Sex Segregation in Undergraduate Engineering Majors

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Abstract

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Gender inequality in engineering persists in spite of women reaching parity in college enrollments and degrees granted. To date, no analyses of educational sex segregation have comprehensively examined segregation within one discipline. To move beyond traditional methods of studying the long-standing stratification by field of study in higher education, I explore gender stratification within one field: engineering. This dissertation investigates why some engineering disciplines have a greater representation of women than other engineering disciplines. I assess the individual and institutional factors and conditions associated with women's representation in certain engineering departments and compare the mechanisms affecting women's and men's choice of majors.

I use national data from the Engineering Workforce Commission, survey data from 21 schools in the Project to Assess Climate in Engineering study, and Carnegie Foundation classification information to study sex segregation in engineering majors from multiple perspectives: the individual, major, institution, and country. I utilize correlations, t-tests, cross-tabulations, log-linear modeling, multilevel logistic regression and weighted least squares regression to test the relative utility of alternative explanations for women's disproportionate representation across engineering majors.

As a whole, the analyses illustrate the importance of context and environment for women's representation in engineering majors. Hypotheses regarding hostile climate and discrimination find wide support across different analyses, suggesting that women's under-representation in certain engineering majors is not a question of choice or ability. However, individual level factors such as having engineering coursework prior to college show an especially strong association with student choice of major. Overall, the analyses indicate that institutions matter, albeit less for women, and women's under-representation in engineering is not reducible to individual choice.

This dissertation provides a broad, descriptive view of the state of sex segregation in engineering as well as a careful analysis of how individual and institutional factors inhibit or encourage sex segregation. This study contributes to the research literature through the use of novel data, testing of occupational segregation theories, and the use of multiple levels of analysis. The analyses provide new insight into an enduring phenomenon, and suggest new avenues for understanding sex segregation in higher education.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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I am also lucky to have good friends to support me through graduate school. My lunches and walks with Cara Maclean and her two boys were just the right diversion during this process. I don't think I would have lasted through my first year in graduate school without my friend Jennifer Edwards, who gave me good advice and reminded me that massages are key to finishing a dissertation. I am also thankful for my new friend, Kim Morrissette, who requested a vacation day on June 12th for my graduation before I was even sure I was going to graduate. Her belief in me gave me hope that I could finish.

I would never have even thought I could achieve this accomplishment without the love and support of my mom and dad. My parents and two sisters were my cheerleaders, and helped keep me accountable by always asking how the writing was going, even when I did not want to answer the question. Emily helped me put some perspective on this process and Jodi never forgot to call or text her support when she knew I was up against a deadline. Truly, I am thankful for all of my immediate, extended, and non-biological family who were always encouraging.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Presently, women attend college in greater percentages than men and graduate in greater numbers (National Center for Education Statistics 2008). However, women lag behind men in engineering enrollments and degrees granted, constituting 18 percent of engineering undergraduates in 2008 (CPST 2008; Gibbons 2008). Why have women's gains in higher education not translated to the engineering disciplines? Given the enduring under-representation of women in engineering, something about engineering in general deters women who might otherwise enter the field. But what explains why women constitute 30 percent of engineering students in one major and less than 10 percent in another? This dissertation investigates why some engineering disciplines have a greater representation of women than other engineering disciplines. I assess the factors and conditions associated with women's relative over- or under-representation in certain engineering departments. How do individual characteristics impact the distribution of females across engineering majors? What institutional factors encourage or inhibit sex segregation?

The scarcity of women in engineering is a social problem. Their under-representation has implications for diversity of thought among the next generation of innovators and intellectuals, and cumulative gender inequality over the life course. A recent report by the National Academies finds that women are dropping out of science and engineering at every transition point in education (2007). This trend continues, despite recent confirmation by a panel of distinguished researchers that women have the ability and desire to succeed in science and engineering (National Academies 2007), contrary to the speech given by former Harvard President, Lawrence Summers (Summers 2005). Summers' speech, which sparked much public discussion and outcry, included statements which implied women did not have the same innate abilities in science and math as men. The resulting debates and condemnations of Summers' choice of words eventually resulted in a vote of "No Confidence" from the Harvard faculty.

Why should society care about women's uneven distribution across engineering majors? Research reports cite the growing global economy and competition from other countries as reasons to increase diversity in science and engineering fields. Recent research has indicated that more diverse work teams produce better outcomes, and that functionally diverse teams are better problem solvers than teams of high ability that don't consider a diversity of perspectives (Ashcraft 2008; Ashcraft and Breitzman 2007; London Business School 2007; Page 2007b). As written by Professor Scott E. Page, "If people think alike then no matter how smart they are they most likely will get stuck at the same locally optimal solutions. Finding new and better solutions, innovating, requires thinking differently. That's why diversity powers innovation" (2007a). Increasing diversity in Science, Technology, Engineering and Mathematics (STEM) would drive technical innovation and improve U.S. chances to remain competitive.

Engineering faculty and administrators are calling for information about differences between engineering majors (PACE 2010). While these faculty members instinctively know that engineering majors are different in terms of student experiences, they want a better understanding of how the majors are different so that they can improve their recruitment and retention of women and under-represented minorities.

To understand why enduring gender inequality in engineering is of concern, it is important to know the context in which engineering programs reside. Colleges in the US have experienced large shifts in their demographic make-up in the last half century. First year undergraduate enrollment trends have improved over time for men and even more so for women. Figure 1.1 shows the percentage of students who enrolled in college of those who graduated from high school or completed a GED within the preceding 12 months (National Center for Education Statistics 2008). In 1960, more than 50 percent of men who graduated high school enrolled in college shortly thereafter. At that time fewer than 40 percent of women enrolled in college right after high school graduation. Female and male enrollment trends converged in the mid to late 1970s, a historic "cross-over" in gender enrollment trends.

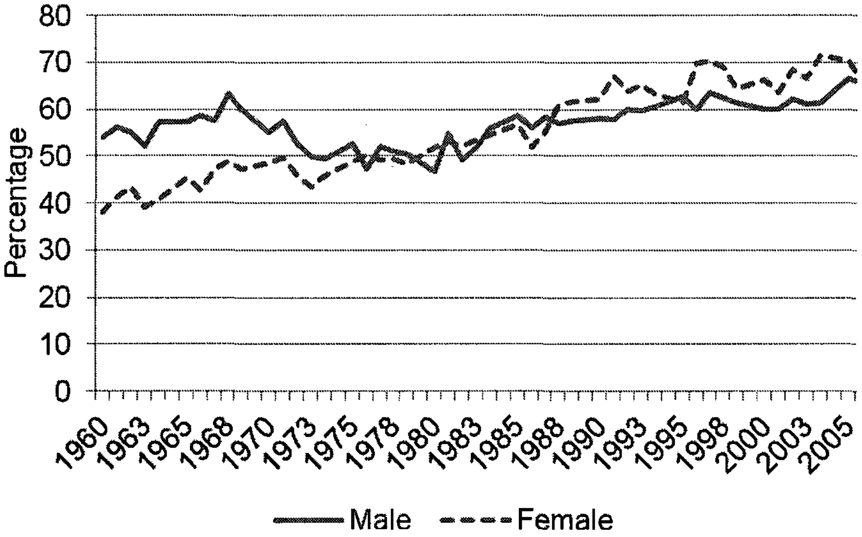


Figure 1.1 College Enrollment Rates of Recent High School Completers, by Sex (NCES 2008)

The overall trends from 1960-2006 are positive for females and males, but the female line reflects larger advances in women going to college. The most recent numbers from the National Center for Education Statistics indicate that in fall 2007, women composed 57 percent of all undergraduates in degree granting institutions (2008). Despite what some would call a “female advantage” in enrollment, college women are concentrated in the humanities and social sciences.

Engineering has remained a largely white male field despite increasing numbers of females in the undergraduate population. The number of women enrolling in engineering undergraduate programs increased from 1996 to 2002 to a high of 77,952. However, the number of women in engineering has declined since 2002, dropping to 69,869 in 2006 (CPST, derived from Engineering Workforce Commission 2008). From 1996 to 2006, women as a percentage of all undergraduates enrolled in engineering decreased from 19.0 to 17.2 percent. Overall, women made up 18 percent of the undergraduate students enrolled in engineering programs in 2008 (Gibbons 2008). Some of the increases and decreases seen in student enrollments in engineering occur in concert with the dot.com boom and bust cycle of the last few decades, causing speculation that this larger economic trend was instrumental in engineering enrollment trends (Lennox, Woratschek, and Davis, 2008).

Despite this under-representation in engineering in general, for which research continues to be conducted (e.g., Brainard et al. 1995; Fox and Colatrella 2006; Lichtenstein et al. 2009; Watson and Froyd 2007), there are large differences between engineering majors in terms of female enrollment (Figure 1.2). In 2006, there was gap of 26 percent between mechanical and bioengineering enrollments. In addition, women reach what some consider a critical mass in three majors: biological engineering, chemical engineering and industrial engineering each enroll greater than 30 percent women.

This study draws insights from explanations used for sex segregation in the workplace to understand sex segregation in engineering majors. Occupational sex segregation is a widely studied phenomenon in sociology and economics. While occupational segregation has improved over time, job-level segregation is extremely pervasive. Women are shut out of high paying, high prestige jobs such as those at the C-suite level (CEO, COO, CIO, etc), and are crowded into service sector fields (Jacobs 2001; Reskin 1993). Sex segregation in jobs and occupations is not just a social justice issue because of continued gender inequality, but it also has real consequences such as the enduring pay gap between men and women (Kilbourne, England and Beron 1994; Reskin and Padavic 1994).

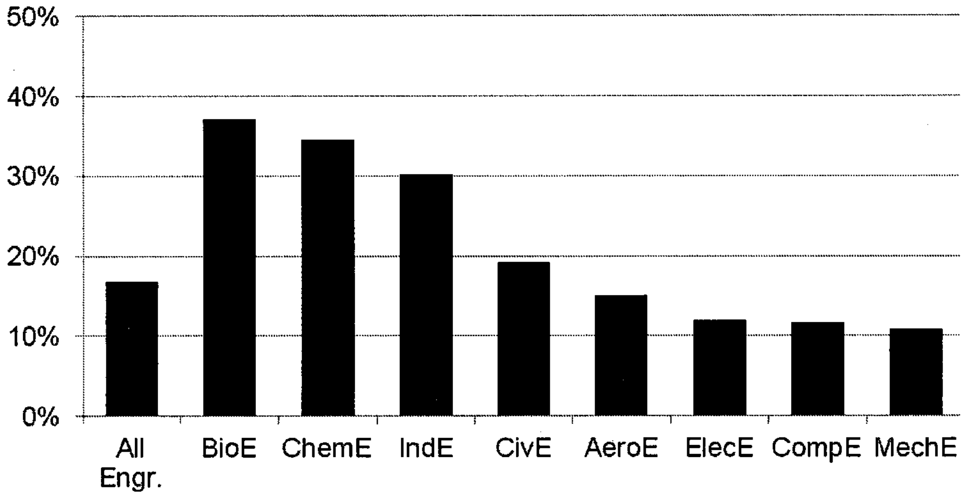


Figure 1.2 Percentage Undergraduate Engineering Students who are Female, by Major (CPST 2006)

It is unclear the extent to which the trends in women's representation across engineering majors are similar to those seen across jobs and occupations. For example, are women crowded into engineering fields that offer lower pay? There are strong theoretical explanations for sex segregation that come from the occupational literature. How can knowledge about occupational sex segregation inform an understanding of the degree to which the segregation process in engineering majors is driven by supply-side or demand-side factors?

1.2 Explaining Sex Segregation in Engineering

Gender inequality in engineering is situated within a higher education system with relative equality between women and men. To understand this situation, I turn to general explanations of sex segregation in organizations. These explanations range from neo-classical arguments supporting the effect of individual characteristics on outcomes to structural arguments that support the effect of organizational policies and practices on outcomes. Because no research has focused on sex segregation within engineering majors, I find it important to examine both the neo-classical (micro) and structural (macro) explanations.

