framework (see Figure 2.1) implies that the new EC2000 accreditation standards will influence the curriculum and instructional practices in engineering programs. Developing the new skills and meeting the standards contained in EC2000 requires new teaching methods. The alterations to curriculum, instruction, culture, practices, and policies then might create a shift in the experiences students have both in and outside of the classroom. Finally, the model suggests that these differences in students' experiences influence the differences in student learning. This study used this model to examine whether there are differences in the effects of program changes and faculty activities on students' experiences and learning outcomes, along with influences of students' experiences on female students' development of their design and analytical skills, their ability to function in a group, and their awareness of societal and global issues from those of male students.

Design. The *Engineering Change* research group adopted a quasi-pre-/post-test, cross-sectional, *ex post facto* design that involved surveys of engineering students graduating in 1994 and 2004. The present study used the survey data from the *Engineering Change* study collected from the graduates from both years.

Population and sample. The population for the *Engineering Change* study included all students who graduated in 1994 or 2004 from ABET-accredited undergraduate engineering programs that offer at least two of seven engineering disciplines: aerospace, chemical, civil, computer, electrical, industrial, and mechanical (Lattuca, Terenzini, & Volkwein, 2006). The target population included 1,241 ABET-accredited engineering programs, of which 1,024 offered at least two of the seven specified disciplines.

The *Engineering Change* study dataset was created using a two-stage, 7x3x2, disproportional, stratified random sample. The first stage entailed a random selection of 40 institutions across the three strata. The first stratum was the seven disciplines. The second stratum was EC2000 review cycle, and the third stratum was whether the institution was part of a National Science Foundation Engineering Education Coalition. The final sample included 39 institutions with 147 programs (one institution failed to provide student contact information and, thus, was dropped from the study).

Students. The first source of data included engineering graduates who finished their degrees in 1994 and 2004 at the included institutions. Because part of the *Engineering Change* study was an interest in the change in learning outcomes between the graduates in 1994 and those in 2004, the study design required that the same procedures be used for both groups of graduates The student survey instrument collected information from the engineering graduating seniors for 1994 and 2004 on precollege characteristics (e.g., basic demographic information and preparation levels); students' in-class experiences, perceptions of program and class climate, involvement in out-of-class engineering-related activities; and self-reports of their learning on the 11 EC2000 3.a-k outcomes criteria. For this analysis, the self-reports of greatest interest were those relating to engineering design and analysis, working in groups, and awareness of societal and global issues.

The 40 selected institutions identified 15,734 individuals as graduates in 1994 from the seven engineering programs in the *Engineering Change* study (Lattuca, Terenzini, & Volkwein, 2006). In the spring semester of 2004, the entire population of 1994 graduates received the student survey instrument. Of those who responded, there were 5,335 usable cases. Of those cases, 928 were female and 4,407 were male. The 39 participating institutions also identified

12,144 individuals as graduates of 2004 in the seven engineering programs (Lattuca, Terenzini, & Volkwein, 2006). These graduating seniors were mailed survey forms in the spring semester of 2004. From the surveys mailed out, there were still 4,158 usable cases. Among the useable cases were 888 female students and 3,270 male students.

Faculty. The study design also included surveying the engineering faculty in any of the seven programs offered on a participating campus. Faculty members reported on changes in their instructional approaches and other professional practices and development activities over the past decade. During the fall semester of 2003, a total of 3,303 faculty members were identified by their institutions and targeted for the *Engineering Change* study. From those surveys sent out, faculty respondents provided 1,201 usable responses.

Program chairs. The data collection procedures used with the program chairs followed those for both cohorts of students and the faculty. Respondents answered questions about a wide array of program characteristics and the changes made to the curriculum since the implementation of the EC2000 accreditation standards. In November 2003, surveys were to 203 engineering program chairs. Of the surveys mailed out, 147 (72%) on 39 campuses provided usable responses.

To test whether the each group of respondents were representative of the larger population, Chi-square goodness-of-fit tests were calculated. Students' representativeness was checked based on gender, discipline, and their institutions' type of control (public or private) and Carnegie classification. Faculty members' and program chairs' representativeness was tested for the type and control of institutions at which they taught, gender, discipline, and institutional membership in an NSF-Coalition. Where response biases existed, weights were derived to align the respondents' distributions with those of the national population from which they came.

Variables. With the graduates' survey data, principal components factor analyses with Varimax rotation produced nine factors assessing learning outcomes. The nine-factor solution retained 75.3% of the overall item variance among the original 36 survey items. Three of these nine factors are the dependent variables in this study. The three factors selected for this study deal with students' group skills, design and analytical skills, and awareness of societal and global issues.

The predictor variables for this study fell into five categories. The first set of variables contained the students' precollege characteristics, which included sociodemographic traits, personal demographics, discipline, and the students' academic preparation. These variables were used as covariates in the statistical procedures summarized below. The second group of variables was the institutional characteristics. The third set consisted of four scales measuring changes in engineering program characteristics, such as in curricular emphases. The fourth area included the faculty variables, which were five scales measuring the changes in faculty members' instructional practices and attitudes. The final group was the student experience set, which consisted of ten items reflecting students' in- and out-of-class activities relevant to engineering education.

Data analyses. The preliminary analyses compared males' and females' means for the variables in the model to see if there were gender differences within each cohort. The nested nature of the program, faculty, and student data included in the analyses also suggested the need for a multi-level analytical technique, such as hierarchical linear modeling (HLM). The first HLM model for each of the three learning outcomes (Design and Analytical Skills, Group Skills, and Societal and Global Issues Awareness) had no predictors and determined the amount of between- and within-program variance for each of the learning outcomes. Level-one (within-

program) of the HLM analysis was at the student level and level-two (between-program) was at the program level. If both the between- and within-program variance terms were significant, models including the program-level and student-level predictors were created to explain the variance for each learning outcome.

The interactions between gender and student experiences, because they are both level-one variables, have to be treated in the same way as in OLS (Preacher, Curran, & Bauer, 2006; Raudenbush & Bryk, 2002). If the interaction terms explained a significant amount of within-program variance for each of the learning outcomes, the HLM software allows researchers to easily graph the effect of each student's experiences on each of the learning outcomes by gender. By comparing the slopes of the lines for female graduates to male graduates, the conditional influences of the student experiences become clear.

Preview of What is Next

The rest of this chapter summarizes the study's findings relating to each of the five questions posed. These sections include the changes that have occurred in the curriculum and climate of engineering program in the ten-year span between 1994 and 2004, the conditional effects of program and faculty changes on students' experiences and their learning outcomes, the conditional effects of student experiences on their learning outcomes, and whether a gender gap exists in the three learning outcomes. Next, the chapter contains a discussion of the findings' implications for practice and policy, followed by three sections on how the findings from this study support, contradict, and add to current literature, and suggests implications for future research. Finally, the last section tries to summarize the lessons learned from this study.

Gender Differences in Students' Experiences

The first question posed by this study was: *Have the changes made by programs and faculty members in response to EC2000 produced gender-related differences in students' experiences?*

While the curriculum and experiences in the classroom have become more female-friendly, they have also become more male-friendly. Women in 2004 said that they were having more positive experiences in the classroom than they had a decade ago, but so were male students. The largest gender differences in reports by male and female graduates were found in collaborative learning, program climate, and involvement in professional society chapters. Each of these experiences along with other in-class experiences is suggested in the literature as having gender differences. The changes made by the programs and faculty have had the same impact on the curriculum and experiences in the classroom for male and female students. In contrast, while students' perceptions of the academic climate have not seemed to change for male or female students, the program and faculty changes have had different influences on females' perceptions of the climate than those of male students. The next two sections provide greater detail on how the changes made in response to EC2000 have affected the curriculum and in-class experiences, as well as students' perceptions of the climate.

Curriculum and in-class experiences. In the classroom, women who graduated in 2004 reported a more female-friendly curriculum and in-class experiences than did their counterparts a decade ago. Female graduates in 2004 rated the amount of collaboration in the classroom, the instructor interaction and feedback, and the encouragement of openness in their programs significantly higher than their counterparts in 1994. The faculty and program changes did not, however, have a stronger effect on the in-class experiences for women than for men.

Students in programs in which faculty supported EC2000 reported more classroom clarity and organization, collaborative learning, and instructor interaction and feedback than did those not in such programs. It would seem that faculty members who were supportive of EC2000 were more likely to make an effort to improve their teaching. The same positive effects on instructors' classroom clarity and organization and their interaction and feedback to students were seen in programs whose chairs said they had implemented continuous curriculum planning. The programs that continuously updated and improved the curriculum may also have encouraged faculty to think about what they were doing in their individual courses and thus enhancing the experiences of student in the classroom. Faculty participating in undergraduate education improvement projects had a negative influence on the extent of collaborative learning. At first glance this finding might seem counter-intuitive because one would imagine that the greater the faculty effort to learn about undergraduate education, the greater their desire to improve it. The items in the scale suggest a focus on content and external funding. Perhaps these kinds of activities detract from an emphasis on, or diminish time spent on, improving pedagogy.

Climate. While female graduates in 2004 did report a slightly more positive gender climate in and outside of their classes than female graduates in 1994, the difference was not significant. Perhaps this lack in difference stemmed from the rather positive rating of climate by females in 1994 (over 4 on a 5-point scale). In both 1994 and 2004, females rated their programs' climates lower than their male counterparts, but the gender gap was smaller than in 1994. Realizing which program and faculty activities could make the climate more welcoming to women is critical to reducing inequalities in the male-dominated field of engineering.

Two program changes and one faculty change in activity seemed to have significant conditional effects on students' perceptions of program climate by gender. A programs'

curricular focus on foundational knowledge and faculty emphasis on project skills increased the gap between male and female students' perceptions of their programs' climate, with females reporting a less-accommodating environment. In contrast, programs in which faculty seemed to support EC2000 helped close the gap and increased females' perceptions of their programs' climate. These findings seem to coincide with past literature that suggests that female engineering students excel at the softer engineering skills (Hecht et al., 1995; Kilgore et al., 2007; Knight et al., 2002). Faculty who support EC2000 might be more likely to include soft skills in their courses and use pedagogies that are more conducive to female learning (Davis et al, 1996; Eccles, 1992; Felder et al, 1995; Koehler, 1990; Peterson & Fennema, 1985), while programs that focus on foundational knowledge and faculty who emphasize project skills may also focus on the foundational math and science skills that disadvantage female students. In addition, the emphasis on project skills would increase the extent of teamwork in which female students would have to participate. This finding might be explained by Colbeck, Cabrera, and Terenzini's (2000) observation that involvement in team projects can reinforce the negative effect of the chilly climate.

Professional society chapters. When compared to males, female engineering graduates in 1994 indicated significantly higher levels of involvement in professional society chapters. The effect size of the gender gap for this experience is larger than that found for all the other experiences. While the effects size of the gender gap for participation in professional society chapters was still more than that of the other out-of-class experiences, the gender gap had decreased to a magnitude half of that a decade earlier and reversed. No program changes or faculty practices were found to have gender conditional effects on students' involvement in professional society chapters.

The Gender Gaps in Student Learning

The study's second question asked: *Have gender gaps in design and problem-solving skills, group skills, and societal and global issues awareness closed?*

Females in 2004 seemed to be more prepared and to have engaged in more of the experiences that the literature suggests enhance student learning, than their counterparts ten years earlier. Even with this preparation and these experiences, the gender gaps in students' development of design and problem-solving skills and societal and global awareness have not narrowed in effect size. The next three subsections explore the gender gaps in each of the three chosen learning outcomes for this study.

Design and problem-solving skills. The gender gap in design and problem-solving skills does not seem to have changed over the last decade. The magnitude in the effect size of the gap between female and male graduates in 1994 (-.28) and 2004 (-.29) points to a continued deficit in female students' perceptions of their abilities to design solutions for engineering problems.

Group skills. Both in 1994 and 2004, the skill in which women rate themselves higher than men is their ability to work with others in groups. While female graduates in 2004 still rated their group skills higher than male graduates in the same year, the self-ratings of female and male graduates were much closer in 2004 (.08) than they were in 1994 (.17). Males cut females' perceived advantage in this skill by more than half, although the magnitudes of the effect sizes are probably not substantive.

Societal and global awareness. The pattern in societal and global awareness is the opposite of that found in group skills. Like design skills, male graduates rated themselves significantly higher than their female counterparts on their awareness of global and societal issues in both 1994 and 2004. In contrast to both of the first skills, the gap between female and

male graduates in their self-rating of societal and global issues awareness nearly doubled in the ten years between 1994 (-.07) and 2004 (-.15), although both differences were small.

Conditional Effects of Program and Faculty Changes on Student Experiences

The third question posed by this study was: *Have changes made by programs and faculty in response to EC2000 varied by gender in their effects on students' experiences while in college?*

The results of this study suggest that the influence of changes made by programs and faculty in accordance with EC2000 did vary by gender and in nearly every instance had a stronger positive influence for female engineering students than for male students. Gender moderated the effects of three of the four program changes and all five of the faculty activities on six of the ten student experiences while in college (instructor clarity and organization, academic climate, internships/cooperative education, design competitions, studying abroad, and international travel). These conditional effects and relative benefits for both male and female students are discussed in the six sections below.

Clarity and organization of instructor. Faculty members' emphasis on project skills differentially affected each gender's perceptions of the clarity of classroom instruction. The greater the emphasis on project skills in the classroom, the more likely it was that male students would think the course was clear and well-organized, and the less likely females thought so. This could be occurring because engineering faculty are assigning projects in the classroom to emphasis communication, teamwork, and project management, but they are leaving these projects unstructured. Female students like more structured problems, while male students prefer to be given projects and just asked to come up with a solution (Osborn & Agogino, 1992). Thus,

a gender difference arises. Whatever the explanation, it appears that faculty are not communicating as well with women as they are with men.

Internship/cooperative education. Programs that introduced continuous curriculum plans and had faculty members who used active learning pedagogies appear to promote women spending more time in internships and cooperative education experiences than males. Perhaps these programs created more flexible curricula that allowed female students, who tend to feel more constrained by rigid courses requirements (Laughlin, 1996; Monasterky, 2005; Seymour & Hewitt, 1997), to take the opportunity to venture outside the foundational course requirements to participate in internships and cooperative education. Another possible interpretation of this finding is that the emphasis on hands-on experiences in the classroom increases female engineering students' interest in hands-on activities outside the class.

Design competitions. Faculty members increasing the amount of discussion in their classes about professionalism and society problems appear to be associated with greater female participation in design competitions than is the case with their male counterparts. Perhaps faculty description of issues that might be faced in the engineering workforce and ways to overcome those obstacles, promoted female students' confidence in their ability to perform in a design competition group. Alternatively, some programs focus more on design and contexts than others and these programs also encourage participation in design competitions for all students.

Study abroad. The extent to which a program increased its systematic curricular planning process significantly and positively affected female students but had no apparent influence on male students' time spent studying abroad. More time spent by faculty members in undergraduate education projects also had a positive influence on time spent by female students traveling abroad, while it had no significant effect for male students. For both study abroad and

international travel, curricular planning seemed to positively influence female participation, but did not have the same effect for male students. Harper (2007) found that engineering programs more actively engaged in continuous improvement also tended to focus more on teaching than did less active programs. This relationship may help explain why such programs they encourage study abroad and perhaps find ways to persuade females in particular to be involved.

International travel. Programs whose faculty described curricular planning processes as systematic and data-driven were positively related to the amount of time female students, but not necessarily male students, spent traveling abroad. Faculty emphasis on project skills may increase females' propensity to travel abroad more so than male students. Perhaps once females feel that they understand the foundational and project skills in engineering and have been taught by competent faculty, they are more inclined to take part in activities that remind them why engineering is important to our society, such as traveling and studying internationally. These activities are in greater alignment with the reasons cited by female students about becoming an engineer in the first place (Hayes & Flannery, 2000; Sax, 1994).

Conditional Effects of Program and Faculty Changes on Student Learning

The study's fourth question asked: *Have the changes in program curricula and faculty practices had a different effect on female engineering students' development of design and problem-solving skills, group skills, and societal and global issues awareness than that of men?*

Three of the four program changes and all five of the faculty changes also had differential effects on students' development of their design skills, group skills, and awareness of global and social issues. The conditional effects of program and faculty changes on students' development of these three engineering abilities are not as numerous as the conditional effects on students' experiences, but they are perhaps more important. Each of the three following sections examines

differences by gender in effects of program and faculty activities on students' development of engineering skills.

Design and problem-solving skills. Programs in which faculty members stressed applied skills positively affected female students' perceptions of their abilities to solve problems and design solutions, but had no notable effect on males' perceptions of the same skills. Perhaps female students need more formalized instruction in design than men in order to develop their design skills. Perhaps female students wish to understand the process, not just engage in it, to feel competent. Greater emphasis on professionalism and societal issues had a negative influence on female students' design skills, while it had no noticeable effect for their male counterparts. If faculty members are open and honest about the profession of engineering, the fact that the profession is so dominantly male might have female graduates questioning their own ability to perform in the engineering field and thus question their engineering competence. Alternatively, perhaps female students learn how complex design discussions are and feel less sure than men of their abilities in this area.

Group skills. Faculty putting greater emphasis on professionalism and societal issues also had a negative influence on female students' self-ratings of group skills, while it had no noticeable effect for their male counterparts. The first explanation in the previous section might also be reasonable here. In contrast, faculty members who use active learning pedagogies in their classes positively affect the group skills of female students, but have no effect for male students. Many studies showing that increasing active learning in the classroom, such as the use of small-group discussion, collaborative learning, and practical problem-solving activities, have particularly positive effects for female students' level of learning (Davis et al., 1996; Eccles, 1992; Felder et al., 1995; Koehler, 1990; Peterson & Fennema, 1985).

Societal and global issues awareness. Unlike their effects on students' perceptions of their design and group skills, the influences of changes in curriculum and instruction at the program and course levels do not seem to have differential effects by gender. While there are some significant differences in the male and female models between the effects of program and faculty changes for development of students' societal and global issues awareness, the individual male and female model effects are not significant, perhaps due to large standard deviations.

The conditional effects on both students' ability to design solutions and work in groups suggest that many of the changes that programs and faculty members initiate have been much more influential and positive for female students than for male students. Thus, when administrators and faculty make decisions, they need to consider not only the effects of those choices on the student body, but also on female engineering students in particular.

Conditional Effects of Student Experiences

The final question posed by this study was: *Do engineering students' in-class and out-of-class experiences have the same effects on female students' development of certain engineering abilities as on male students' development of the same abilities?*

The results suggest that students' experiences while in college did not have the same influence on female students' abilities in the three selected outcomes for this study that they did for male students' development of those same skills. Gender was a moderator for nine of the ten student experiences. In most of those cases, the effects of student experiences were stronger for female students than they were for male students. The next three sections explore the conditional effects of the ten student experiences on each of the students' engineering abilities.

Design and problem-solving skills. Five student experiences had differential effects for men and women on their development of design and problem-solving skills. The effects of

interaction with the faculty on female students' ability to solve engineering problems and design solutions were nearly double those for male graduates of the same year. For male graduates, being in courses that were clear and organized had a more positive influence on their development of an ability to design solutions to problems than that of females. International study positively influenced female graduates' design abilities and negatively affected male graduates' development of that same engineering skill. While participation in design competitions is significantly more influential for male students on their design and problem-solving skills, the positive effect for females is still noteworthy. The differential effect of membership in a student chapter of a professional society was significant for all three learning outcomes, with a positive effect for females and nonexistent effect for male graduates. Perhaps studying abroad and professional chapter activities increase women's self-reports of their design skills because these out-of-class activities increase self-confidence among female engineering students (Robin & Reilly, 1993; Schulz et al., 1998).

Group skills. Three conditional gender effects of students' experiences on development of the ability to work in groups existed. Collaboration had a slightly greater influence on increasing female students' group skills than those of male students. Participating in an internship also had a positive influence on female graduates but had no effect on male graduates' development of the same skills that year. International travel positively affected female graduates' abilities to work well with others in a group, while it had no notable effect on male graduates' development of the same skill. The differential effect of membership in a professional society was significant for all three learning outcomes, with the effect being positive for females and nonexistent for male graduates.

Societal and global issues awareness. Gender was a moderator for six effects relating to social and global issues awareness. The impact of both collaborative learning and interaction with faculty on female students' awareness of global and societal issues awareness was nearly double that of male students' development of that same awareness. In contrast, the supportiveness of a program's climate had a negative effect on females but no influence on students' awareness of global and societal problems. This finding suggests that for programs in which women perceived a more welcoming atmosphere, the perception may also have been that these programs had not fully informed them of the issues they would face in society and globally and about the realities for women in the engineering workforce. Participating in an internship, time spent studying abroad, and membership in a student chapter of a professional society all had positive impacts on female graduates but had no effect on male graduates' development of the same skills that year. International travel had a positive influence on global and societal issues awareness for both male and female students, but the effect was significantly stronger for females.