As a neo-classical explanation, human capital theory rests upon the basic assumption that greater investment in one's productivity results in greater returns to human capital (Becker 1991). Human capital theory also suggests that biology operates to influence one's sense of roles or norms and therefore impacts aspirations to certain occupations (Becker 1991; Marini and Brinton 1984; Shauman 2006; Xie and Shauman 1997). Also at the level of the individual, status beliefs theory (Ridgeway 1991) encompasses concepts such as socialization, self-efficacy, and self-confidence. Status beliefs theory is built upon the assumption that beliefs about the status of a person or group are based upon interactions with others (Ridgeway 1991; Correll 2001, 2004). This theory helps explain why female students might feel less capable or confident than male students, and how that might affect their decisions to major in certain fields.

Demand-side explanations for sex segregation emphasize how segregation reflects lack of 'demand' for women both as students and practitioners within fields of engineering. Discrimination, stereotyping and hostile climate help explain why the demand for women might be different than the demand for men (Becker 1971; Reskin 1993). Stereotyping theories suggest that social categorization is generally a useful and normal part of everyday interaction, but can have negative consequences, including the differential treatment of members of the stereotyped group (Heilman 1995; Reskin 1993). Stereotypes can affect outcomes because members of the stereotyped group learn to believe them, and act accordingly (stereotype threat) (Steele 1997). A hostile climate is a passive means of discrimination while overt discrimination is a clear indication that others do not think you belong. Explanations utilizing discrimination, stereotyping and hostile climate suggest that women are actively or passively pushed out of those fields, which counters other explanations of individual "choice" (Goldin and Rouse 2000; Newman 1978; Reskin 2000).

1.3 Overview of the Dissertation

In an in-depth look across engineering majors, I examine how supply and demand factors affect sex segregation in engineering majors, and compare the mechanisms affecting women and men's placement in particular majors. I analyze two different data sets and use multiple analytic techniques not normally used in the study of engineering students to examine this issue from multiple angles. Because no research exists on this topic, I take a multi-dimensional approach, examining the issue from different levels and perspectives. As a new piece of intellectual thought, this dissertation provides a broad descriptive view of what sex segregation looks like in engineering programs as well as a careful analysis of how individual and institutional factors inhibit or encourage sex segregation.

To give context to the rest of the dissertation, I summarize the relevant theory and literature in Chapter 2. I provide an abbreviated review of the expansive literature on occupational sex segregation, the small amount of scholarship that exists on educational sex segregation, and the literature regarding why students choose certain majors. Comparisons to occupational sex segregation research yield insights about the mechanisms that may influence sex segregation in a white male-dominated discipline such as engineering.

Chapter 3 describes the two quantitative data sources I use for secondary data analysis. I provide a brief overview of the collection methodology for the two data sources, describe the basic demographics of each data set, and detail the strengths and weaknesses of these data sets. Additionally, I provide an overview of the analytic methods used in the three analysis chapters, and describe how these methods are appropriate for the data and research questions.

There are many different way to think about sex segregation in engineering. Chapter 4 contains an exploratory analysis of sex segregation in engineering majors. The research questions for this chapter are: How do aggregate measures of sex segregation in engineering differ by institution? What does segregation by sex look like using the Duncan Index of Dissimilarity, the Index of Association and other measures of segregation? Are the trends the same? What is the structure of segregation in engineering majors? First, I discuss the summary indices of sex segregation that are often used in the literature and provide some descriptive statistics on the national undergraduate engineering situation using each of these measures. I compare the national sex segregation statistics to those from the Project to Assess Climate in Engineering (PACE) to provide context for the data used in subsequent chapters. Correlations between these segregation measures with institutional characteristics illuminate the relationships between sex segregation and types of institutions. In addition, I describe the structure of sex segregation across undergraduate engineering majors using national data from the Engineering Workforce Commission. This exploratory analysis shows a large amount of variation in sex segregation and representation of female students across schools. The relationship between sex, major and school is extremely complex, as shown by the log-linear analysis in which the saturated model fits best. This chapter's analysis also indicates that the levels of sex segregation in the PACE data are not very different from the national averages, which supports the usefulness of using PACE survey data for further analysis.

Since Chapter 4 provides a macro level structural and institutional examination of sex segregation, in Chapter 5, I focus on the individual level and ask: What are the differences between students in engineering departments with the highest levels of sex segregation and departments with the lowest levels of sex segregation? Do these sorting mechanisms differ between specific majors, regardless of the level of female representation? How are women and men different in terms of these sorting factors? Examining sex segregation at the level of the individual permits an understanding of sex segregation in engineering from a different perspective. In this chapter I utilize two multilevel logistic regression models to examine the impact of individual and institutional characteristics on student's choice of major. I first model the choice of students to be in a major with the highest proportion of female students compared to a major with the lowest proportion of female students. Next, I model the choice of students to be in one of eight majors compared to a ninth major, biological engineering.

The results of Chapter 5 describe the supply and demand-side factors associated with high and low levels of female undergraduate representation in engineering. The human capital and Status Belief theoretical explanations find mixed support in this chapter. Certain variables such as prior engineering experience are highly related to a student's location in a major that has the lowest representation of women, while variables that were expected to have an impact, such as engineering confidence, show limited association with the dependent variables. Variables measuring discrimination and hostile climate generally have the expected impacts. Negative experiences are generally related to a student's location in an engineering major with relatively few women. Notably, there is equivocal evidence for each of the theoretical explanations.

I examine sex segregation in engineering from one last perspective in Chapter 6: the level of the major, or the meso-level. I focus on the characteristics of the major and control for institutional characteristics to understand what meso-level factors are associated with the over- or under-representation of women in engineering majors. Using weighted least squares regression, I model the association between values of the Representation Ratio and major-level aggregated measures of human capital, status beliefs and discrimination. I include two measures of the prestige of the major to assess the extent to which vertical segregation is occurring in engineering majors. Demand-side factors provide the greatest explanatory power regarding female representation, when examined from the level of the major. Specifically, two measures of a welcoming climate, one related to professors and one related to students, are related to the over- or under-representation of women in an engineering major. No human capital variables reach significance, and only one status belief variable is related to women's disproportionate representation in engineering majors. The two prestige variables are related to the Representation Ratio values, but their influence is unclear since their effects are very small in size.

Finally, I use Chapter 7 to come full circle and bring together the different analyses at the different levels and describe how these analyses have contributed to research literature. This dissertation surrounds the research questions from different perspectives and doing so provides new understandings of sex segregation within an educational field. I also discuss the limitations of the research and the implications this dissertation has for future research in the field.

1.4 Relevance/Contribution of this Project

This research project digs deeper than previous examinations of female under-representation in engineering. Almost all previous work on women's under-representation in engineering focuses on the level of the discipline and does not look within engineering at the different majors. Just as in occupational segregation research, the trends and patterns of women's representation change when it is examined in greater detail. While women are under-represented in every engineering major compared to their representation among all undergraduates, their presence in some engineering majors is greater than in others, and their experiences within those majors is different as well.

This project has provided new information on the extent to which engineering colleges are segregated by sex across majors. This research also increases understandings of sex segregation within and across schools. Given that prior research finds greater sex segregation within schools than across schools (Jacobs 1999a), the results from this research suggest that this phenomena may be gender specific. For women, a smaller percentage of the total variation in the choice of an engineering major with the highest or lowest female representation is attributable to the variation between schools. This moves the field a step forward in terms of understanding the causes of sex segregation in engineering because it tells us that institutions matter, albeit less for women, and the reasons for women's under-representation are greater than individual choice.

This dissertation examines the impact of factors at the micro, meso and macro levels to understand sex segregation within engineering majors. I purposely look at this issue from different perspectives and viewpoints to gain a broad view. By surrounding the problem, I offer multiple viewpoints from which to understand the inequality in undergraduate engineering, in the midst of equality in higher education.

There are both theoretical and methodological implications of this dissertation.

Utilizing occupational segregation as an analogy is useful, but sex segregation within engineering has some unique characteristics. Certain occupational segregation findings were not borne out within this analysis—for example, the occupational segregation literature would suggest that prestigious, well-paid majors/fields will have greater male representation than less prestigious majors, but conflicting evidence for this exists in the engineering case. There is contrasting evidence regarding the extent to which vertical segregation is happening within engineering. Horizontal segregation clearly exists, but analyses of vertical segregation, using measures of prestige of the major or field, either find no effect, or have extremely small effects. More research needs to be done to assess the extent to which vertical segregation is operating in engineering, since prior work (Charles and Grusky 2004) shows that certain types of sex segregation are more responsive to particular types of changes or interventions.

Sex segregation in engineering is also a unique case because there is greater homogeneity of students within the field, which is not the case for the labor market. All engineering students must possess a minimal level of skill in calculus and physics, which may be part of the reason why human capital explanations seem to provide little power for explaining differences in sex segregation. An understanding of how the process of engineering's stratification is different from the process of stratification that has been documented in the labor market improves sociological knowledge of the causes of and associations with sex segregation in particular fields.

Demand-side explanations offer a stronger explanation for sex segregation in engineering. There is a large amount of evidence that organizational characteristics and major/department characteristics are associated with women's disproportionate representation across engineering majors. There is wide variation in women's representation across majors and across schools, suggesting that organizational factors play a role in funneling certain types of students to certain majors. In addition, the lack of a clear sex segregation structure within undergraduate engineering underscores the importance of context for women's representation in engineering. High intraclass correlations from some of the multilevel models also indicate that much of the variation in the dependent variable is located at the level of the school, not at the individual level.

This dissertation is methodologically unique because it utilizes novel data with a significant number of respondents across many schools, which enables me to look at nine different majors within engineering. Most previous research on sex segregation in education compares disciplines such as humanities, engineering, social sciences, science and math. Even those studies that have examined some differences among engineering fields use a one institution dataset and look only at four majors which are lumped into two groups (Hartman, Hartman and Kadlowec 2007). My data enable a detailed analysis heretofore not possible. My analytic approach utilizes techniques such as multilevel logistic regression which are not common in the engineering education literature, but can help move the field forward into new types of statistical modeling.

From an engineering educator's viewpoint, the results from the research provide constructive ideas for improving both the quality of engineering programs and the types of interventions that might help both male and female students, and identify current policies that might reinforce barriers to student commitment to engineering. My approach of looking within engineering responds to the requests of engineering deans and associate deans for more data on the differences between fields of engineering. The results show that while some supply-side factors do matter, such as the importance of pre-college experience with engineering, organizations have much they can do at a higher level to improve the climate for women and all students. Professors, administrators and support program managers can all benefit from knowing the factors associated with student location in certain majors, and understanding that they can have an impact at the level of the college or major by changing policies or providing training to professors on student interaction.

In addition, this research on sex segregation in undergraduate engineering programs provides a better understanding of the causes and possible consequences of sex segregation by major. While the causes and consequences of sex segregation in occupations are fairly well known, the same issues are not as well known in academic settings, and certainly not in engineering. Sex segregation in engineering has lasting consequences for lifetime earnings by men and women, which underscores the importance of understanding this phenomenon better. This dissertation also contributes to a sociological understanding of why certain fields move from inequality to parity, but more longitudinal research can be done in this area. Understanding these issues better in the case of engineering is key to an improved understanding of social inequality and its processes.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

To begin my study of the disproportionate enrollment of women in particular engineering majors, I examine previous research and theory on sex segregation in organizations. In the context of a female “advantage” in college enrollments, questions about enduring gender inequality in engineering as well as the differential representation of women across engineering majors are increasingly relevant to our understanding of sex segregation in organizations. Social stratification is prevalent in higher education and the workforce; this chapter focuses on prior research in both fields to provide a well-rounded view of the explanations for sex segregation.

Explanations for sex segregation generally focus on either the individual or the institution. At the individual level, differences in “taste”, preferences, abilities, gender beliefs, and educational background influence outcomes. At the institutional level, the environment, the strength of institutional norms and values, common practices, and organizational characteristics can affect outcomes. This chapter contains an abbreviated review of the scholarship that exists on educational sex segregation, the representation of women in engineering, and occupational sex segregation. Lastly, the chapter summarizes the theory underlying the subsequent analyses and the testable implications of that theory.