The Literature Versus This Study's Findings

The findings from this study support much of the literature on the effects of individual student experiences on female students' development of engineering skills. Different program and faculty changes and student experiences are more important for the development of female students than male students. The next sections explore how the study findings add to, contradict, or support the past literature on the effects of program and faculty changes, in-class experiences, and out-of-class experiences on students' learning.

Program and faculty changes. Past literature indicates that students' college experiences are the largest and most consistent predictors of learning outcomes (Kuh, 2001; Lambert,

Terenzini, & Lattuca, 2007; Pascarella et al., 1996; Reason et al., 2006; Springer, Terenzini, Pascarella, & Nora, 1995; Terenzini, Springer, Pascarella, & Nora, 1995). In this study, though, a few effects of faculty activities also appear to be strong predictors of female students' development of design and problem-solving skills. For females, the two of the largest influences on their development of design and problem-solving skills were faculty activities, faculty emphasis on applied skills and participation in undergraduate education projects. One of the faculty activities, participation in undergraduate education projects, also so seems to have a strong effect on females' development of their group skills. In the aggregate model and even the male model, these findings were not true. Thus, these results highlight the importance of disaggregating students in order to understand the processes and factors that affect female students' development of skills in engineering.

In-class experiences. Study findings strongly support the proposition that pedagogies that allow students in engineering courses to interact with one another in collaborative learning experiences positively influence female students' development of their engineering skills (Bock, 1999; Cross, 1998; Davis et al., 1996; Eccles, 1992; Felder et al., 1995; Koehler, 1990; Peterson & Fennema, 1985; Willis, 1990). In addition, the findings suggest that while collaborative learning might be more influential for female learning, it is also a positive experience for male students (Cross, 1998; Bjorklund, Parente, & Sathianathan, 2004; Bruffee, 1999; Henes et al., 1995; Palmer, 1998; Terenzini, Cabrera, & Colbeck, 2000; Worley, 2002).

Student-faculty interactions have a positive influence on student development of engineering design and professional skills (Bjorklund, Parente, & Sathianathan, 2004; Colbeck, Cabrera, & Terenzini, 2000; Sax, Bryant, & Harper, 2005; Terenzini, Cabrera, & Colbeck, 2000). Consistent with these other findings, the analyses of data for graduates suggested that

both female and male students' development of their design abilities and awareness of global and societal issues were positively affected by increased interaction with faculty. In contrast, student-faculty interaction had no effect on either male or female graduates' ability to work in groups. These findings suggest that interaction and feedback from faculty are in fact important for students' development of engineering design and professional skills, but less important in developing teamwork skills that must be practiced with peers.

The results from this study reinforce the proposition that female students, even more so than male students, need interaction with their faculty members (Robinson & Reilly, 1993; Seymour & Hewitt, 1997; Zeldin & Pajares, 2000; Zhao, Carini, & Kuh, 2005). The findings of this study also stands in contrast to Zhao, Carini, and Kuh (2005), who found that women have fewer opportunities for valuable informal exchanges with faculty, and agrees with Sax, Bryant, and Harper (2005) that females seem to report having interacted slightly more often with faculty than their male counterparts did.

Studies have shown that instructor clarity can have a positive influence on students' development of engineering skills (Colbeck, Cabrera, & Terenzini, 2000; Lambert, Terenzini, & Lattuca, 2007; Lattuca, Terenzini, & Volkwein, 2006; Terenzini, Cabrera, & Colbeck, 2000). The results from this study support that literature, and then take this idea a step forward to consider whether the clarity and organization in courses was any more or less beneficial for female students' development of their engineering skills. These findings suggest that while clarity and organization in the classroom are critical to the development of all students' engineering skills, it is particularly crucial for female students.

Out-of-class experiences. The strongest contradictions between this study and other investigations seem to occur with the out-of-class experiences. The evidence presented by

Lattuca, Terenzini, and Volkwein (2006) with the same data, but not disaggregated by gender, masked the conditional effects of gender on participation in internships, study abroad, international travel, and professional society chapters. For example, while the findings from the *Engineering Change* study suggest that studying abroad is influential for all students, this study discovered that time spent abroad had a strong effect on female graduates' development of global issues awareness but had no impact for male graduates. These findings underscore the importance of paying attention to crucial variables such as gender when considering the effects of certain factors on student learning and that caution must be given to policies that rely on large datasets that are not disaggregated by pivotal characteristics.

The climate in engineering programs is most commonly cited in the literature as the reason for female students' decision not to persist in the engineering major or for their lack of academic success in engineering (Harris et al., 2004; Lee, 2002; Salter & Persaud, 2003; Seymour & Hewitt, 1997; Whitt et al., 1999). The climate in engineering has often been labeled 'chilly' because of the competitive nature of engineering and a lack of supportive faculty members, which female students need (Vogt, Hocevar, & Hagedorn, 2007). In support of these studies, the results from this research also suggest that women come into engineering programs with equal or stronger abilities than those of their male counterparts, but by the time female students graduate they no longer have that same advantage. Females rate themselves lower than male engineering students on both their design skills and their awareness of societal and global issues.

Surprisingly, though, climate does not seem to be the answer to these gender gaps. Program climate did not seem to have any more influence on the engineering skills of female graduates than on male graduates. On the contrary. A supportive climate seems to have a more

substantial effect on ability to work in groups for male students who graduated than for female counterparts. The supportiveness of a program's climate had a negative effect on females and no influence on students' awareness of global and societal problems. Thus, programs in which females felt a more welcoming atmosphere may also fail to alert women to the issues to be faced in society and globally. Creating a warm climate in a program without preparing students for the issues they will face once they graduate can be dangerous. Overall, it would seem that, for the females who stay in engineering long enough to graduate, climate does not seem to be a reason for learning gaps between male and female students. Perhaps this is because, as Zhao et al. (2005) suggested, females find ways to deal with a chilly climate through such resources as social networks.

The research on the effects of participation in design competitions on engineering skills has been shown to be positive for all students when models contained both male and female students (Colbeck, Cabrera, & Terenzini, 2000; Lambert, Terenzini, & Lattuca, 2007; Lattuca, Terenzini, & Volkwein, 2006). In contrast, one study that included only women in its analysis found that involvement in these team projects can reinforce the negative effect of a chilly climate (Colbeck, Cabrera, & Terenzini, 2000). When considering the combined male and female graduates of 2004, in the *Engineering Change* study, even after controlling for all in-class experiences and precollege characteristics, involvement in a design competition had a positive and statically significant effect on six of the nine learning outcomes, including both design and problem-solving skills and group skills (Lattuca, Terenzini, & Volkwein, 2006).

The findings from this study support the idea that participation in design competitions had a positive influence for both male and female students' development of an ability to design solutions. While participation in design competitions had significantly more influence on male

students' design and problem-solving skills, the positive effect for females is still noteworthy. Participation in design competitions had a positive effect on female students' ability to work well with others in a group, but had no significant effects for their male counterparts. This may mean that women's experiences in these team competitions have improved since the last studies were conducted.

While in-class experiences are some of the strongest predictors of all three learning outcomes on both the male and female models, the biggest gender differences in the effects of student experiences on students' development of these engineering skills are found in the out-of-class experiences. Many of these experiences had a much greater influence on female students' development of key engineering skills, than male students' development of the same skills.

Implications for Practice

If there were no differences in the male and female graduates' development of engineering skills, then perhaps there would be no reason to pay particular attention to the difference in factors that affect that learning. These findings suggest, however, that females leave college believing that they are not as well prepared to design engineering solutions or to solve problems as men. Designing solutions to problems is perhaps the most important skill taught by engineering programs. Thus, in order to encourage females to enter the engineering workforce, greater efforts may need to be made to ensure that they are just as well-prepared in their abilities as their male counterparts in these areas.

How to make the climate in engineering warmer for female engineering students is the leading question in research on the experiences of women in engineering education. This study reveals two other faculty activities that seem to have a very positive influence on female students' perceptions of climate. Focusing on design and the application of good engineering

tools and skills is positively related to females' perceptions of their programs' climate. In addition, faculty members who participate in undergraduate education enhancement projects signal female students that their instructors are invested in improving engineering education of all students. Their investment may also translate into a more welcoming program climate for female students.

In order to reach women students, programs may need to invest time and resources in student experiences that particularly promote female students' learning. These experiences include positive interaction with faculty, clear and organized courses, internships, study abroad, and international travel. In addition, administrators and faculty might want to promote experiences that are positive for both female and male students, such as collaborative learning, a program that encourages openness, and participation in student design competitions.

Faculty and administrators can help motivate females to participate in these experiences by changing certain program policies and faculty activities. For example, programs that engage in continuous curricular improvement were more successful in increasing the amount of time female students spent traveling abroad than those programs that did not. Faculty might also want to consider how project skills are taught in the classroom because increasing the emphasis on project skills seems to create unintended consequences for female students in course clarity and climate. Faculty members should consider increasing discussion in their classes about professionalism and societal problems to help encourage females to participate in design competitions as frequently as their male counterparts. Faculty might want to be cautious in this action, however, because the way faculty members incorporate conversations about ethics, responsibility, global and social contexts, and contemporary issues could be a negative influence on female students' development of design skills and abilities to work well in groups. No

explanation for this counter-intuitive finding exists, suggesting that more research needs to be done in order to confirm its validity and, if confirmed, to understand its implications.

Finally, faculty and administrators can take actions that have an influence on students' engineering abilities. Though the program changes did not have conditional effects directly on student learning, administrators should encourage all faculty members to increase emphasis on certain skills, such as applied skills, during curriculum planning. Faculty members can stress applied skills to positively affect female students' abilities to problem-solve and design solutions. Faculty members can also use active learning pedagogies in their classes to encourage female students to develop their group skills. These activities and others discussed in this chapter are ways in which programs and faculty members can make a difference in closing the gender gap that has long been present in male-dominated fields such as engineering.