2.2 Segregation and Gender in Higher Education

As has been well documented in the literature, female disadvantage in higher education has almost disappeared. In general, women do very well in terms of access to higher education, accounting for more than half of the undergraduate college student population (Jacobs 1996; U.S. Department of Education 2008). Women are also more likely than men to enroll in college immediately after high school (Buchmann, DiPrete and McDaniel 2008; Freeman 2004). In 1982, women reached parity with men in terms of college graduation rates and since then have continued to increase their annual percentage of degrees granted (Buchmann, DiPrete and McDaniel 2008). In the 2006-2007 academic year, women earned 57 percent of all bachelor's degrees in the United States (U.S. Department of Education 2008). This female advantage in college enrollment and completion marks a change from the past when males were more likely to immediately enroll in college and were less likely to drop out (Buchmann, DiPrete and McDaniel 2008).

Explaining why these trends have occurred, DiPrete and Buchmann (2006) find that the value of education has increased more for women than it has for men. In other words, women have experienced a faster rise in the return to their education than men have, which may in part explain the trends in college completion that show women to be doing better than men. Other explanations for the gender gap include individual level factors such as financial and social resources, family educational background, socialization, and prior academic performance. Institutional level factors affecting the gender gap in higher education include gender role attitudes in society, declining wage gaps in the labor market, and expansion of the four- and two-year college educational system (Buchmann, DiPrete and McDaniel 2008).

Despite the female advantage in college enrollment and completion, women continue to lag behind men in terms of their enrollment in certain fields of study. Sex segregation by field of study seems to be a persistent problem that has not changed much in engineering and most science fields, even in the midst of vast improvements in women's representation in higher education in general (Polachek 1978). This is especially perplexing since women now outperform men in high school by getting better grades, taking more biology and chemistry classes, more Advanced Placement exams in high school, and taking the same level of high school math courses as men (Bae, Choy, Geddes, Sable, and Snyder 2000; Buchmann, DiPrete and McDaniel 2008; Catsambis 2005; Davies and Guppy 1997; Gallagher and Kaufman 2005; Xie and Shauman 2003). Lack of preparation or performance is no longer a sufficient explanation of women's virtual absence from many science and engineering fields.

The national trends indicate that sex segregation in higher education by undergraduate field of study declined by about 40 percent from the late 1960's to the mid 1980's (Jacobs 1989, 1995). However, after the mid 1980's, sex segregation by field of study only incrementally declined (Jacobs 1995) because women did not continue to enter male-dominated fields (England and Li 2006) and because of the expansion in the early 1980's of fields of study that were more gender integrated than others (Jacobs 1995). For example, women moved out of fields such as education and English and into business (England and Li 2006). Overall, men did not move into those female-dominated fields, so this did not impact the levels of sex segregation in undergraduate education (England and Li 2006; Jacobs 1995).

The international literature on sex segregation in higher education provides another view of the factors that affect gender inequalities. Charles and Bradley (2002) published a cross-national (twelve industrialized countries) study on sex segregation by field of study. They find that the level of egalitarian ideals and attitudes of the country, on average, impact the distributions of women across the different tertiary levels of education but are less relevant to the dispersion of women across fields of study, although there are still some effects for certain fields of study (2002). They use the language of horizontal and vertical segregation, with horizontal segregation meaning sex segregation by field of study and vertical segregation meaning sex segregation by level of study (tertiary level). According to Gerber and Cheung (2008), horizontal inequalities may be even more important to understand than vertical inequalities in higher education. In terms of gender, horizontal inequalities/segregation should be examined carefully since access to higher education (vertical segregation) for women and men has reached parity. This suggests that my dissertation's focus on inequalities across engineering majors is both timely and important.

There is not a lack of research on sex segregation in higher education in general (Charles and Bradley 2002; England and Li 2006; Jacobs 1985, 1995; Polachek 1978), but none of the research focuses on one particular discipline such as engineering and examines the trends across the sub-disciplines. An analysis of horizontal segregation within engineering can yield important insights because of the inequality that continues to persist there. Some existing research explains why students choose certain disciplines. The factors from the literature related to student's choice of major are described below.

2.3 Choice of Major

A number of research studies seek to understand why women leave engineering majors, but few address the relationship between gender, experience and choice of a specific engineering major. According to the literature on factors affecting the selection of majors in the science, engineering, and/or quantitative fields, students choose their majors for a wide variety of reasons. Factors include student preparation and achievement pre-college, individual preferences for specific fields, labor market prospects, sex role socialization, and preferences about careers focused on helping others, working with people or making money (Eccles and Hoffman 1984; Frehill 1997; Gianakos and Subich 1988; Lackland and De Lisi 2001; Maple and Stage 1991; Peterson and Roscoe 1983; Turner and Bowen 1999).

Gender socialization, pre-college preparation, supportive environments, confidence and aspirations are all implicated in students' choice of major, although not necessarily the choice of engineering majors.

Gender socialization begins before college and results, in part, in the sex typing of fields of study such as engineering (Wilson and Boldizar 1990). Socialization likely has a role in whether women decide to go into male-dominated fields (Yoder and Schleicher 1996), such as engineering, but the role socialization plays in the decisions to choose specific engineering majors remains unclear. Research has found associations between students' major choices and gender socialization (Tillberg and Cohoon 2005), self-efficacy (Marra, Schuurman, Moore and Bogue 2005; Nauta and Epperson 2003), and societal relevance (Goodman et al. 2002; Sax 1994). But none of these studies analyzes the differences between engineering sub-fields by sex.

While pre-college preparation is a factor often associated with the decision to enter STEM programs or to persist in STEM programs, there is conflicting evidence about the impact of pre-college preparation on choice of major. On one hand, gender differences in academic achievement in high school do not explain the gender differences in the expectation of choosing a science or engineering major (Xie and Shauman 2003). Academic preparation and ability, as measured by SAT scores, explains only a small portion of the gender variation in majors (Turner and Bowen 1999). On the other hand, high school math and physical science coursework predicts choice of an engineering major, or other STEM major (Frehill 1997; Wilson and Boldizar 1990) as well as of a medicine or law field (Ayalon 2003).

Supportive and positive environments within schools and departments have been found to be related to women's choice of major. Hearn and Olzak (1981) found that men were more likely than women to choose undergraduate departments that were associated with high rewards post-graduation, while women were more likely than men to choose supportive departments. In the same vein, women in female-only colleges were more likely to switch majors into more male dominated disciplines than were women at co-educational institutions, in part because all women's colleges provide a more supportive environment (Solnick 1995).

Self-confidence also impacts a woman's choice of major. In one study, women in highly male-dominated engineering majors exhibit a higher level of engineering self-confidence than those in less male-dominated majors (Hartman, Hartman and Kadlowec 2007). Specifically, women in the mechanical and electrical/computer engineering majors seem to have a greater degree of confidence in their computer and calculus skills than the women entering chemical or civil/environmental engineering (Hartman, Hartman and Kadlowec 2007). The authors concluded that women seemed to choose majors in which they felt they had strengths (Hartman, Hartman and Kadlowec 2007; Hartman and Hartman 2007).

Another explanation of why women choose different fields of study or have different career aspirations comes from Correll (2001, 2004). Priming students with beliefs about gender-related task performance impacts their assessments of their ability to perform those tasks; priming subsequently impacts one's confidence in careers that require this ability, holding actual performance constant (Correll 2004). It seems reasonable to extend this model to students' choices of major. Students' assessment of ability, or their level of self-efficacy (Marra, Schuurman, Moore and Bogue 2005; Nauta and Epperson 2003), are likely to influence which engineering major a student ends up in, although there is no current research to support this hypothesis. The conceptual model supported by the findings of Correll (2001) suggests that cultural beliefs about gender influence perceptions of ability (regardless of actual ability), which influence decisions about careers. In another study, the effects of expected income and math achievement on choice of major operate primarily through high school students' aspirations for a college major (Wilson and Boldizar 1990). Additional evidence exists that career aspirations impact STEM degree pursuit (Xie and Shauman 2003). Furthermore, occupational values, such as the importance of intrinsic or extrinsic rewards are predictive of choice of major. In fact, according to Frehill, if the intrinsic rewards of engineering were clearer, an additional 3.2 percent of the sex gap would close (1997).

A student's choice of major can have lasting consequences for their future financial well-being, as evidenced by the large differences in initial earnings after college (Bobbit-Zeher 2007; NACE 2009). Engineering fields yield the highest returns to college education, while those in education related fields experience the lowest returns to their time and money spent in college (Gerber and Cheung 2008). Gender differences in the choice of major influence the gender gap in earnings among college graduates (Jacobs 1996). In fact, data on earnings in the 1990's indicates that anywhere from 15 to 25 percent of the gender wage gap is attributable to the unequal distribution of women and men across majors in college (Bobbit-Zeher 2007; Gerber and Cheung 2008; Joy 2003). Traditional explanations of why different majors result in different returns often revolve around human capital and specialized skills (See Gerber and Cheung 2008 for a discussion).

2.4 Sex Segregation in the Labor Market

There is a large literature on the trends of, reasons for, and consequences resulting from sex segregation in the labor market. The scholarship on labor market segregation provides a useful analogy for my analysis of the segregation of women into particular engineering majors. In this section I describe a broad view of sex segregation in the labor market.

Sociologists generally recognize the 1970's as the beginning of a period of decline in occupational sex segregation. The 1970's had the fastest period of decline, and, although occupational sex segregation continued to decrease in the 1980's, it decreased at a much slower rate (Goldin 1990; Reskin 1993). Labor market sex segregation saw a decline of about 18 percent from the late 1960's to mid 1980's (Jacobs 1995; Reskin 1993). But that does not mean sex segregation is in the past.

Trends in job segregation change when data are broken down from all men and women to black men and women, black and white women etc. (Reskin and Padavic 1999). Job sex segregation is highest between white men and white women and second highest between black men and black women, although the difference between whites and blacks is small in any given year from 1940 to 1990. Racial job segregation is lowest between black men and white men and almost 20 points higher between black women and white women in 1940; however, job segregation between black and white women reached the level of segregation between black and white men by 1990. Regardless of race, women are generally segregated into female-dominated occupations, and this experience is the same for all women (Reskin and Padavic 1999). For example, Reskin and Roos (1990, p5) described the changes in levels of occupational segregation by race and sex over a 41 year span. Using Gross's index of segregation (1968), they found that sex segregation in occupations was remarkably constant from 1940-1981, particularly for whites. Alternatively, levels of occupational segregation by race improved greatly during this time period, especially for non-white women (Reskin and Roos 1990).

Segregation has been conceptualized in many different ways. While Charles and Grusky (2004) contend that there are two important aspects of sex segregation, vertical and horizontal segregation, Massey and Denton (1989) conceptualize segregation as containing three important characteristics: distribution across fields, crowding, and degree of intergroup contact (see also Jacobs 1993). Distribution across fields is commonly measured with the Index of Dissimilarity (Duncan and Duncan 1955), although the Size Standardized Index of Dissimilarity and the Index of Association are alternatives (Charles and Grusky 2004). Crowding or feminization of fields is measured with indices of concentration and indicate of the degree to which women are "restricted" to certain fields (Jacobs 1995). Degree of intergroup contact is typically measured with an index created by Lieberson (1980) which is called P*.

Sex segregation in the labor market is in part created and maintained by the ideology of "difference". Even though occupations are integrating, jobs continue to be segregated, or have become more segregated as occupations integrate (Goldin 1990; Reskin and Hartmann 1986; Reskin and Roos 1990). Women are funneled into jobs without authority and into occupations that either have "feminine qualities" or have been vacated by men (Reskin and Roos 1990). Even when progress toward equality is being made, the ideology of "difference" maintains inequality by segregating women into different jobs. Women and minorities have broken into certain areas of the labor force, but other areas have remained highly segregated.

2.5 Theoretical Grounding

This dissertation examines the uneven representation of women across engineering majors, which requires a comprehensive theoretical framework as this topic has not been studied before. However, occupational sex segregation has been thoroughly studied and documented, so I utilize the supply and demand side theories often used in that literature. This section describes the specific theories I use to understand why and how sex segregation is maintained, albeit to different extents, in engineering majors. Using a supply-demand framework allows me to assess both micro and macro processes that may be operating to influence student choice of engineering major. I use the supply-demand framework to organize the theoretical alternative explanations.