It is important for faculty and administrators to understand the differences in learning among women and men in order to identify the best ways to produce graduates with the skills needed in the workplace (Baxter Magolda, 1992). More needs to be done in engineering education than just helping women to adapt to a traditionally masculine field (Salminen-Karlsson, 2002). Responding to individual students' needs at each level of learning can strengthen the overall educational experience in and outside of the classroom (Baxter Magolda, 1992). After identifying gender patterns in development and learning, the significant differences reveal that males and females may need different challenges and support systems to ensure their future skill levels. The findings from this study are only the first step toward understanding what female students need to maximize their learning potential. By discovering which experiences encourage women to learn and by expanding our definitions of that learning process, higher

education engineering administrators and educators can ensure that they do not inadvertently marginalize female students.

Implications for Future Research

This study's findings suggest that future studies should use models of students' learning that involve different conceptual frameworks, designs, variables, and analytical procedures. This section contains a discussion of the importance of disaggregating datasets by key student characteristics such as gender in order to gain a better idea of what is happening. In addition, this section explores future topics that should be added to complex models of student learning, such as the one for this study.

Implications for the methods of future research. The findings of this study indicate that if a factor like gender is not taken into account, certain forces that may be particularly important in shaping female students' learning might be left out of studies of their development. The importance of studying conditional effects is exemplified by the fact that our knowledge of the effects of college on students is based on studies with samples that are not disaggregated by key student characteristics such as gender (Pascarella & Terenzini, 1991, 2005). The direct impact of faculty members' decisions to emphasize applied skills and use active pedagogies in their classrooms would be missed in a model that included both male and female engineering students, yet in doing so this would overlook the differential influence of these decisions on the development of certain abilities in female students. When conditional influences are not evaluated, the distinctive experiences of men and women and the effects of those differences may be overlooked.

Few large-scale studies have explored the effects of the relationship between gender and participation in in-class and out-of-class experiences on students' development and learning

while in college. Even fewer have considered the possibility of an interaction between gender and program and faculty policies. None has been done in engineering, a field that arguably needs such attention because of its lack of women. Understanding the factors that promote women's development of engineering skills will help colleges and universities design educational experiences that promote learning among all students, as well as to diversify engineering, science and technology programs. Pascarella and Terenzini (2005) emphasized the importance of studying conditional effects and urged scholars to take such effects into account in future research.

Implications for additional topics for future research. Considerable variance remains unexplained in the models presented in this study. This suggests that there are still factors that may be contributing to differences in learning between male and female engineering students. Since the datasets used in this study were collected with a model for all students in mind and not specifically for females, some factors found in the literature, based mostly on qualitative research, could not be explored here. Some of the most intriguing are the Women in Science and Engineering Societies and female students' interaction with female faculty in particular. Several topics should be included in informal conversations with female engineering students, such as participation in Engineers Without Borders, interaction with female alumnae, and participation in undergraduate research.

MIT implemented the first institution-wide undergraduate research program in 1969. Over the last three decades many other institutions have followed their lead and involved students in undergraduate research (Zydney et al., 2002). Zydney et al. (2002) surveyed alumni from the University of Delaware's College of Engineering. They found that students involved in undergraduate research increased their cognitive skills, personal skills, and likelihood of going to

graduate school. Other studies of science and engineering students found that undergraduate research increased technical skills, problem-solving skills, and professional self-confidence (Kardash, 2000; Mabrouk & Peters, 2000; Sabatini, 19XX). On the other hand, Hackett, Croissant, and Schneider (1992) discovered that while students did rate their undergraduate research experience as influential, there were no effects of this experience on students' development of analytical, intellectual, leadership, or communication skills.

In addition to the professional society chapters created for all students, many institutions have created societies specifically for women engineers. There is some debate in the current literature, however, over whether these societies are helpful or harmful (Marra & Bogue, 2003; McLoughlin, 2005). Exploring the effects of these societies with a large nationally representative dataset would be worthwhile. These societies are supposed to create warmer climates for women and give them a forum for support and networking (Marra & Bogue, 2003). While these societies may have the best of intentions, a recent study suggests that they may reinforce the stereotype that female engineers need extra help and are not the equals of their male counterparts (McLoughlin, 2005).

The findings from this study suggest that interaction with faculty is particularly important for female students. In future research with a large dataset, the influence of interaction with female faculty, in particular, could be studied. The literature also suggests that the connections made with female faculty members help female students persist in engineering and have confidence in their engineering skills (Kardash & Wallace, 2001; Robinson & Reilly, 1993). Seymour and Hewitt (1997) found that women were likely to succeed in an environment that included female faculty members as both teachers and as role models.

As long as females continue to be vastly outnumbered in engineering and the gender gap in learning persists, studies of possible reasons need to be in the forefront of research on engineering education. Researchers should continue to explore alternative possible explanations to extend the learning model used in this study in order to understand the reasons for these differences between the genders in the development of engineering skills. There is never going to be a simple single solution to the problem. Clearly, the more clarity we attach to the complex model for female engineering students' learning, the more improvements we may make to the processes that help female students learn.

Conclusion

Creating gender equity in engineering education is more than simply a matter of social justice or diversifying the engineering field. It is also a significant public policy issue that will affect the future economic competitiveness of the United States in the global marketplace. Undergraduate engineering programs not only need to attract and retain female students, but they must provide full access to the educational experiences women must have to develop the engineering skills and confidence in those abilities to succeed in the engineering profession and the economic benefits of having them.

The findings from this study shed light on the complexity of the processes at work in student learning and the importance of creating models that can guide research on not only male students' development and change while in college, but also that of female students. Changes in program and faculty activities, made in accordance with the new accreditation standards set forth by EC2000, affected both student experiences and learning, differing by gender. This study also found that students' in-class and out-of-class experiences have significant differences in influence on female and male students. In particular, out-of-class experiences are more

influential on female students' development of all three learning outcomes than male students' development of those same skills. For the learning that occurs in engineering programs, and perhaps many other professional and academic fields, gender seems to be a moderator for the effects of programmatic and faculty activities, as well as the influences of students' undergraduate experiences.

Conversations that consider national policies about students' learning in higher education suffer when researchers and policy makers discount comprehensive research designs and ignore the role of gender in student learning. National policy cannot overlook the differences in the pathways to learning for male and female students. The desire to find the silver bullet to enhance learning for all students narrows, rather than enriches, exploration, innovation, action, and policies. As long as male models dominate academic and policy decision-making, a true transformation of male-dominated fields will never occur and the experiences and levels of learning for women will not reach their ultimate potential.

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APPENDIX A

Survey of 1994 Graduates

ENGINEERING CHANGE
A STUDY OF 1993-94 ENGINEERING ALUMNI

PENNSTATE
Center for the Study of Higher Education

ABET

Endorsed by:

AIAA	American Institute of Aeronautics and Astronautics
AIChE	American Institute of Chemical Engineers
ASCE	American Society of Civil Engineers
ASME International	American Society of Mechanical Engineers
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IIE	Institute of Industrial Engineers
ASEE	American Society for Engineering Education

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Most of the questions below ask you to reflect on your undergraduate engineering program, your experience in it, or your engineering abilities and skills at the time you graduated. Please respond to these questions as they applied to you at that time.

Using pen or pencil, please completely fill in the appropriate box or circle with your response.

Part I. Personal Information

1. **When you entered the institution from which you received your undergraduate engineering degree, were you:**

   ○ A first-time student ○ A transfer student from a two-year institution
   ○ A transfer student from a four-year institution

2. **How old were you when you entered that institution?** ☐☐

3. **Are you:** ○ Male ○ Female

4. **Were you a U.S. citizen at the time you graduated?** ○ Yes ○ No (If "no," please go to Question 6)

5. **If "Yes," with which of the following racial/ethnic groups do you closely identify? (Select all that apply.)**

   ○ White/European American ○ American Indian/Alaskan Native
   ○ Black/African American ○ Hawaiian or Pacific Islander
   ○ Hispanic or Latino ○ Other (please specify): _____
   ○ Asian

6. **When you graduated, what was the highest level of formal schooling attained by your parents or guardians?**

	Mother	Father	Guardian
High School Diploma, GED, or less	○	○	○
Some college (incl. Associate's degree)	○	○	○
Bachelor's degree	○	○	○
Advanced degree	○	○	○

7. **When you graduated, approximately what was your parents'/guardians' annual family income?**

   ○ Below $20,000 ○ $90,001-$110,000
   ○ $20,001-$30,000 ○ $110,001-$130,000
   ○ $30,001-$50,000 ○ $130,001-$150,000
   ○ $50,001-$70,000 ○ More than $150,000
   ○ $70,001-$90,000 ○ I don't know

8. **Did you take the SAT or ACT tests? (Please select all that apply.)**

   ○ No. I did not take either exam.
   ○ Yes, I took the SAT exams, and my scores were approximately:
   SAT-Verbal ☐☐☐ SAT-Math ☐☐☐
   ○ Yes, I took the ACT exam, and my Composite Score was approximately: ☐☐

9. **<u>When you entered that institution</u>, how well prepared were you for basic science and math courses?**

   ○ Not at all
   ○ Slightly
   ○ Moderately
   ○ Very well prepared

-

10. Approximately what was your overall academic average in:

	High School	College
3.50-4.00 (A- to A)	○	○
3.00-3.49 (B to A-)	○	○
2.50-2.99 (B- to B)	○	○
2.00-2.49 (C to B-)	○	○
1.50-1.99 (C- to C)	○	○
Below 1.49 (Below C-)	○	○

11. As an undergraduate, were you:

a. Enrolled primarily as a (please select one): ○ Full-time student ○ Part-time student

b. Employed primarily (please select one): ○ Not employed while taking classes

○ On-campus, part-time while taking classes

○ Off-campus, part-time while taking classes

○ Full-time while taking classes

12. As an undergraduate, approximately <u>how many months</u> did you spend:

		Number of Months			
	None	1 - 4	5 - 8	9 - 12	More than 12 Months
As an intern or a co-op student in industry or an engineering firm	○	○	○	○	○
In organized study abroad	○	○	○	○	○
Traveling internationally (not study abroad)	○	○	○	○	○
Involved in student design project(s)/competition(s) beyond class requirements	○	○	○	○	○

13. As an undergraduate, how active were you in a student chapter of a professional society or engineering organization?

○ Not at all ○ Somewhat ○ Moderately ○ Highly

Part II. Your Undergraduate Engineering Experiences

14. Thinking about your <u>in-class and out-of-class experiences</u>, please rate your ability <u>at the time you graduated</u> to do the following:

	Ability at time of completing Undergraduate Engineering Program				
<u>A. Technical Skills and Abilities</u>:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Apply knowledge of math	○	○	○	○	○
Apply knowledge of physical sciences	○	○	○	○	○
Apply discipline-specific engineering knowledge	○	○	○	○	○
Design an experiment	○	○	○	○	○
Carry out an experiment	○	○	○	○	○
Analyze evidence or data from an experiment	○	○	○	○	○
Interpret results of an experiment	○	○	○	○	○
Understand essential aspects of the engineering design process	○	○	○	○	○
Apply systematic design procedures to open-ended problems	○	○	○	○	○
Design solutions to meet desired needs	○	○	○	○	○
Define key engineering problems	○	○	○	○	○
Formulate a range of solutions to an engineering problem	○	○	○	○	○

B. Professional Skills:	Ability at time of completing Undergraduate Engineering Program: No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Work in teams of people with a variety of skills and backgrounds	○	○	○	○	○
Work with others to accomplish team goals	○	○	○	○	○
Work in teams where knowledge and ideas from multiple engineering disciplines must be applied	○	○	○	○	○
Conduct yourself professionally	○	○	○	○	○
Work through ethical issues in engineering	○	○	○	○	○
Consider ethical issues when working on engineering problems	○	○	○	○	○
Understand the engineering code of ethics	○	○	○	○	○
Understand technical codes and standards	○	○	○	○	○
Convey ideas in writing	○	○	○	○	○
Convey ideas verbally	○	○	○	○	○
Convey ideas in formal presentations	○	○	○	○	○
Convey ideas with graphical representations (e.g. figures, graphs)	○	○	○	○	○
Understand the impact of engineering solutions in a **global context**	○	○	○	○	○
Understand the impact of engineering solutions in a **societal context**	○	○	○	○	○
Understand contemporary issues (economic, environmental, political, societal, etc.) at the local, national, and world level	○	○	○	○	○
Understand that engineering decisions and contemporary issues can impact each other	○	○	○	○	○
Use knowledge of contemporary issues to make engineering decisions	○	○	○	○	○
Apply engineering **techniques** in engineering practice	○	○	○	○	○
Apply engineering **skills** in engineering practice	○	○	○	○	○
Apply engineering **tools** in engineering practice	○	○	○	○	○
Integrate engineering techniques, skills, and tools to solve real-world problems	○	○	○	○	○
Manage a project	○	○	○	○	○
Apply interpersonal skills in managing people	○	○	○	○	○

C. Analytical/Thinking Skills:	Ability at time of completing Undergraduate Engineering Program: No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Break down complex problems into simpler ones	○	○	○	○	○
Apply fundamentals to problems that I hadn't seen before	○	○	○	○	○
Identify critical variables, information, and/or relationships involved in a problem	○	○	○	○	○
Know when to use a formula, algorithm, or other rule	○	○	○	○	○
Recognize and understand organizing principles (laws, methods, rules, etc.) underlying problems	○	○	○	○	○
Draw conclusions from evidence or premises	○	○	○	○	○
Develop a course of action based on my understanding of a whole system	○	○	○	○	○
Ensure that a process or product meets a variety of technical and practical criteria	○	○	○	○	○
Compare and judge alternative outcomes	○	○	○	○	○
Develop learning strategies that I could apply in my professional life	○	○	○	○	○

15. When you graduated, to what extent were you:	Not at All	Somewhat	Moderately	Highly
Motivated to acquire and apply new technologies and tools	○	○	○	○
Able to learn and apply new technologies and tools	○	○	○	○
Willing to take advantage of new opportunities to learn	○	○	○	○

16. How often did the following occur in the courses you took as an undergraduate in your department?

	Almost Never	Occasionally	Often	Almost Always
Assignments and class activities were clearly explained.	○	○	○	○
Assignments, presentations, and learning activities were clearly related to one another.	○	○	○	○
Instructors made clear what was expected of students in the way of activities and effort.	○	○	○	○
I worked cooperatively with other students on course assignments.	○	○	○	○
Students taught and learned from each other.	○	○	○	○
There were opportunities to work in groups.	○	○	○	○
I discussed ideas with my classmates (individuals or groups).	○	○	○	○
I got feedback on my work or ideas from my classmates.	○	○	○	○
I interacted with other students in the course **outside of class**.	○	○	○	○
We did things that required students to be active participants in the teaching and learning process.	○	○	○	○
Instructors gave me **frequent** feedback on my work.	○	○	○	○
Instructors gave me **detailed** feedback on my work.	○	○	○	○
Instructors guided students' learning activities rather than lecturing or demonstrating the course material.	○	○	○	○
I interacted with instructors as part of the course.	○	○	○	○
I interacted with instructors **outside of class** (e.g. office hours, advising).	○	○	○	○

17. How often did the following occur in your undergraduate engineering major?

	Almost Never	Occasionally	Often	Almost Always
My engineering courses emphasized tolerance and respect for differences.	○	○	○	○
My engineering courses encouraged me to examine my beliefs and values.	○	○	○	○
My engineering friends and I discussed diversity issues.	○	○	○	○
In my major, I observed the use of offensive words, behaviors, or gestures directed at students because of their identity.	○	○	○	○
I was harassed or hassled by others in my major because of my identity.	○	○	○	○

18. Please indicate the extent to which you agree or disagree with the following statements as they applied to your undergraduate department:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The faculty in my department were committed to treating all students fairly.	○	○	○	○	○
My department emphasized the importance of diversity in the engineering workplace.	○	○	○	○	○
I knew some students who felt like they didn't fit in my department because of their identity.	○	○	○	○	○
The campus climate at my institution was generally one of openness and tolerance.	○	○	○	○	○

Part III. Additional Information

19. How satisfied were you with your engineering program overall?

○ Very dissatisfied ○ Dissatisfied ○ Neither satisfied nor dissatisfied ○ Satisfied ○ Very satisfied

20. When did you receive your undergraduate engineering degree?

1993: ○ Spring ○ Summer ○ Fall ○ Winter

1994: ○ Spring ○ Summer ○ Fall ○ Winter

Other (please specify): ☐☐☐☐ ○ Spring ○ Summer ○ Fall ○ Winter

21. What was the major field of your bachelor's degree?

○ Aerospace Engineering ○ Electrical Engineering

○ Chemical Engineering ○ Industrial Engineering

○ Civil Engineering ○ Mechanical Engineering

○ Computer Engineering ○ Other (please specify): _____

22. Did you have a second major or minor?

○ No ○ Yes

○ In engineering, science, or math

○ Outside of engineering, science, or math (please specify): _____

23. Did you take the Fundamentals of Engineering (FE) Examination while an undergraduate?

○ Yes ○ No (If "no," please go to Question 24)

a. If you took the FE, did you pass? ○ Yes ○ No

b. How important was it to do well on the exam?

○ Not important ○ Slightly important ○ Moderately important ○ Very important

24. Please indicate any degrees (and the field) you hold beyond the bachelor's degree.

Field/Degree	Master's	Advanced Certificate	Doctorate
Aerospace Engineering	○	○	○
Chemical Engineering	○	○	○
Civil Engineering	○	○	○
Computer Engineering	○	○	○
Electrical Engineering	○	○	○
Industrial Engineering	○	○	○
Mechanical Engineering	○	○	○
Other (please specify): _____	○	○	○

25. Please describe your professional plans when you graduated and your current circumstances. (Please select all that apply.)

		Plans when you received your undergraduate degree	Current Cirumstances
Employment:	In an engineering-related occupation full-time	○	○
	In an engineering-related occupation part-time	○	○
	Outside engineering full-time	○	○
	Outside engineering part-time	○	○
Graduate School:	In an engineering discipline full-time	○	○
	In an engineering discipline part-time	○	○
	Outside engineering full-time	○	○
	Outside engineering part-time	○	○
Unemployed:			○ If unemploy
Other:		○	○ please go to Question 31

26. Are currently you in the professional engineer track of your organization?

○ Yes ○ No (If "no," please go to Question 27)

26a. If "Yes," at what level:

○ Entry-level

○ Mid-level

○ Senior-level

27. Are you currently in the management track of your organization?

○ Yes ○ No (If "no," please go to Question 28)

27a. If "Yes," at what level:

○ Line/entry-levelmanagement

○ Program/mid-levelmanagement

○ Executive/senior-levelmanagement

28. Which of the following best describes your functional area?

○ Academic/corporate education

○ Business/finance

○ Human resources

○ Information/technology/network support

○ Management/administration/executive

○ Marketing/sales

○ Production, installation, delivery of services

○ Research/development/testing

○ Other (please specify): _____

29. What is your organization's primary line of business at your location? [Categories used by the Engineering Workforce Commission of the American Association of Engineering Societies, Inc.]

- O Accommodation and food services
- O Administrative and support and waste management and remediation services
- O Agriculture, forestry, fishing and hunting
- O Arts, entertainment, and recreation
- O Construction
- O Educational services
- O Finance and insurance
- O Health care and social assistance
- O Information
- O Management of companies and enterprises
- O Manufacturing
- O Mining (including oil and gas)
- O Professional, scientific, and technical services
- O Public administration (government/civil service/military)
- O Real estate and rental leasing
- O Retail trade
- O Transportation and warehousing
- O Utilities
- O Wholesale trade
- O Other (please specify): _____

30. Approximately how many employees are there in your company at your location?

O less than 50 O 50 - 499 O 500 - 3,000 O 3,001 - 10,000 O More than 10,000

31. Have you been involved in hiring or evaluating recent bachelor's degree-level engineering graduates from any of the following fields: Aerospace, Chemical, Civil, Computer, Electrical, Industrial, or Mechanical Engineering?

O Yes O No

32. If so, have you been involved in this process for 7 or more years (not necessarily for the same organization)?

O Yes O No

33. If you answered "Yes" to Questions 31 and 32, are you willing to complete a 5 minute survey of employer views on the qualifications of recent engineering bachelor's degree recipients?

- O I would like to complete the survey on-line. Please go to http://web.survey.psu.edu/employer7?
- O I would like to complete a paper version. Please send me a paper version of the survey. (Survey will be sent to same address as this one unless you e-mail us a preferred address.)
- O No, I do not care to complete the "Employer" survey.

Many thanks for your help!

Please return this survey in the postage-paid envelope provided.

APPENDIX B

Survey of 2004 Graduates

Survey of Seniors in Engineering Programs

(Sponsored by ABET)

Conducted by:

The Pennsylvania State University
Center for the Study of Higher Education

PENNSTATE

1855

Please turn page to begin survey

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Using pen or pencil, please fill in the appropriate box or circle with your response.