2.5.1 Supply-Side Explanations

I utilize two supply-side explanations in this study. Human capital theory includes concepts related to biology and skills, while status beliefs theory (Ridgeway 1991) encompasses factors such as socialization, self-efficacy, and self-confidence. Both neoclassical economic perspectives and sociological research on status beliefs yield the prediction that women will be under-represented in engineering, albeit for different reasons.

Human capital is often described as a person's knowledge, skills, or competence that ultimately relates to their ability to create economic benefits. There are differing views about human capital, but most writings assume that human capital is not stagnant but can be invested in by individuals (Becker 1993). Common human capital variables include educational attainment, training and employment experience that all combine to create the human capital earnings function (Goldin 1980; Polachek 1979). Human capital explanations have been used to specifically predict women's labor market choices (Polachek 1979, 1985). Much research indicates that human capital variables serve as important covariates in models explaining occupational choice. However, some studies indicate that human capital does not have as strong an impact as previously thought (Beller 1982; Corcoran, Duncan and Ponza 1984; England 1982).

Human capital theory is built upon the basic assumption that greater investment in one's productivity results in greater returns to human capital (Becker 1991, 1993). Researchers often use human capital theory as an explanatory framework in occupational sex segregation literature since it suggests that biology and/or socialization operate to influence one's sense of roles or norms and therefore impacts aspirations to certain occupations (Becker 1991; Marini and Brinton 1984; Shauman 2006; Xie and Shauman 1997). This perspective suggests that women's employment is based, in part, on a weighing of the benefits of paid labor force participation versus participation in the non-paid labor force (e.g. domestic work). In this view, women choose occupations where their investments in human capital will experience minimal depreciation during their breaks from the labor force due to motherhood and/or family obligations (Becker 1981; Polachek 1979, 1981). For this reason, the occupations with low exit and entry costs are generally female dominated occupations (Polachek 1979, 1981). In this neoclassical economic approach, it is assumed that men are more likely than women to invest in human capital (education, skills), resulting in differential labor market outcomes. In the case of engineering, this means that women may have a different level of skill because they did not take the appropriate high school math and science courses, or had no exposure to engineering concepts prior to college because they did not see them as relevant skills for future employment.

These skill differentials have been used in the past to explain why women do not work in certain jobs, although most recent research shows that men and women are more alike than they are different (Clewell and Campbell 2002). For example, gender differences in math achievement levels are very small (Xie and Shauman 2003). In general, few sex differences surround participation in science and math high school classes and Advanced Placement course taking, and those that exist are minimal with only a few exceptions (Clewell and Campbell 2002; Huang Taddase and Walter 2000). However, there is still enough discussion around gender differences in ability that even former Harvard president Larry Summers said there are different distributions of aptitude or ability between men and women in science (Summers 2005). Pre-college preparation is an important measure of skill differentials because it measures the human capital that each person brings to college and can theoretically impact their choice of major.

Pre-college preparation has been studied frequently in the past as a factor associated with the decision to enter science, technology, engineering and mathematics (STEM) programs or the decision to persist in STEM programs. However, a recent study found that women are less likely to pursue engineering even though they have sufficient high school coursework (Tyson, Lee, Borman, and Hanson, 2007). In addition, gender differences in academic achievement in high school do not explain the gender differences in the expectation of choosing a science or engineering major (Xie and Shauman 2003). Similarly, academic preparation and ability explained only a small portion of the gender variation in major choice (Turner and Bowen 1999). In particular, students with physical science high school coursework often choose engineering over liberal arts or business (Frehill 1997). In fact, objective factors of success--such as GPA--show engineering women to be equal to or higher than men (Adelman, 1998). Despite the mounting evidence that pre-college preparation has little impact for women, this concept will be included in analyses. It is important to note that receiving the right kinds of pre-college preparation is likely related to whether one or one's parents have been socialized to believe those types of classes are appropriate. Human capital in the form of prior engineering experience could be relevant for the analysis here which has never been done before.

Some of the assumptions and utility of human capital theory, however, have been contested in other research (Reskin and Padavic 1994; Tomaskovic-Devey 1993; Corcoran, Duncan and Ponza 1984; England 1982; Okamoto and England 1999). Specifically, on-the-job training and labor market experience are the only factors shown to be differential human capital investments between men and women (Reskin and Padavic 1999; Tomaskovic-Devey 1993). Other research shows that human capital theory does not explain sex segregation in occupations, since women in male-dominated and female-dominated occupations experience similar levels of wage depreciation when out of the labor force (Corcoran, Duncan and Ponza 1984; England 1982; Okamoto and England 1999). However, the theory continues to have relevance in both academic and policy circles and will be utilized in this study as one of the primary theoretical constructs.

The other supply-side theory that can be used to understand segregation in engineering fields is status beliefs theory (Ridgeway 1991; Correll 2001, 2004). This theory helps explain why female and minority students often feel "less worthy" than male and majority students, and how that feeling might affect their decisions to major in certain fields. It also helps explain why people might have differing views of a person's competence based on their sex. Status value beliefs are typically associated with a nominal characteristic such as sex or race, and are often related to a general perception of a person's competence (Ridgeway

1991; Ridgeway and Erickson 2000). Status beliefs can be linked to different aspirations for oneself (Correll 2001, 2004). For example, status beliefs may help explain how male and female students sort themselves into different fields in engineering. That is, people already hold status value beliefs attached to their propensity to succeed in engineering before choosing a major. Members of under-represented groups internalize these widespread cultural beliefs. For women and men, these status value beliefs are highly related to an ideology of difference. Status beliefs theory partially explains the process by which male and female students choose different fields in engineering.

Status beliefs theory encompasses concepts that measure the internal, individual characteristics and beliefs that can affect one's belief that they can succeed in a particular engineering field. This includes self-confidence, self-efficacy and socialization. Status beliefs about groups come from social cognition, interactions and structural conditions (Ridgeway and Erickson 2000); they give certain persons more worth in society because of a characteristic that has status value. The basis of status beliefs is the perceived difference in competence and which varies with the salience of the status value characteristic; status beliefs can come from actual differences in resources, and a differential distribution of resources is sufficient to create status value beliefs (Ridgeway 1991). These beliefs can change if the distribution of resources changes, but there is typically a lag time between structural change and status belief change (Ridgeway 1997). Influence hierarchies help explain how the status beliefs of one group, such as teachers, might be transferred to their students (Ridgeway and Erickson 2000). This part of the theory suggests that the status beliefs of educators make it clear who "belongs" in a field, and those status beliefs might be transferred to other students, which serves to create a hostile climate for under-represented students. In this sense, status belief theory contributes an understanding of how hostile classroom climates might come about.

Highly related to status beliefs theory are two other supply-side concepts that have been extremely persistent in the literature on women's under-representation in engineering: gender socialization and self-confidence (Frehill 1997). Gender socialization begins at a very young age (Thorne 1993); as a result of gender cues, girls and boys learn that fields such as engineering are more "appropriate" for boys (Wilson and Boldizar 1990; Yoder and Schleicher 1996). Because some educators speculate that a good proportion of entering college students do not really know what engineering is, let alone the difference between engineering majors, the role socialization plays in the choice of specific engineering majors remains unclear. Research has found associations between students' choice of an information technology major and gender socialization (Tillberg and Cohoon, 2005), which indicates that the status beliefs that arise from years of socialization may have an impact on the choice of an engineering major. Perception of self may also play some role in the segregation of majors, and hence careers.

The conceptual model supported by the findings of Correll (2001) suggests that cultural beliefs about gender influence perceptions of ability (regardless of actual ability) which in turn influence decisions about careers. Thus perceptions of ability, confidence and self-efficacy are relevant explanations for women's location in engineering. Women in engineering and science consistently report lower self-confidence and self-efficacy than men in engineering (Brainard and Carlin 1998; Crawford and MacLeod 1990; Grandy 1994; Rayman and Brett 1995). In addition, students' assessment of ability, or their level of self-efficacy has been found to influence choice of major (Hartman, Hartman and Kadlowec 2007; Marra, Schuurman, Moore and Bogue 2005; Nauta and Epperson 2003).

Human capital theory and status beliefs theory both depend, to some degree, on socialization. In human capital theory, socialization impacts understandings of the appropriate occupation for a woman and therefore can affect whether one acquires the skills necessary to succeed in an occupation such as engineering. In status beliefs theory, socialization is linked to aspirations and beliefs that one can succeed in a particular field. For the purposes of this study, I generally categorize socialization as a concept within status beliefs theory, but it could also be included in human capital theory.

2.5.2 Demand-Side Explanations

Alternative demand side explanations for sex segregation emphasize how segregation reflects "demand" for women both as students and practitioners within fields of engineering. These explanations include discrimination, stereotyping, hostile climate and organizational characteristics. Discrimination and stereotyping help explain why the demand for women may be different than the demand for men (Becker 1971; Reskin 1993). In addition, while organizational characteristics or structure are not a theory per se, they can either encourage or discourage greater female representation. There are three important parts of institutions that also reflect "demand" for female students: prestige of college, faculty representation and college/department policies and practices.

Discrimination perspectives assert that students are pushed away from certain fields as a result of the behavior of other people or organizations. In my operationalization of discrimination, stereotyping, hostile climate and overt harassment combine to make students feel unwelcome or uncomfortable, resulting in differential distributions of students across majors. Discrimination is said to result from both social cognition processes and inter-group conflict (Reskin 2000). Social cognition is the brain's way of breaking the world up into easily digestible parts, such that it puts people into categories automatically. Implicit bias is the result of social cognition processes. This categorization is based in part on stereotypes, and does not occur with the expectation of excluding certain groups or favoring others, but occurs as part of normal cognitive processes (Fiske 1998).

Stereotypes can affect individual outcomes because members of the stereotyped group learn to believe them, and act accordingly (stereotype threat), or because others treat members of a stereotyped group differently than everyone else through discriminatory behavior (Goldin and Rouse 2000; Newman 1978; Reskin 2000; Steele 1997). Stereotyping theories suggest that social categorization is generally a useful and normal part of everyday interaction, but it can have negative consequences (Heilman 1995; Reskin 1993). Explanations utilizing discrimination and stereotyping provide explanations for women's under-representation, namely that women are actively or passively kept out of certain fields, which contradicts other explanations of individual choice. While the labor market literature widely uses these explanations, the degree to which hostile climate and discrimination impacts male and female outcomes in college is less clear. There is evidence that gender stereotypes are extremely pervasive in college, and that many of the stereotypes students hold are incorrect, particularly regarding the percentage of women in all majors and the GPA's of male students, which students underestimate and overestimate, respectively (Beyer 1999). Discrimination also has varied impacts on long-term outcomes such as earnings.

The literature on discrimination and hostile climate is varied in terms of its impact on sex segregation in occupations and resulting wage differentials. Some research finds that discrimination does have an impact, while others find no impact (Bielby and Baron 1986; Goldin 1980; Reskin and Roos 1990). In education, a sense of faculty supportiveness can be gained through interactions with professors and TA's, which is important for outcomes: men are more likely than women to choose undergraduate departments that are associated with high rewards post-graduation, while women are more likely than men to choose supportive departments (Hearn and Olzak 1981). A lack of community and social acceptance are known obstacles to women's progress (Goodman et al. 2002; McIlwee and Robinson 1992).

Because discrimination by sex and race/ethnicity is partly based on cognitive processes, it is important to understand the ways organizational processes and structures can help or hurt a group's chance for opportunities (Reskin 2000). Policies can reduce levels of segregation, as shown in different labor market applications (Baron and Pfeffer 1994; Bielby 2000). Organizational arrangements, then, can help or hurt gender and/or race equality.

In undergraduate education, such policies are less well known, and it is possible that the independent culture and bureaucracy of higher education results in departments being less willing to implement policies and make changes. However, there are some policies that have been shown to increase numbers of those groups under-represented in STEM fields. For example, the computer science (CS) department at Carnegie Mellon implemented new requirements for their major and also changed their admissions policies (Margolis and Fisher 2002). These policy changes as well as others resulted in an increase in the entering proportion of women into computer science from 7% to 42% in a period of just 5 years

(Margolis and Fisher 2002). The example above illustrates why this study must include organizational arrangements and characteristics as an important influence on sex segregation

Lastly, related to institutional characteristics and structure, institutional composition in terms of female representation has mixed impacts on women's outcomes in general (Jacobs 1995). Some research has shown that for certain majors, the percentage of female faculty in a major affects the percentage of female students in the major (Sonnert, Fox and Adkins 2007), but others have found no relationship (Canes and Rosen 1995). In studies of sex segregation among faculty in science and engineering, institution type is very important for explaining segregation (Frehill 2006; Nelson 2005).

Using the framework of supply and demand just discussed, Table 2.1 shows the theoretical constructs and related concepts already described and how they are operationalized in this study. Chapter 3 describes these measures in more detail. Certain questions are combined together into factors that measure a construct while other constructs are represented with single question measures. The Project to Assess Climate in Engineering survey contributes all supply-side measures and the demand-side passive and overt discrimination measures. The organizational characteristics come from Carnegie Classifications, *US News & World Report* college rankings, and American Society for Engineering Education data on faculty representation.

Table 2.1 Theoretical Constructs, Related Concepts and Operationalization

Theoretical Constructs & Related Concepts	**Operationalization**
Supply-Human Capital Theory	
Human Capital	GPA Engineering course before college
Supply-Status Beliefs	
Socialization	Engineers can re-enter career Engineering supports working parents Engineers can design their own schedules Work/family balance Engineering is respected by society Society values engineers Engineering is well-paid
Self-Confidence, Efficacy	Comparison of engineering ability Engineering confidence Intent to graduate Coursework will prepare for job
Demand-Discrimination	
Stereotyping	Engineering faculty express stereotypes about men and women
Passive	Professors care about student learning Professors encourage to think creatively Professors write helpful comments on work Professors inspire to study engineering Professors take suggestions seriously Sense of engineering community Students help each other succeed in class
Overt	Singled out unfairly in class b/c of gender Sexual harassment by faculty or students
Demand-Organizational Characteristics	
Prestige	Prestige of major Prestige of college
Faculty Representation	Proportion female tenured/tenure-track faculty
Organizational	Carnegie (RUVH)

2.6 Summary

With the pervasive under-representation of women in engineering, women's uneven representation across engineering fields and public debate on whether women are as capable as men in the science and math fields (Summers 2005), this dissertation cuts to the heart of the matter to determine what accounts for women's disproportionate representation in certain engineering fields. By using well-known theories at the micro and macro levels, I am able to test different alternative explanations for women's under-representation, and therefore am able to say something about the applicability of these theoretical explanations for sex segregation in engineering education.

The framework of supply and demand organizes the different theoretical explanations that I use as the basis for this project. Human capital theory, status beliefs theory and the discrimination literature serve to provide alternative explanations for the disproportionate dispersion of women and men across engineering departments. Human capital theory predicts that women will more likely be found in majors that have lower entry and exit costs. Status beliefs theory predicts that students' sense of self-confidence, self-efficacy, socialization and expectation of the type of life afforded by certain engineering disciplines will impact the departments in which students study. Higher self-confidence and self-efficacy should relate to the choice of a more prestigious, male-dominated major, while negative perceptions of the work-family flexibility of engineering means students will likely choose less male-dominated majors where they feel they have a greater chance of achieving work-family balance. Also, discrimination perspectives focus on both passive and overt forms of discouragement: departments where women experience hostile, unwelcoming cultures are likely to have lower representation of women than departments that foster community and provide strong student support.

There are other theories not examined here that could shed some light on the sex segregation processes occurring in undergraduate engineering majors. For example, another way to think about how students end up in certain majors would be to consider the literature on job matching processes. While much of this literature comes from economists, more recent work takes a sociological view which considers social/structural constraints instead of making broad assumptions (Granovetter 1988). An important part of this literature focuses on the impact of strong and weak ties or networks (Granovetter 1995).

To apply this research to engineering education would require thinking about and testing the impact of a student's ties both prior to school and during school. Previous research has found that students with family members who are engineers are much more likely to study engineering than students with no engineers in their family (Goodman et al. 2002; Seymour and Hewitt 1997). Clearly, the strong ties of the family have an impact on going into engineering, but it is not known to what degree these ties impact the particular major a student chooses. In addition, the strong and weak ties that students form when they enter college may have some impact on whether they stay in engineering or in a particular engineering major. One can imagine a student who begins as an engineering major, but who has many non-engineering friends through her dorm; she might be less likely to continue as an engineering major after she sees that the workload does not allow her to spend as much time with her new friends. Even though these other literatures could help our understandings of sex segregation in engineering, and they may warrant further examination in a different study, I focus on the explanations most commonly found in the literature on occupational sex segregation.

Explanations of and research on sex segregation in the labor force and higher education provide a solid foundation for this study. Each of the theories discussed above impact the representation of women in certain fields. Subsequent chapters examine the extent to which these explanations hold true for the distribution of women across engineering majors.

CHAPTER 3: DATA AND METHODOLOGY

3.1 Introduction

While women are under-represented in engineering compared to the general college student population, they are disproportionately allocated across engineering majors, resulting in a unique situation for examining sex segregation in higher education. In order to investigate how supply and demand factors affect sex segregation in engineering majors, I use data from the Engineering Workforce Commission (EWC) and from the Alfred P. Sloan Foundation funded Project to Assess Climate in Engineering (PACE). Because of these two data sources, I am able to examine the under-representation of women in engineering majors from a multiple angles, in the end assembling a broad view of the factors affecting sex segregation in engineering. This chapter describes the data, the strengths and weaknesses of the data to answer this research question, and introduces the methods used in Chapters 4, 5 and 6.

3.2 Engineering Workforce Commission Data

National-level data on engineering undergraduate enrollments in fall 2007 were obtained from the Commission on Professionals in Science and Technology (CPST), derived from the Engineering Workforce Commission (EWC) data in February 2009. Only students working full-time toward a bachelor's degree in an engineering discipline are included in this data set. The Engineering Workforce Commission data is collected annually via a survey to departments and covers more than 500 Accreditation Board for Engineering and Technology (ABET)-accredited US universities and colleges. The survey requests data on undergraduate and graduate engineering and engineering technology programs. I use institutional level data from 351 colleges and universities in the United States that grant

Bachelor's degrees in engineering. This is matched with institutional classification data from the Carnegie Foundation for the 351 engineering schools.

3.2.1 Strengths and Weaknesses of EWC Data

The Engineering Workforce Commission is one of the few sources for engineering enrollment information by sex and major, making it a powerful research tool. The Integrated Postsecondary Education Digest of Statistics (IPEDS) does not provide enrollment information by sex and major. EWC data are updated yearly. The Commission on Professionals in Science and Technology (CPST) trusts the data sufficiently to use it when compiling its statistics on science and engineering fields. The data from EWC are measured at the institution level and can easily be matched with other institutional data such as that from the Carnegie Foundation. This is not a sample: the data from the Engineering Workforce Commission encompass the population of schools that grant bachelor's degrees in engineering.

Because I only use the EWC data for the 351 schools that grant bachelor's degrees in engineering, I am not able to generalize to community colleges or technical colleges that only grant associate engineering degrees, nor to graduate universities such as the Air Force Institute of Technology that grant graduate degrees but not bachelor's degrees in engineering. The EWC does collect data on these other types of schools, but I chose not to use it and instead focus on bachelor's degree granting undergraduate engineering programs.

3.3 Project to Assess Climate in Engineering Survey Data

In October 2006, the Alfred P. Sloan Foundation awarded a grant to the Center for Workforce Development at the University of Washington for a multi-site research project intended to identify issues that affect persistence rates among engineering undergraduates, paying specific attention to the intersection of race, gender and academic experience. The Principal Investigator (PI) of the Project to Assess Climate in Engineering (PACE) is Suzanne G. Brainard, PhD, and the Co-PI is Susan S. Metz. PACE has three main data collection components: an online student survey for undergraduates in engineering, interviews with current undergraduate engineering students, and interviews with undergraduate students who left engineering for another major at their university. The online student survey is used extensively in this study and is described in the following sections. Every school received approval for the study from their institution's Institutional Review Board (IRB) except for one school that declined to review the study since the data would be anonymous and the University of Washington IRB had already approved the project.

3.3.1 Study Sampling

To reduce variation across sites, the PACE study was restricted to those undergraduate engineering programs defined as one-tiered. In other words, each of the programs either enrolls its students directly from high school into the College/School of Engineering and/or provides an engineering advisor during the first year to students who indicated an interest in engineering on their college application form. Based on conventional wisdom, these schools have different cultures and senses of community than engineering schools where the student does not actually enter engineering until late in their second or early in their third year of school. Tracking enrollments at one-tiered schools is straightforward as all students are identified with the college of engineering. The restriction to one-tiered schools decreases error in the sampling frame used for the survey because the definition of who is to be included is the same for all schools. This would not be the case at two-tiered schools where many students are not officially affiliated with the college of engineering until their second or third year of school. At two-tiered schools, the sampling frame would either exclude first and/or second year students resulting in systematic bias, or would have to use a different definition at each school for the sampling frame, thereby increasing error and decreasing comparability. Using this sampling frame reduces the likelihood of non-coverage.

In general, PACE chose schools that had large enough populations of engineering students to enable analysis at the institutional level. Beyond that, the PACE research team wanted to choose schools with significant numbers of women and under-represented minorities, and to be able to compare schools with large proportions of a population of interest to those with low proportions of a population of interest. Thus, the research team obtained a list of engineering schools from the Commission for Professionals in Science and Technology with data on fall 2004 enrollments and 2005 degrees granted. Using these data, a multi-tiered recruitment process began. The goal was to recruit 25 to 30 engineering schools for the project. There were a handful of schools that were not part of the sampling strategy but were invited to participate in the project because of their participation in a previous project of the PI (Brainard, Metz and Gillmore 1999), or because they were chosen as a benchmark of a school that had already committed to the project.

A total of 22 schools are involved with PACE. However, one PACE school is excluded from many of the analyses in this study, resulting in a usable sample of 21 schools. This school was only able to obtain nine respondents to the survey and could not recruit a sufficient number of students with whom to conduct interviews. The bivariate and multivariate analysis using PACE survey data includes 21 schools. The 21 schools are named in Table 3.1.

The PACE institutions reflect the profiles of institutions that grant a significant number of degrees to women and minorities. For instance, of the 21 schools included in PACE analyses, five are among the top ten leading schools in the production of engineering undergraduate degrees awarded to women. Two are in the top ten leading schools in the production of engineering undergraduate degrees awarded to African Americans. Three are in the top ten leading schools in the production of engineering undergraduate degrees awarded to Hispanics (Gibbons 2008).

Table 3.1 Institutional Participation in PACE

Arizona State University	Rensselaer Polytechnic University
Boston University	Rose-Hulman Institute of Technology
California State University – Los Angeles	Texas A&M University
Clemson University	Texas Tech University
Michigan Tech University	University of Maryland
New Jersey Institute of Technology	University of Michigan
New Mexico State University	The University of Texas at Austin
North Carolina State University	The University of Texas at El Paso
The Ohio State University	Virginia Tech
Penn State University	Worcester Polytechnic Institute
Purdue University	

As seen in Table 3.2, of the 21 PACE schools, 17 (81 percent) are public; three (14 percent) are minority serving institutions (US Department of Education); 43 percent are land-grant universities and 11 (52 percent) of the schools are ranked in the top 50 for undergraduate engineering schools in 2009 by *US News and World Report* (2009). Four of the PACE schools did not make the top 100 *US News* rankings. About 57 percent of PACE schools fall into the Carnegie Classification "RU/VH" category, indicating a Research University with

Very High research activity. The PACE schools vary in size from a little over 1904 to almost 51,000 students enrolled at the entire university (Carnegie Foundation Classification).

Table 3.2 PACE and EWC School Characteristic Comparison

	PACE (n=21)	EWC (n=351)
Public university	81%	62%
Minority Serving Institution	14%	9%
Land grant university	43%	19%
Top 50 *US News*	52%	14%
2000 CC Research Universities-Extensive	71%	37%
2000 CC Research Universities-Intensive	19%	17%
2005 Basic CC RU/VH	57%	25%
2005 Basic CC RU/H: (high research activity)	29%	23%
Minimum enrollment, all levels	1904	76
Maximum enrollment	50995	50995
Mean enrollment	26966	14296

In comparison with the 351 school Engineering Workforce Commission (EWC) population, the PACE schools are comprised of a greater percentage of public, land-grant, large, top 50 ranked universities, and universities with very high research activity, as measured by the 2000 Carnegie Classification (CC) for Doctoral/Research Universities-Extensive and the newer classification category from 2005, RU/VH: Research Universities (very high research activity). Table 3.2 presents a comparison between the PACE and EWC schools on a number of relevant characteristics. This means that the PACE results are generalizable to the population of large, public, high research activity universities that are responsible for granting the majority engineering degrees.