Part I. Personal Information

1. **When you entered this institution were you:**

   ○ A first-time college student ○ A transfer student from a two-year institution
   ○ A transfer student from a four-year institution

2. **What was your age when you entered this institution:** ☐☐

3. **Are you:** ○ Male ○ Female

4. **Are you a U.S. Citizen?** ○ Yes ○ No [If "no," please go to Question 6]

5. **If "Yes," with which of the following racial/ethnic groups do you closely identify? (Select all that apply.)**

   ○ White/European American ○ American Indian/Alaskan Native
   ○ Black/African American ○ Hawaiian or Pacific Islander
   ○ Hispanic or Latino ○ Other (please specify): _____
   ○ Asian

6. **What is the highest level of formal schooling attained by your parents or guardian?**

	Mother	Father	Guardian
High School Diploma, GED, or less	○	○	○
Some college (incl. Associate's degree)	○	○	○
Bachelor's degree	○	○	○
Advanced degree	○	○	○

7. **Approximately what is your parents'/guardians' annual family income?**

   ○ Below $20,000 ○ $90,001-$110,000
   ○ $20,001-$30,000 ○ $110,001-$130,000
   ○ $30,001-$50,000 ○ $130,001-$150,000
   ○ $50,001-$70,000 ○ More than $150,000
   ○ $70,001-$90,000

8. **Did you take the SAT or ACT tests? (Please select all that apply.)**

   ○ No. I did not take either exam.
   ○ Yes, I took the SAT exams, and my scores were approximately:
   SAT-Verbal ☐☐☐ SAT-Math ☐☐☐
   ○ Yes, I took the ACT exam, and my Composite Score was approximately: ☐☐

9. **Knowing what you know now, how well prepared were you for basic science and math courses when you entered college?**

   ○ Not at all
   ○ Slightly
   ○ Moderately
   ○ Very well prepared

10. What was your approximate overall academic average in:

	High School	College
3.50-4.00 (A- to A)	○	○
3.00-3.49 (B to A-)	○	○
2.50-2.99 (B- to B)	○	○
2.00-2.49 (C to B-)	○	○
1.50-1.99 (C- to C)	○	○
Below 1.49 (Below C-)	○	○

11. As an undergraduate, were you (select all that apply):

a. Enrolled primarily as a ○ Full-time student ○ Part-time student

b. Employed primarily
- ○ Not employed while taking classes
- ○ On-campus, part-time while taking classes
- ○ Off-campus, part-time while taking classes
- ○ Full-time while taking classes

12. As an undergraduate, approximately <u>how many months</u> did you spend:

	None	1 - 4	5 - 8	9 - 12	More than 12 Months
As an intern or a co-op student in industry or an engineering firm	○	○	○	○	○
In a study abroad program	○	○	○	○	○
Traveling internationally (not study abroad)	○	○	○	○	○
Involved in student design project(s)/competition(s) beyond class requirements	○	○	○	○	○

13. As an undergraduate, how active have you been in a student chapter of a professional society or engineering organization?

○ Not at all ○ Somewhat ○ Moderately ○ Highly

Part II. Your Undergraduate Engineering Experiences

14. Thinking about your <u>in-class and out-of-class experiences</u>, please rate your ability to do the following:

<u>A. Technical Skills and Abilities</u>:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Apply knowledge of math	○	○	○	○	○
Apply knowledge of physical sciences	○	○	○	○	○
Apply discipline-specific engineering knowledge	○	○	○	○	○
Design an experiment	○	○	○	○	○
Carry out an experiment	○	○	○	○	○
Analyze evidence or data from an experiment	○	○	○	○	○
Interpret results of an experiment	○	○	○	○	○
Understand essential aspects of the engineering design process	○	○	○	○	○
Apply systematic design procedures to open-ended problems	○	○	○	○	○
Design solutions to meet desired needs	○	○	○	○	○
Define key engineering problems	○	○	○	○	○
Formulate a range of solutions to an engineering problem	○	○	○	○	○

B. Professional Skills:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Work in teams of people with a variety of skills and backgrounds	○	○	○	○	○
Work with others to accomplish team goals	○	○	○	○	○
Work in teams where knowledge and ideas from multiple engineering disciplines must be applied	○	○	○	○	○
Work through ethical issues in engineering	○	○	○	○	○
Consider ethical issues when working on engineering problems	○	○	○	○	○
Conduct yourself professionally	○	○	○	○	○
Understand the engineering code of ethics	○	○	○	○	○
Understand technical codes and standards	○	○	○	○	○
Convey ideas in writing	○	○	○	○	○
Convey ideas verbally	○	○	○	○	○
Convey ideas in formal presentations	○	○	○	○	○
Convey ideas in graphs, figures, etc.	○	○	○	○	○
Understand the impact of engineering solutions in a **global context**	○	○	○	○	○
Understand the impact of engineering solutions in a **societal context**	○	○	○	○	○
Understand contemporary issues (economic, environmental, political, societal, etc.) at the local, national, and world level	○	○	○	○	○
Understand that engineering decisions and contemporary issues can impact each other	○	○	○	○	○
Use knowledge of contemporary issues to make engineering decisions	○	○	○	○	○
Apply engineering **techniques** in engineering practice	○	○	○	○	○
Apply engineering **skills** in engineering practice	○	○	○	○	○
Apply engineering **tools** in engineering practice	○	○	○	○	○
Integrate engineering techniques, skills, and tools to solve real-world problems	○	○	○	○	○
Manage a project	○	○	○	○	○
Apply interpersonal skills in managing people	○	○	○	○	○

C. Analytical/Thinking Skills:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Break down complex problems to simpler ones	○	○	○	○	○
Apply fundamentals to problems that I haven't seen before	○	○	○	○	○
Identify critical variables, information, and/or relationships involved in a problem	○	○	○	○	○
Know when to use a formula, algorithm, or other rule	○	○	○	○	○
Recognize and understand organizing principles (laws, methods, rules, etc.) that underlie problems	○	○	○	○	○
Draw conclusions from evidence or premises	○	○	○	○	○
Develop a course of action based on my understanding of a whole system	○	○	○	○	○
Ensure that a process or product meets a variety of technical and practical criteria	○	○	○	○	○
Compare and judge alternative outcomes	○	○	○	○	○
Develop learning strategies that I can apply in my professional life	○	○	○	○	○

15. To what extent are you:	Not at All	Somewhat	Moderately	Highly
Motivated to acquire and apply new technologies and tools	○	○	○	○
Able to learn and apply new technologies and tools	○	○	○	○
Willing to take advantage of new opportunities to learn	○	○	○	○

16. How often did the following occur in the courses you took in your department?

	Almost Never	Occasionally	Often	Almost Always
Assignments and class activities were clearly explained.	○	○	○	○
Assignments, presentations, and learning activities were clearly related to one another.	○	○	○	○
Instructors made clear what was expected of students in the way of activities and effort.	○	○	○	○
I worked cooperatively with other students on course assignments.	○	○	○	○
Students taught and learned from each other.	○	○	○	○
We worked in groups.	○	○	○	○
I discussed ideas with my classmates (individuals or groups).	○	○	○	○
I got feedback on my work or ideas from my classmates.	○	○	○	○
I interacted with other students in the course **outside of class**.	○	○	○	○
We did things that required students to be active participants in the teaching and learning process.	○	○	○	○
Instructors gave me **frequent** feedback on my work.	○	○	○	○
Instructors gave me **detailed** feedback on my work.	○	○	○	○
Instructors guided students' learning activities rather than lecturing or demonstrating the course material.	○	○	○	○
I interacted with instructors as part of the course.	○	○	○	○
I interacted with instructors **outside of class** (including office hours, advising, socializing, etc.).	○	○	○	○

17. How often did the following occur in your engineering major?

	Almost Never	Occasionally	Often	Almost Always
My engineering courses emphasized tolerance and respect for differences.	○	○	○	○
My engineering courses encouraged me to examine my beliefs and values.	○	○	○	○
My engineering friends and I discussed diversity issues.	○	○	○	○
In my major, I observed the use of offensive words, behaviors, or gestures directed at students because of their identity.	○	○	○	○
I was harassed or hassled by others in my major because of my identity.	○	○	○	○

18. Please indicate the extent to which you agree or disagree with the following statements:

	Strongly Disagree	Disagree	Neither nor Disagree	Agree	Strongly Agree
The faculty in my department are committed to treating all students fairly.	○	○	○	○	○
My department emphasizes the importance of diversity in the engineering workplace.	○	○	○	○	○
I know some students who feel like they don't fit in this department because of their identity.	○	○	○	○	○
The campus climate at this institution is generally one of openness and tolerance.	○	○	○	○	○

Part III. Additional Information and Plans

19. How satisfied are you with your engineering program overall?

○ Very dissatisfied ○ Somewhat dissatisfied ○ Neither satisfied nor dissatisfied ○ Somewhat satisfied ○ Very satisfied

20. What is your anticipated graduation date?

○ Spring '04 ○ Summer '04 ○ Fall '04 ○ Other

21. What is the major field of your bachelor's degree?

○ Aerospace Engineering ○ Electrical Engineering

○ Chemical Engineering ○ Industrial Engineering

○ Civil Engineering ○ Mechanical Engineering

○ Computer Engineering ○ Other (please specify): _____

22. Do you have a second major or minor?

○ No ○ Yes
○ in engineering, science, or math
○ outside of engineering (please specify): _____

23. By the end of this academic year, will you have taken the Fundamentals of Engineering (FE) Examination?

○ Yes ○ No (please go to #24)

a. If you have taken the FE, did you pass? ○ Yes ○ No

b. How important is it to you to do well on the exam?

○ Not important ○ Slightly important ○ Moderately important ○ Very important

24. What are your plans for the <u>next year</u>?

Continue undergraduate education:	○ Full-time ○ Part-time
Employment:	○ In an engineering-related occupation full-time ○ In an engineering-related occupation part-time ○ Outside engineering full-time ○ Outside engineering part-time
Graduate School:	○ In an engineering discipline full-time ○ In an engineering discipline part-time ○ Outside engineering full-time ○ Outside engineering part-time ○ Other (please explain): _____

Thank you for your participation!

Please return your completed survey in the prepaid envelope provided.

APPENDIX C

Survey of Engineering Faculty

A SURVEY OF FACULTY TEACHING AND STUDENT LEARNING IN ENGINEERING

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Instructions: If circles are provided, please completely fill in the circle next to your answer (example: ● Yes ○ No). If boxes are provided, please write inside the box (example: 0 3). If you are asked to specify an answer, please clearly print your answer on the line provided.