3.3.2 Survey Respondent Sampling

The population for the survey consisted of all students over age 18, currently enrolled in an undergraduate engineering program at all of the participating PACE schools in spring 2008.

The population was stratified based on gender and then race/ethnicity. The research team intentionally over-sampled women and under-represented minority students (URMs) as defined by the National Science Foundation – African-Americans, Hispanics, Native Americans and Native Hawaiian/Pacific Islanders – to ensure that these groups would be sufficiently represented among those who completed the survey. Male students in other racial categories were randomly selected based on their representation in the population.

Specifically, all women and URMs were invited, and the size of this population was matched by a random sample of White-American, Asian-American and foreign male students, all of whom are over-represented in engineering programs in the United States. To explain the sampling process in more detail, I offer the following example: University Q enrolls 1000 students in its engineering program. Of these, all 200 women and 100 African-American, Hispanic, or Native American men are invited to take the online climate survey for a total of 300 students. The population of White American, Asian American, International and "unknown" or "other" race men are sampled in proportion to their representation in the population to create a sample of 300 students from the over-represented groups for a total of 600 University Q invited participants.

3.3.3 Survey Instrument

The PACE survey instrument was pre-tested on undergraduate engineering students at a Pacific Northwest university not included in the PACE project. Based on this feedback and feedback from an advisory board of experts, changes were made to the survey to improve validity. Reliability and validity of the survey were analyzed post-administration. Internal consistency coefficients were computed for all subscales that were comprised of five or more items, and negatively worded items were reverse-scored before analysis (but the reverse was true for the first transfer student subscale). Each of the seven subscales showed adequate to excellent internal consistency with a mean α of .77. These subscales are not used in the analysis sections of this dissertation.

3.3.4 Survey Administration

A web survey was chosen for this project to minimize time and cost (Dillman 2000). Web surveys have become increasingly utilized since the mid 1990's (Couper and Miller 2008), and bring with them their own strengths and weaknesses just as with more traditional modes of surveying such as telephone, paper and pencil, or face-to-face surveying. College students are generally considered a high internet coverage population, as most if not all schools automatically assign students a school email address for official communications. Research has shown that high internet coverage populations are good candidates for web research (Couper, Traugott, and Lamias 2001; Sills and Song 2002).

The response rates differ quite a bit from school to school—the average response rate for the 21 schools is 29 percent. In order from lowest to highest, the response rates from the 21 schools are: 7, 13, 17, 19, 21, 21, 23, 23, 25, 27, 29, 31, 32, 34, 35, 35, 36, 40, 44, 48, and 53. To put these rates into context, evidence exists that response rates for all modes of survey research have been declining (Curtin, Presser and Singer 2005). For example, the University of Michigan's Survey of Consumer Attitudes response rates for telephone interviews decreased from 72 percent in 1979 to 48 percent in 2003 (Curtin, Presser and Singer 2005). Most research shows that web surveys have a disadvantage in response rates compared to other modes of surveys (e.g., Kwak and Radler 2002). In a meta-analysis of 45 published studies comparing web surveys to other survey methods, the lowest web survey response rate was 11 percent and the highest was 82 percent (Kaplowitz et al 2008).

The research team used a number of research-proven strategies, including incentives, to improve the low response rate typically associated with web-based surveys. The mean and median response rate is 29 percent. While the average PACE response rate is not far from many web survey rates, it is still lower than is generally desirable for social science research. The concern with the response rate is that the subset of those who responded to the survey is different in some way from those who did not respond. Typically, responders are people who have something to say, either negative or positive, about the topic at hand. So, the low response rate could mean that the survey missed capturing the opinions of students who have an "average" experience.

3.3.5 PACE Survey Respondent Descriptive Information

Between February and June of 2008, 38,376 engineering undergraduate students were invited to participate in the PACE online climate survey and 10,554 students responded. The response rate at the 21 individual institutions ranged from seven to 53 percent with an overall mean of 29 percent. Table 3.3 reports the race/ethnicity by sex breakdown for the entire PACE population, that is, all undergraduate engineering students who were enrolled in the spring of 2008 at the PACE schools. For comparison purposes, Table 3.4 reports the breakdown of the respondent pool by race/ethnicity and sex. The population data (Table 3.3) come from institutional records while the respondent data (Table 3.4) come from self-reports on the survey.

Because the research team over-sampled women and under-represented minorities, it was expected that these respondent proportions would not match the population proportions. This is completely true in the case of sex since the proportions of women who are in the respondent pool are greater than the population for every race/ethnicity category. However, only a few respondent race/ethnicity categories are more than two percentage points different from their proportion in the population. International student survey respondents are over-represented by five percentage points compared to their proportion in the population. Whites are under-represented among respondents by four percentage points, and students with unknown race/ethnicity are under-represented among respondents by three percentage points. Because the differences in terms of responses by sex and race/ethnicity are fairly small, the survey responses are relatively representative of the population of students, with the exception of white men and women.

Table 3.3 Race/Ethnicity and Sex for the PACE Population (21 schools)

	Male N	**%**	**Female N**	**%**	**Total N**	**%**
African American	1959	3	700	1	2659	4
Asian American	4848	7	1275	2	6123	9
Hawaiian/Pacific Islander	6	0	2	0	8	0
Hispanic American	5116	7	1330	2	6446	9
International	3115	5	664	1	3779	6
Native American	295	0	86	0	381	1
White	37955	55	7668	11	45623	66
Other	923	1	177	0	1100	2
Unknown	2050	3	449	1	2499	4
TOTAL	56267	82	12351	18	68618	100

Table 3.4 Race/Ethnicity and Sex for the PACE Respondent Pool (21 schools)

	Male N	**%**	**Female N**	**%**	**Total N**	**%**
African American	209	2	164	2	373	4
Asian American	429	4	409	4	838	8
Hawaiian/Pacific Islander	17	0	18	0	35	0
Hispanic American	851	8	389	4	1240	12
International	636	6	434	4	1070	11
Native American	86	1	53	1	139	1
White	3321	33	2994	29	6315	62
Other	5	0	2	0	7	0
Unknown	88	1	62	1	150	1
TOTAL	5642	55	4525	45	10167	100

However, in order to correct for over- or under-representation among the survey respondents, I calculated sampling weights and post-stratification weights for each individual by race, sex and school. That is, an Asian American female student from School #1 was assigned both a sampling weight and a post-stratification weight. Sampling weights adjust for the fact that some populations had a greater probability of being chosen to take part in the survey. The post-stratification weight corrects for the differential response rates across populations. The product of the sampling weight and the post-stratification weight is the final weight for the individual. Thus, once weights are applied, each school's respondents are representative of the population from which they came.

3.3.6 Strengths and Weaknesses

The PACE dataset is unique in that it looks at a significant number of schools and contains responses to questions about the engineering learning environment, student-student and student-professor interaction, and other measures of climate. The number of schools in this type of a survey is one of the largest in recent engineering education research, and enables generalization that is not possible with single institution studies. The data is representative of the population of schools that grant a large number of degrees to engineering students. In fact, while the 21 PACE schools represent only six percent of engineering schools, they account for 18 percent of the full-time undergraduate engineering enrollments in the country for 2008 (ASEE 2008). Thus, a significant percentage of students experience the environments analyzed in this study.

In addition, because of the over-sampling of women and under-represented minorities, the data contain sufficient numbers of students in certain groups to disaggregate without confidentiality concerns. In the science and engineering research literature, a common limitation is a lack of under-represented students to enable robust analysis. This data set overcomes that limitation. The PACE data permit investigations that were not possible in the past. This is a strength of the PACE data

Each of the PACE schools provided their aggregate enrollments by sex and major for the quarter in which the survey was conducted, facilitating a close connection between student experiences that were reported and the sex distribution in each major.

A weakness of the PACE data is that the participating schools are generally large, land-grant, highly ranked, public and have very high research activity. While there are private and small schools in the PACE study, the data are more representative of large public schools. However, as mentioned above, the PACE schools account for 18 percent of the engineering undergraduate enrollments nationwide, suggesting that they represent a significant portion of the population of interest.

Additionally, because the original goal of this survey was to examine the culture and climate in engineering, fewer student background questions exist than one would like. Omitted variable bias is mitigated through use of substitute variables. For example, instead of information about experiences in high school with math and science curriculum, the survey asks whether students had taken any engineering courses prior to college. However, there is no substitute for family background questions such as parental occupation.

As with most multivariate analyses, even those utilizing longitudinal data, concern regarding endogeneity exists. Endogeneity occurs when a variable included in the model is correlated with unobserved factors that affect the outcome variable. The unobserved factors are included in the error term. If the value of an independent variable actually depends upon the dependent variable, there is an endogeneity problem. Endogeneity can be caused by *omitted variable bias*, *measurement error* and *simultaneous measurement*, as well as other factors. Problems with endogeneity can cause biased parameter estimates and result in incorrect hypothesis tests. In this data set, some student background variables are missing and all variables are measured at one point in time, using a cross-sectional approach. Care is taken to minimize endogeneity problems.

Other datasets exist that researchers have used to examine related questions. However, these instruments are inadequate for determining student perceptions about the campus climate for women and men in engineering due to the lack of questions focused on this issue. Examples of other datasets include the National Study of Student Learning (Pascarella, Whitt, Yeager, Edison, Terenzini, Nora, and Hagedorn 1997), Cooperative Institutional Research Program (Sax 1996), ACT's College Outcomes Survey or Student Opinion Survey (ACT 1990), College Student Experiences Questionnaire developed by George Kuh (2003), or the College Student Survey developed at UCLA (Astin and Astin 1992). Many of these data sets are most appropriate for measuring student satisfaction and do not focus on engineering disciplines and the unique experiences that may exist in engineering. The PACE data is novel in its focus on engineering undergraduate students and their experiences in school.

While research clearly identifies barriers to progress for women in science and engineering, little is known about the characteristics associated with different levels of sex segregation across engineering majors. As a multi-site study with data from diverse undergraduate engineering programs, PACE is uniquely suited to address this gap in the literature.

3.4 Variables in the Analysis

Each of the chapters examines sex segregation in engineering from a different perspective. This means that the samples used and variables differ across the three analysis chapters. While each chapter provides details on the variable definitions and descriptive statistics for that particular sample, I provide here an overview of the variables that are used in the analyses. I provide the actual question wordings from the PACE survey (Table 3.5) and some descriptive statistics for the PACE and EWC data.

Table 3.5 PACE Survey Question Wording for Independent Variables

Independent Variables

GPA
- Cumulative GPA (write-in)

Engr Prior*
- Prior to beginning college, did you take any engineering courses?

Family Friendly (Factor Variable)**
- Engineers can leave and come back to their careers more easily than can people in other professions.
- Engineering is a field that supports people who want to have children and continue working.
- Engineers can design their own work schedules.
- Engineering is a field that supports a balance between work and family life.

Positive View Engr (Factor Variable)**
- Engineering is an occupation that is respected by other people.
- Society values the work engineers do.
- Engineers are well-paid.

Ability Comparison***
- Compared to other students in my classes, I think my academic abilities in my engineering classes are:

Engineering Confidence**
- I am confident in my ability to succeed in my college engineering courses.

Intend to Graduate**
- I intend to complete my engineering degree.

Prepared for Job**
- My engineering coursework will prepare me for a job in engineering.

Table 3.5 Continued

Independent Variables

Gender Stereotypes*

- In class, I have heard engineering faculty express stereotypes about men and women.

Singled Out b/c of Gender*

- In class, I have been singled out unfairly because of my gender.

Sexual Harassment*

- I have been sexually harassed by and engineering faculty member.
- I have been sexually harassed by an engineering student.

Engineering Community****

- Do you feel like you are part of an engineering community?

Professors Care (Factor Variable) ****

- Do your professors care whether or not you learn the course material?
- Do your professors encourage you to think creatively?
- Do your professors write helpful comments on the material you turn in?
- Do your professors take your suggestions and comments in class seriously?
- Do your professors inspire you to study engineering?

Help Others Succeed****

- Do engineering students help each other succeed in class?

*Scale categories: Yes, No

**Scale categories: Strongly Disagree, Somewhat Disagree, Neutral, Somewhat Agree, Strongly Agree

***Scale categories: Far Below Average, Below Average, Average, Above Average, Far Above Average

****Scale categories: Never, Rarely, Sometimes, Usually, All the Time

Table 3.6 shows the means and standard deviations for the dependent variables used in Chapters 5 and 6. Not all majors exist at all schools, so the N is reported as well. Table 3.7 reports the descriptive statistics for the independent variables used in the analysis in Chapter 5. The number of respondents in Table 3.7 is not the same as the analysis chapters, but students with more than one major are filtered out, just as in subsequent chapters. Approximately 12 percent of students with only one engineering major are Hispanic and about 15 percent of students had some experience with engineering prior to beginning college. On average, 14 percent of students report that they hear gender stereotypes from their professors, and about eight percent report that they have been singled out because of their gender. Students generally report high intentions to graduate and fairly high levels of engineering self-confidence.

Table 3.6 Dependent Variables for PACE Data

		Proportion Female		Representation Ratio	
PACE School Majors	**N**	**Mean**	**S.D.**	**Mean**	**S.D.**
Aerospace	14	0.14	0.02	0.76	0.14
Biological	17	0.39	0.05	2.14	0.43
Chemical	18	0.32	0.06	1.77	0.29
Civil	20	0.22	0.06	1.20	0.24
Computer	17	0.08	0.04	0.45	0.20
Electrical	21	0.11	0.03	0.59	0.14
Industrial	15	0.32	0.07	1.77	0.34
Materials Science	11	0.28	0.06	1.55	0.18
Mechanical	21	0.13	0.04	0.68	0.21

Table 3.7 Descriptive Statistics for PACE Survey

Independent Variables	**N**	**Min**	**Max**	**Mean**	**SD**
Controls					
Female	8456	0.00	1.00	0.44	0.50
African American	8605	0.00	1.00	0.04	0.19
Hispanic American	8605	0.00	1.00	0.12	0.33
Human Capital					
GPA	8104	1.00	4.00	3.25	0.50
Engr Prior	8526	0.00	1.00	0.15	0.36
Status Beliefs					
Family Friendly (centered)	8113	-3.54	3.20	0.00	0.99
Positive View Engr (centered)	8113	-6.51	1.86	0.00	0.99
Engineering Confidence	8559	1.00	5.00	4.28	0.84
Intend to Graduate	8545	1.00	5.00	4.83	0.54
Prepared for Job	8432	1.00	5.00	3.97	0.94
Ability Comparison	8528	1.00	5.00	3.57	0.71
Discrimination					
Gender Stereotypes	8321	0.00	1.00	0.14	0.35
Professors Care (centered)	7686	-4.10	2.78	-0.00	0.99
Engr Community	8552	1.00	5.00	3.64	0.99
Help Others Succeed	8542	1.00	5.00	3.81	0.85
Singled Out b/c Gender	8224	0.00	1.00	0.08	0.28
Sexual Harassment	8485	0.00	1.00	0.03	0.17

Note: Table includes students reporting only one major.

The Engineering Workforce Commission descriptive statistics in Table 3.8 are for all schools with more than one major and at least one female enrolled in an undergraduate engineering program. This narrows the sample down to 305 schools from 351. The average proportion of female students in these 305 schools is 17 percent. A total of 37 percent of the schools are under private control, and 28 percent are schools with very high levels of research activity, as defined by the Carnegie Classifications. The average number of female faculty in an engineering college is almost ten, but it varies from zero female faculty members to 60 faculty members.

Table 3.8 Descriptive Statistics for Engineering Workforce Commission Schools

	N	**Min**	**Max**	**Mean**	**SD**
Dependent Variables					
D	305	0.12	51.60	21.12	9.68
SSD	305	0.14	52.59	24.92	9.54
A	305	0.26	6.19	3.25	1.19
Proportion female students	305	0.03	0.38	0.17	0.06
Independent Variables					
Enrollment size	304	229	50995	15640	11512
Private	304	0.00	1.00	0.37	0.48
RUVH	305	0.00	1.00	0.28	0.45
RUH	305	0.00	1.00	0.26	0.44
Has Fem Majors	305	0.00	1.00	0.71	0.45
Large City	305	0.00	1.00	0.30	0.46
Mid-size City	305	0.00	1.00	0.34	0.48
US News Top 50	305	0.00	1.00	0.16	0.37
US News Top 100	305	0.00	1.00	0.32	0.47
Number Female Faculty	294	0.00	60.00	9.71	10.11
Proportion Female Faculty	279	0.00	0.36	0.12	0.06

3.5 Methods

Each of three analysis chapters in this dissertation examines sex segregation in undergraduate engineering from a different perspective. Chapter 4 reports on sex segregation in engineering from a national level as well as examines the underlying structure of sex segregation in engineering. I move from that broad view of sex segregation to an individual level analysis of the influence of supply and demand factors in Chapter 5, utilizing multilevel modeling to account for the correlated error structure within schools. The last analysis chapter broadens the focus again by looking at the characteristics of the major to understand how, at a meso level, characteristics of the major are related to the proportion of women in those majors. The chapters build on one another to provide a broad view of the micro-, meso-, and macro-level processes influencing women's representation across engineering majors. The rest of this section describes the analytic methods used in the analysis chapters, describing why a particular method was chosen.

Chapter 4 is an exploratory analysis of sex segregation in undergraduate engineering departments. It includes calculation of multiple segregation indices for the PACE and EWC data, a discussion of the overall level of variation in sex segregation in engineering majors, and a correlation analysis of segregation indices and institutional characteristics using the national EWC data. Additionally, following the work of Charles (2003) and Charles and Grusky (2004), I utilize log-linear modeling to analyze contingency tables in a major by sex by school, three-way table. This modeling examines whether there is an underlying structure to the distribution of women by major and school (Agresti, 1990).

Chapter 5 is an analysis of factors influencing the representation of women in engineering majors. It examines the following questions: What are the differences between students in engineering majors with high levels of segregation and students in majors with low levels of segregation? How are majors different with respect to the experiences of the students within them? Data from PACE is used to compare students in majors to one another in two multilevel logistic regression analyses. First, majors are divided into quartiles based on the proportion of women in the major, and those students in the highest and lowest quartiles are compared to one another on a number of covariates suggested by theory. Next, students in eight engineering majors are compared to students in biological engineering to better understand how human capital, status beliefs and discrimination operate to influence participation these majors. All the dependent variables are dichotomous, necessitating logistic regression modeling.

Because the PACE data combine information from individuals at 21 different schools, it is necessary to make sure the analysis controls for school level variation. The nested structure of the data with students within schools means students at each of the schools are likely to respond more similarly to each other than across schools. Nested data such as PACE have a correlated error structure and multilevel modeling accommodates for this correlated error structure and minimizes the variance within schools. A likelihood ratio test indicates that there is sufficient variation between the schools to necessitate a multilevel model.

The analyses in Chapter 5 utilize multilevel logistic regression modeling which has the benefits of measuring individual level and school level predictors and variance, allowing the covariates to vary by school and including group level explanatory variables (Gelman and Hill 2007; Raudenbush and Bryk 2002). Multilevel modeling allows me to fit a model to individuals while measuring and controlling for unexplained variation at the level of the schools. I use a school group predictor and test different school level variables. Multilevel analysis allows me to include both of these things in my model which would not be possible using classical multiple regression techniques. Multilevel modeling does not require the use of reference groups for the group indicator variable because it uses the constant term to remove the collinearity that would occur in a normal multivariate regression (Gelman and Hill 2007). Multilevel modeling reduces the error terms that would exist if organizational level variables were included in a classical individual-level linear or logistic regression (Gelman and Hill 2007; Raudenbush and Bryk 2002; Snijders and Bosker 1999).

As mentioned above, multilevel modeling allows individual analysis while at the same time controlling for systematic unmeasured variation among the PACE schools. This type of modeling allows intercepts, coefficients and error terms to vary by group. Varying intercept models allow the effect for each group to start at a different level, but it assumes the slope is the same across groups. Varying slope models are one way of thinking about interaction effects in that they represent different effects of explanatory variables by the group variable. The simplest way to represent a multilevel model is in the manner usually used for individual level data:

$y = \alpha_j + \beta_j x + \epsilon$, where the subscript j indexes the schools.

Chapter 6 is an analysis of the factors at the level of the major that affect the over- or under-representation of women in engineering majors. The dependent variable is the Representation Ratio score for each of five majors represented at 13 of the 22 PACE schools. This variable, which has been logged to correct for distributional skewness, indicates the extent to which the proportion of women in a major is greater or less than the average representation of women in all of engineering at that school. The independent variables are a combination of derived (aggregated) and group level variables measured at the level of the major. The number of students in a major is heteroskedastic with the dependent variable (Representation Ratio score of the major), so this chapter utilizes a weighted least squares regression analysis to correct for non-constant residual errors. The weight I use is proportional to the log of the residuals squared of *Number of Students in Major.* I use the WLSO program in Stata 10, which allows for different types of weighting.

3.6 Summary

In my investigation of the reasons for women's uneven representation across engineering majors, I take a multi-faceted approach, using multiple sources of data and different types of analysis. Because the literature on sex segregation in organizations contains various explanations, I examine factors affecting segregation from the level of the institution in chapters 4 and 5, the level of the individual in chapter 5 and the level of the major in chapter 6. Women's under-representation in certain engineering majors has consequences not just for the women who choose not to enter or decide to leave these fields, in terms of their long-term career outcomes, but also for our society which fails to benefit from the perspective women bring to the table.

The data I use in this project support my strategy of surrounding the question from different angles. The Engineering Workforce Commission data provide an unprecedented look at sex segregation in undergraduate engineering at the national level. The PACE dataset is a unique collection of survey data matched to organization level data, focusing on engineering at a large number of institutions, and allows examination within engineering, which heretofore has not happened on this scale.

The PACE data's sampling strategy yielded the schools that were needed for the project, but it also made the PACE sample disproportionately composed of large, public, land-grant universities and universities with very high research activity. The result of this bias is analyses that are more representative of these types of schools than smaller liberal arts colleges and universities. But the PACE schools also represent 18 percent of the full-time undergraduate students enrolled in US engineering programs in 2008, which facilitates generalizability because the data represent almost 1/5 of all engineering students nationwide. The sex and race composition of the survey respondents is relatively similar to the composition of the population with only a few exceptions. At the individual level, representativeness is high, although I have calculated sampling and post-stratification weights to correct for the instances where there is deviation.

The analyses begin with a general description of the sex composition and level of segregation in undergraduate engineering majors, and proceed to provide important information on the characteristics and experiences of students in majors with high and low levels of segregation. This dissertation utilizes varied analytic methods including correlation analysis, log-linear contingency table analysis, sophisticated multilevel logistic regression modeling and weighted least squares regression models to better understand how supply and demand factors are related to high and low levels of sex segregation in engineering majors. These analytic methods help to control for the correlated error structure and heteroskedasticity in the data. The result is solid evidence regarding the uneven distribution of women across engineering majors.

Undergraduate engineering remains a male-dominated bastion within higher education, even though the undergraduate population at large contains more women than men at most schools. Putting aside the larger question of why this is the case, I dig deeper to look within engineering and ask why do certain engineering majors remain more highly segregated than other engineering majors. The data and methods described in this chapter enable me to examine these questions from a multiple viewpoints, and in the end permit a broad understanding of differences across engineering majors.