1. How many years have you been teaching as an engineering faculty member? ☐☐ Years

2. How many years have you been a faculty member at this institution? ☐☐ Years

3. In what engineering discipline are you employed? (If you hold a joint appointment please indicate that area as well.)

- ○ Aerospace Engineering
- ○ Chemical Engineering
- ○ Civil Engineering
- ○ Computer Engineering
- ○ Electrical Engineering
- ○ Industrial Engineering
- ○ Mechanical Engineering
- ○ Other (please specify) _____ _____

Part I Faculty Teaching

Please think about a particular undergraduate course that you teach more or less regularly. With that course in mind, please answer the following questions.

4. Please indicate the level of students in that course.

- ○ Mainly lower division
- ○ Mainly upper division
- ○ Mixed

5. Approximately how many students are enrolled in that course?

- ○ Under 20
- ○ 21-40
- ○ 41-60
- ○ More than 60

6. Indicate the category that best describes that course. (Select all that apply.)

- ○ First-year design course
- ○ Required engineering course
- ○ Capstone course
- ○ Elective/Optional engineering course
- ○ Other (specify) _____

7. In what year did you most recently teach that course (approximately)? ☐☐☐☐

8. In what year did you first teach that course (approximately)? ☐☐☐☐

Keeping that course in mind, please answer questions 9 through 14.

9. Compared to the first time you taught that course how, if at all, has the emphasis on the following changed?

Change in emphasis on:	Not Applicable	Significant Decrease	Some Decrease	No Change	Some Increase	Significant Increase
Engineering design	○	○	○	○	○	○
Teamwork	○	○	○	○	○	○
Engineering in global/social contexts	○	○	○	○	○	○
Professional ethics	○	○	○	○	○	○
Professional responsibility	○	○	○	○	○	○
Technical writing	○	○	○	○	○	○
Verbal communication	○	○	○	○	○	○
Knowledge of contemporary issues	○	○	○	○	○	○
Experimental methods	○	○	○	○	○	○
Foundational math	○	○	○	○	○	○
Basic science	○	○	○	○	○	○
Basic engineering science	○	○	○	○	○	○
Modern engineering tools	○	○	○	○	○	○
Project management	○	○	○	○	○	○
Other (please specify)_____	○	○	○	○	○	○

10. To what extent has each of the following influenced the **course changes** above?

Extent of influence on curricular change:	Not At All	Slightly	Moderately	A Great Deal
Collective faculty decision	○	○	○	○
Change in program goals	○	○	○	○
Organizational restructuring	○	○	○	○
ABET accreditation	○	○	○	○
Student feedback	○	○	○	○
Increased resources	○	○	○	○
Decreased resources	○	○	○	○
Industry/employer feedback	○	○	○	○
Decision by Dean or other administrator	○	○	○	○
NSF coalition	○	○	○	○
Research on undergraduate engineering education	○	○	○	○
My own initiative	○	○	○	○

11. Compared to the first time you taught that course how, if at all, has the emphasis you place on the following **teaching methods** changed?

Change in emphasis on:	Not Applicable	Significant Decrease	Some Decrease	No Change	Some Increase	Significant Increase
Use of groups in class	○	○	○	○	○	○
Design projects	○	○	○	○	○	○
Assignments or exercises focusing on application	○	○	○	○	○	○
Open-ended problems	○	○	○	○	○	○
Student presentations	○	○	○	○	○	○
Hands-on experiences	○	○	○	○	○	○
Case studies or real world examples	○	○	○	○	○	○
Lectures	○	○	○	○	○	○
Computer simulations	○	○	○	○	○	○
Problems from the textbook	○	○	○	○	○	○

12. How has each of the following influenced your use of **active teaching methods**, such as group work, projects, and student presentations?

Extent of influence on instruction:	Not At All	Slightly	Moderately	A Great Deal
Collective faculty decision	○	○	○	○
Change in program goals	○	○	○	○
Organizational restructuring	○	○	○	○
ABET accreditation	○	○	○	○
NSF coalition	○	○	○	○
Student feedback	○	○	○	○
Increased resources	○	○	○	○
Decreased resources	○	○	○	○
Industry/employer feedback	○	○	○	○
My own initiative	○	○	○	○

13. Approximately how much weight do you give to each of the following when **assigning grades** in that course?

Quizzes and exams ☐☐☐ %

Class participation and presentations ☐☐☐ %

Group work or team project(s) ☐☐☐ %

Individual paper(s) or project(s) ☐☐☐ %

Homework or lab problems ☐☐☐ %

Other (please specify)_____ ☐☐☐ %

TOTAL 100%

Part II Student Learning

14. What impact did the changes you made in course content and/or teaching methods have on your students' ability to do the following?

Impact of changes on students' ability to:	Does Not Apply	High Negative Impact	Some Negative Impact	No Impact	Some Positive Impact	High Positive Impact
Apply knowledge of mathematics, science, and engineering	○	○	○	○	○	○
Design and conduct experiments, as well as to analyze and interpret data	○	○	○	○	○	○
Design a system, component, or process to meet desired needs	○	○	○	○	○	○
Function on multi-disciplinary teams	○	○	○	○	○	○
Identify, formulate, and solve engineering problems	○	○	○	○	○	○
Understand professional and ethical responsibilities	○	○	○	○	○	○
Communicate effectively	○	○	○	○	○	○
Understand the impact of engineering solutions in a global and societal context	○	○	○	○	○	○
Recognize the need for and engage in life-long learning	○	○	○	○	○	○
Knowledge of contemporary issues	○	○	○	○	○	○
Use the techniques, skills, and modern engineering tools necessary for engineering practice	○	○	○	○	○	○
Manage a project	○	○	○	○	○	○

15. Think about **graduating seniors currently in your program**. On average, please rate their ability to do the following.

Graduating seniors' ability to:	No Ability	Some Ability	Adequate Ability	More than Adequate Ability	High Ability
Apply knowledge of mathematics, sciences and engineering	○	○	○	○	○
Design and conduct experiments, as well as to analyze and interpret data	○	○	○	○	○
Design a system, component, or process to meet desired needs	○	○	○	○	○
Function on multi-disciplinary teams	○	○	○	○	○
Ability to identify, formulate, and solve engineering problems	○	○	○	○	○
Understand professional and ethical responsibilities	○	○	○	○	○
Communicate effectively	○	○	○	○	○
Understand the impact of engineering solutions in a global and societal context	○	○	○	○	○
Recognize the need for, and engage in, life-long learning	○	○	○	○	○
Knowledge of contemporary issues	○	○	○	○	○
Use the techniques, skills, and modern engineering tools necessary for engineering practice	○	○	○	○	○
Manage a project	○	○	○	○	○

16. Compared to graduates 7-10 years ago, have current graduating seniors' abilities increased or decreased?

Change in graduates' abilities:	Greatly Decreased	Slightly Decreased	About the Same	Slightly Increased	Greatly Increased
To use engineering, math, science, and technical skills	○	○	○	○	○
To apply problem-solving skills	○	○	○	○	○
To communicate and work in teams	○	○	○	○	○
To understand the organizational, cultural, and environmental contexts and constraints of engineering practice, design, and research	○	○	○	○	○
To continue to learn, grow, and adapt as technology and society evolve in unpredictable directions	○	○	○	○	○

17. To what extent, in your opinion, are these changes attributable to ABET's EC2000?

- ○ Not at all
- ○ Some
- ○ Moderately
- ○ A great deal

18. During the past 12 months, have you participated in the following **professional development activities?** Compared to 5 years ago, is this less, the same, or more?

	Current Participation		Participation Compared To Five Years Ago		
Participation in:	**Yes**	**No**	**Less**	**Same**	**More**
Seminars or workshops on teaching and learning	○	○	○	○	○
Seminars or workshops on assessing student learning	○	○	○	○	○
Conference or journal submission on undergraduate education	○	○	○	○	○
Using services of on-campus instructional center	○	○	○	○	○
Developing or teaching a course with someone in another engineering discipline	○	○	○	○	○
Activities to enhance content knowledge	○	○	○	○	○
Reading materials on teaching	○	○	○	○	○
A project to improve undergraduate engineering education	○	○	○	○	○
Applying for external funding for an undergraduate engineering education project	○	○	○	○	○

19. Over the past decade, how has the **emphasis your program gives to teaching** changed?

Change in emphasis on teaching in:	**Significant Decrease**	**Some Decrease**	**No Change**	**Some Increase**	**Significant Increase**
Recruiting and hiring	○	○	○	○	○
Promotion and tenure	○	○	○	○	○
Salary and merit increases	○	○	○	○	○

20. To what extent do you agree or disagree with the following statements about **current curriculum planning and revision practices** in your program?

Statements about curriculum planning and revision:	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
Faculty in my program periodically review the program mission and objectives.	○	○	○	○	○
Faculty in my program generally resist new curricular ideas or experimentation.	○	○	○	○	○
Program faculty collaborate on curriculum development and revision.	○	○	○	○	○
The program curriculum is a frequent agenda item at program meetings.	○	○	○	○	○
Curriculum revisions are typically made in response to some problem rather than through a periodic planning process.	○	○	○	○	○
Curriculum planning in my program is systematic.	○	○	○	○	○
Curriculum decisions are usually based on opinions rather than data.	○	○	○	○	○
Faculty are knowledgeable about the program's curriculum beyond their own courses.	○	○	○	○	○

21. What is your level of enthusiasm for outcomes assessment as part of a process of program improvement?
    - ○ None at all
    - ○ Some
    - ○ Moderate
    - ○ A great deal

22. What has been your level of personal effort in student outcomes assessment?
    - ○ None at all
    - ○ Some
    - ○ Moderate
    - ○ A great deal

23. In your view, is that:
    - ○ Too much
    - ○ Too little
    - ○ About right

24. How much has ABET's EC2000 increased your knowledge of the strengths and weaknesses of your program?
    - ○ Not at all
    - ○ Some
    - ○ Moderately
    - ○ A great deal

25. How familiar are you with ABET's EC2000 Accreditation Criteria dealing with student outcomes?

- ○ Not at all
- ○ Slightly familiar
- ○ Moderately familiar
- ○ Very familiar

26. Approximately how many years have you been employed full-time as an engineer in industry or private practice?

☐☐ Years

27. What is your gender?

- ○ Male
- ○ Female

28. What is your ethnic background? (Indicate all that apply.)

- ○ White/European American
- ○ Black/African American
- ○ Hispanic or Latino
- ○ Asian
- ○ American Indian or Alaska Native
- ○ Hawaiian or other Pacific Islander
- ○ Other (please specify) _____

29. What is the major field of **your bachelor's degree**?

- ○ Aerospace Engineering
- ○ Chemical Engineering
- ○ Civil Engineering
- ○ Computer Engineering
- ○ Electrical Engineering
- ○ Industrial Engineering
- ○ Mechanical Engineering
- ○ Other

30. What is the major field of **your highest degree**?

- ○ Aerospace Engineering
- ○ Chemical Engineering
- ○ Civil Engineering
- ○ Computer Engineering
- ○ Electrical Engineering
- ○ Industrial Engineering
- ○ Mechanical Engineering
- ○ Other (please specify) _____

Thank you for your participation! Please return your completed survey in the prepaid envelope provided.

APPENDIX D

Survey of Engineering Program Chairs

SURVEY OF ENGINEERING PROGRAM CHANGES

(SPONSORED BY ABET)

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You have been selected to complete this survey because you administer at least one of the following engineering programs

- Aerospace
- Chemical
- Civil
- Computer
- Electrical
- Industrial
- Mechanical

While you may also administer another program, this survey focuses only on those programs listed above.

Instructions: If circles are provided, please completely fill in the circle next to your answer (example: ● Yes ○ No). If boxes are provided, please write inside the box (example: 03). If you are asked to specify an answer, please clearly print your answer on the line provided.

1. What is the deadline for engineering students to **declare a major** in your program?

   ○ Upon entrance to the institution
   ○ End of first year
   ○ End of second year
   ○ Third year or later

2. What is your program's **policy on co-op experiences** for students?

   ○ No policy or position
   ○ No policy, but most faculty recommend
   ○ Policy is to recommend
   ○ Policy is to require for graduation

3. What is your program's **policy on the Fundamentals of Engineering (FE) Examination**? (Check one in each row.)

10 years ago:	**Currently:**
○ No policy or position	○ No policy or position
○ Policy is to recommend taking the FE	○ Policy is to recommend taking the FE
○ Policy requires taking the FE	○ Policy requires taking the FE
○ Policy requires passing the FE	○ Policy requires passing the FE

4. How important are the following in **assessing learning outcomes** in your program?

Importance of:	**Not At All**	**Slightly**	**Moderately**	**Very Important**
FE data	○	○	○	○
GRE scores	○	○	○	○
Locally-designed instrument(s)	○	○	○	○

5. Over the past decade how, if at all, has your program's emphasis on **these curricular topics** changed?

Change in program emphasis on:	Significant Decrease	Some Decrease	No Change	Some Increase	Significant Increase
Engineering design	○	○	○	○	○
Interpersonal/group communication	○	○	○	○	○
Engineering in global and social contexts	○	○	○	○	○
Professional ethics	○	○	○	○	○
Professional responsibility	○	○	○	○	○
Technical writing	○	○	○	○	○
Verbal communication	○	○	○	○	○
Knowledge of contemporary issues	○	○	○	○	○
Experimental methods	○	○	○	○	○
Foundational math	○	○	○	○	○
Basic science	○	○	○	○	○
Basic engineering science	○	○	○	○	○
Project management	○	○	○	○	○
Use of modern engineering tools	○	○	○	○	○
Engineering problem solving	○	○	○	○	○
Teamwork	○	○	○	○	○
Importance of life-long learning	○	○	○	○	○
Other (please specify)_____	○	○	○	○	○

6. To what extent were these changes (listed in question 5 above) influenced by each of the following?

Extent of influence on curricular change:	Not At All	Slightly	Moderately	A Great Deal
Collective faculty decision	○	○	○	○
Change in program goals	○	○	○	○
Organizational restructuring	○	○	○	○
ABET accreditation	○	○	○	○
Student feedback	○	○	○	○
Increased resources	○	○	○	○
Decreased resources	○	○	○	○
Industry/employer feedback	○	○	○	○
Decision by Dean or other administrator	○	○	○	○
NSF coalition	○	○	○	○
Research on undergraduate engineering education	○	○	○	○
My own initiative	○	○	○	○

7. To what extent, if at all, has ABET's EC2000 influenced your program's emphasis on these **curricular components**?

Change in program emphasis on:	Not At All	Slightly	Moderately	A Great Deal
Required courses in science	○	○	○	○
Required courses in engineering	○	○	○	○
Elective courses in major	○	○	○	○
Required courses in social sciences and/or humanities	○	○	○	○
Design course(s)	○	○	○	○
Internships	○	○	○	○
Program-related out-of-class activities (e.g. design competition, field trips)	○	○	○	○
Other (please specify) _____	○	○	○	○

8. To what extent do you agree or disagree with the following statements about **current curriculum planning and revision practices** in your program?

Statements about curriculum planning and revision:	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Faculty in my program periodically review the program mission and objectives.	○	○	○	○	○
Faculty in my program generally resist new curricular ideas or experimentation.	○	○	○	○	○
Program faculty collaborate on curriculum development and revision.	○	○	○	○	○
The program curriculum is a frequent agenda item at program meetings.	○	○	○	○	○
Curriculum revisions are typically made in response to some problem rather than through a periodic planning process.	○	○	○	○	○
Curriculum planning in my program is systematic.	○	○	○	○	○
Curriculum decisions are usually based on opinions rather than data.	○	○	○	○	○
Faculty are knowledgeable about the program's curriculum beyond their own courses.	○	○	○	○	○

9. What proportion of your program faculty generally supports the following activities?

Proportion of faculty who support:	Almost None	Less than Half	About Half	More than Half	Almost All
Ongoing, systematic efforts to improve program quality	○	○	○	○	○
Curriculum/course development and revision	○	○	○	○	○
Assessment of student learning	○	○	○	○	○
Greater emphasis on students' "soft" skills (e.g. teamwork, communication)	○	○	○	○	○
Using assessment information in decision-making	○	○	○	○	○

10. Over the past decade, how has the **emphasis your program gives to teaching** changed?

Change in program emphasis on teaching in:	Significant Decrease	Some Decrease	No Change	Some Increase	Significant Increase
Faculty recruiting and hiring	○	○	○	○	○
Faculty promotion and tenure	○	○	○	○	○
Faculty salary and merit increases	○	○	○	○	○
Professional development activities	○	○	○	○	○

11. Over the past decade, have there been any changes in your program's **use of assessment information** for:

Change in program's use of assessment data for:	Significant Decrease	Some Decrease	No Change	Some Increase	Significant Increase
Ongoing, systematic efforts to improve program quality	○	○	○	○	○
External funders/sponsors	○	○	○	○	○
Internal budget allocations	○	○	○	○	○
ABET accreditation	○	○	○	○	○

12. If you have gone through an EC2000 review, or are currently preparing for one, indicate the extent to which EC2000 increased your knowledge of the strengths and weaknesses of your program.

- ○ No EC2000 review ⟶ Go to Question 14.
- ○ Not at all
- ○ Some
- ○ Moderately
- ○ A great deal

13. If weaknesses were identified, which one of the following best describes your **program's financial response?**

- ○ No weaknesses identified
- ○ No financial action taken
- ○ Secured additional institutional funds to address weakness(es)
- ○ Reallocated funds to address weakness(es)
- ○ Raised external funds to address weakness(es)

14. How adequate are resources to sustain and support EC2000 accreditation?

- ○ Not adequate
- ○ Adequate
- ○ More than adequate

15. **Over the past decade**, approximately how much have the following institutional **resources for your program** changed?

Approximate change in program resources over the past 10 years:	Decrease			No Change	Increase		
	> 10%	5 - 10%	< 5%		< 5%	5 - 10%	> 10%
Instructional staff	○	○	○	○	○	○	○
Support staff	○	○	○	○	○	○	○
Instructional resources	○	○	○	○	○	○	○
Institutional funds for innovations	○	○	○	○	○	○	○
Faculty professional development	○	○	○	○	○	○	○
Research resources	○	○	○	○	○	○	○
Facilities	○	○	○	○	○	○	○
Financial resources	○	○	○	○	○	○	○

16. How familiar are you with ABET's EC2000 Accreditation Criterion on student learning outcomes?

- ○ Not at all
- ○ Slightly Familiar
- ○ Moderately Familiar
- ○ Very Familiar

17. How long have you been administratively responsible, to some degree, for your undergraduate engineering program? ☐☐ Years

18. How many years have you been employed by your current institution? ☐☐ Years

19. How many years have you been teaching as an engineering faculty member? ☐☐ Years

20. What is your gender? O Male O Female

21. What is your ethnic background? (Indicate all that apply.)

- O White/European American
- O Black/African American
- O Hispanic or Latino
- O Asian
- O American Indian or Alaska Native
- O Hawaiian or other Pacific Islander
- O Other (please specify) _____

22. What is the major field of your highest degree?

- O Aerospace Engineering
- O Chemical Engineering
- O Civil Engineering
- O Computer Engineering
- O Electrical Engineering
- O Industrial Engineering
- O Mechanical Engineering
- O Other (please specify) _____

23. Please provide any additional comments that will help us understand changes in your undergraduate engineering program.

Thank you for your participation!

Please return your completed survey in the prepaid envelope provided.

CURRICULUM VITAE

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Education

B.A., Indiana University - Bloomington
(Mathematics with minor in Political Science), May 2000
M.P.A., Indiana University - Bloomington
(Public Financial Administration and Public Management), May 2002
Ph.D., The Pennsylvania State University
(Higher Education with cognate in Sociology), May 2008

Professional Experience in Higher Education

Graduate Research Assistant, May 2004 to present
Center for the Study of Higher Education
The Pennsylvania State University, State College, PA

Adjunct Professor, August 2002 to present
Mathematics Department
Hawaii Pacific University, Honolulu, HI

Graduate Assistant (Financial Aid Advisor & Analyst), May 2001 – August 2001
Financial Aid Office
Indiana University, Bloomington, IN

Resident Assistant, August 1998 – May 2001
Indiana University, Bloomington, IN

Publications

Lambert, A. D., Terenzini, P. T., & Lattuca, L. R. (2007). More than meets the eye: Curricular and programmatic effects on student learning. *Research in Higher Education, 48*(2), 141-168.

Museus, S. D., Nichols, A. H., & Lambert, A. D. (in press). Effects of climate on second-year persistence decisions: An examination of racial/ethnic differences using structural equation modeling. *The Review of Higher Education*.

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