CHAPTER 4: MEASURING SEX SEGREGATION OF ENGINEERING MAJORS

4.1 Introduction

Women may comprise 57 percent of undergraduate college students nationwide, but they remain under-represented in engineering and over-represented in fields such as humanities and education (Gerber and Cheung 2008; US Department of Education 2008). Studies that aggregate engineering majors into one group mask the heterogeneity existing between the majors within these broad categories (Gerber and Cheung 2008). In order to describe that heterogeneity, which heretofore has not been done within engineering, I draw from national level engineering data and a sample of engineering colleges to examine trends in sex segregation. While it is known that engineering majors differ, on average, in the proportion of women in the major, many questions remain unanswered, including the following: Is the structure of segregation the same across institutions, or does it differ across institutions? How does the representation of women in engineering majors vary across schools? Which types of schools are the most segregated? Is there an underlying structure to sex segregation in engineering majors? And lastly, what does this analysis tell us about the influence of supply or demand factors on women's uneven representation across engineering majors and schools?

The results show large variation in the representation of women within majors and across schools. This suggests that the environments and organizational types (which are demand-side) in which students learn have an impact on women's representation. This finding also provides hope that sex segregation might not be as "sticky" as originally thought. The most segregated schools have high and very high research activity, higher numbers of female faculty, one of five majors that are relatively integrated and are ranked in the top 100 of *US News.* A school's location in a large city is associated with lower levels of sex segregation.

In addition, there is no evidence of an underlying structure to sex segregation in engineering majors.

4.2 Data and Methods

This chapter utilizes national level data provided to the University of Washington Center for Workforce Development by the Commission for Professionals in Science and Technology (CPST March 2009). CPST derived the data from the Engineering Workforce Commission's (EWC) survey of fall 2007 undergraduate engineering enrollments at all schools granting bachelor's degrees in engineering. In this data set, each school is a case, and all the engineering majors at that school report enrollment by gender. I match the EWC data to data from the Carnegie Foundation for the Advancement of Teaching to examine institutional level factors associated with sex segregation in engineering (2009).

I also use data from 21 schools participating in the Project to Assess Climate in Engineering (PACE). For confidentiality, each PACE school has been randomly assigned a school ID number which I use to identify and discuss them. The PACE data come from spring 2008 engineering enrollment numbers, by major and sex, provided to the PACE research team by each school. One school (#20) did not provide correct spring enrollment numbers so I substitute the fall 2008 enrollment numbers from the American Society for Engineering Education.

Across the 21 PACE schools, there are 38 different engineering majors. Ten of the 38 majors exist at only one PACE school, and another ten exist at a majority of PACE schools. The ten most common engineering majors are aerospace engineering, biological engineering, chemical engineering, civil engineering, computer engineering, electrical engineering, industrial engineering, material science engineering, mechanical engineering and undecided majors. I combine bioengineering, biosystems engineering and biomedical engineering into biological engineering; computer science, computer systems, and computer engineering into computer engineering. For descriptive analysis of the PACE data, I report these ten most common majors. For other analyses, I remove undecided majors, and only examine nine majors.

This chapter contains three different analyses. First, I conduct an exploratory analysis of sex segregation in engineering majors. I discuss the summary indices of sex segregation often used in the occupational sex segregation literature; I also provide some descriptive statistics on what national undergraduate engineering variation and variation in the Project to Assess Climate in Engineering data look like using each of these measures. A comparison of the national and PACE data provides a context for the data in subsequent chapters. Next, correlations of the segregation measures from the EWC data with institutional characteristics from the Carnegie classifications illuminate the relationships between sex segregation and types of institutions. Lastly, I use log-linear analysis of contingency tables to describe the structure of sex segregation across undergraduate engineering majors using PACE survey data.

4.3 Indicators of Segregation

The first step in this analysis is to calculate and report on the degree of sex segregation by undergraduate engineering major across all engineering schools. To assess the heterogeneity across engineering disciplines by sex, I focus on student enrollment as the relevant measure of the segregation of women in engineering majors. I describe and discuss the national engineering and PACE school sex segregation situation using the following measures: Proportion, Representation Ratio, Index of Dissimilarity, Size Standardized Index of Dissimilarity, and the Index of Association. Each measure provides a slightly different picture of sex segregation, and because scholars disagree on the most useful measure, this chapter looks at all five to examine sex segregation from multiple perspectives.

4.3.1 Proportion

A simple Proportion (P) can be calculated that represents the size of the population of interest with respect to the entire population. For women in engineering, I calculate this at the level of the engineering school and the level of the major. The proportion of women in each major is calculated as the number of women in major j (F_j) divided by the sum of the number of men in major j (M_j) and women in major j (F_j).

$$P_j = \frac{F_j}{(F_j + M_j)}$$

The strength of the proportion measure is its simplicity: it has an easy interpretation and simply describes the representation of women in each major relative to all men and women in the major, or, at the college level, the representation of women in engineering relative to all students in engineering. Women were 17 percent of the undergraduate engineering enrollments at the school level in fall 2007 at 351 engineering schools (Figure 4.1), and 19 percent of undergraduate engineering enrollments at the 21 PACE schools in spring 2008.

The outlier school in the EWC data with 56 percent female students is an extremely small school with one “other” major and only 16 engineering students, nine of whom are women. Examining the scatterplot in Figure 4.2 shows that the variation in the proportion of women in engineering occurs primarily at the smaller schools. The case with 56 percent female is a clear outlier.

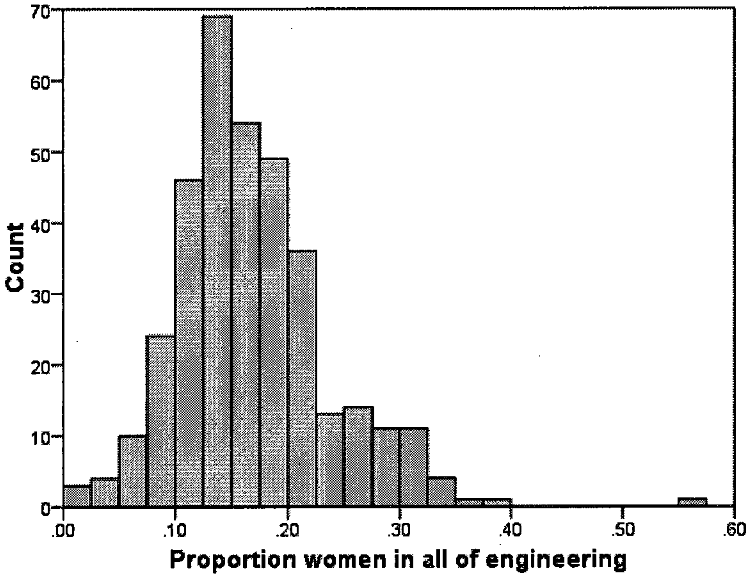


Figure 4.1 Histogram of Proportion of Women in Engineering at 351 EWC Schools

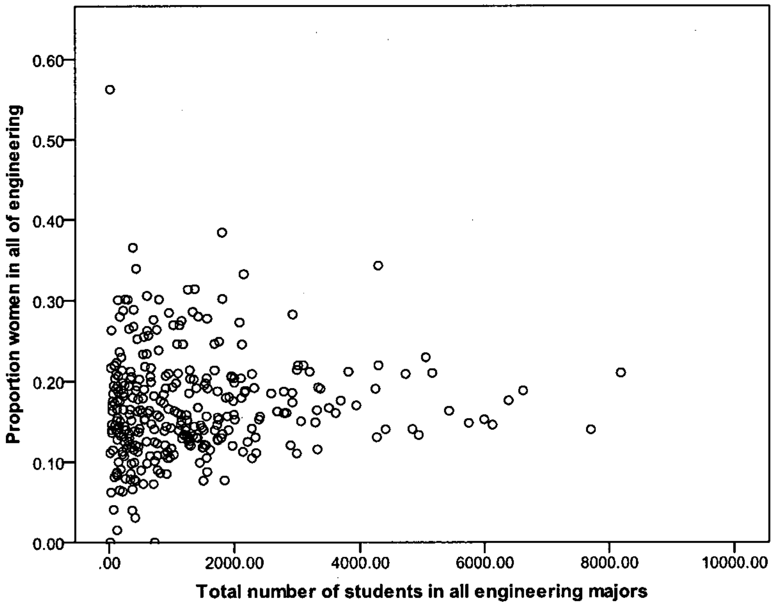


Figure 4.2 Summary Scatterplot of Size of Engineering School by Proportion Women in Engineering (EWC data)

As seen in Figure 4.3, women range from 14 to 24 percent of enrolled undergraduate engineering students at the PACE schools. Eight PACE schools have 20 percent or more women in all of their undergraduate engineering programs (Figure 4.3). Compared to the national EWC data in which women's percentage ranges from 0 to 56 percent, the PACE schools are concentrated within a smaller range and are concentrated in the middle of the national distribution.

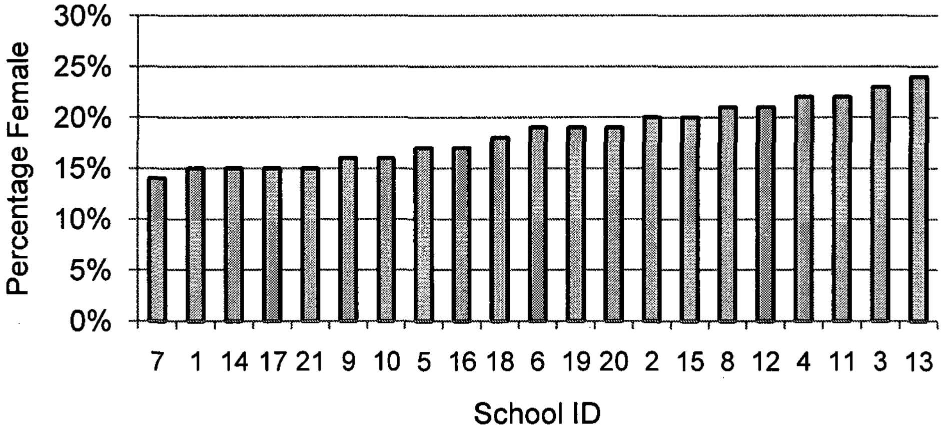


Figure 4.3 Undergraduate Engineering Population Percentage Female at PACE Schools

The proportion measure can focus at the level of the major, which is important for this exploratory analysis. The descriptive statistics of the proportion of women in each engineering major for all schools reporting to the Engineering Workforce Commission and PACE schools are in Table 4.1. In the national data, the engineering majors with the largest proportions of women, on average, are: environmental engineering (42 percent), bioengineering (38 percent), and chemical engineering (34 percent). On the other hand, mechanical (11 percent), computer (11 percent) and electrical/electronic (12 percent) engineering have the lowest proportions of females on average. Note that mechanical, computer and electrical engineering are three of the top four most common majors, with civil engineering as the fourth most common major. Each of these majors exists at 225 or more of the 351 schools that grant bachelor's degrees in engineering. Since these three common majors have the lowest female representation, the result is a low level of women in engineering at most schools across the country.

When looking at the maximum values in the national data, nine majors have at least one school with more than 50 percent female students. Looking at the minimum and maximum proportions and the standard deviation provides strong evidence that even within male-dominated majors such as computer engineering, some schools almost reach parity with about 48 percent female in undergraduate computer engineering. While some majors are well known as male-dominated bastions, there are pockets of parity within these majors. This does not imply that the proportion of women in these majors is normally distributed across schools. In fact, in certain majors, there are significant issues with skewness and kurtosis, which I discuss later.

The maximum value of the PACE proportion female in the major indicates that in no major do women constitute more than half of the population, although biological engineering and industrial engineering come close with maximum values of .47 and .46, respectively. The mean proportion of women in PACE biological engineering majors is 39 percent. Computer engineering has the smallest proportion of women enrolled with a mean of eight percent, a maximum of 19 percent and a minimum of three percent. Electrical engineering is not far behind with a mean of 11 percent.

Table 4.1 Descriptive Statistics of the Proportion of Women in Engineering Majors (EWC and PACE data)

Discipline	**N**	**Min.**	**Max.**	**Mean**	**Median**	**S.D.**
EWC Majors						
Aerospace and Related	62	0.08	0.34	0.15	0.14	0.05
Agricultural	16	0.03	0.44	0.22	0.19	0.13
Architectural	19	0.19	0.40	0.29	0.29	0.06
Bioengineering	103	0.17	0.61	0.38	0.38	0.07
Ceramics	5	0.08	0.42	0.23	0.21	0.13
Chemical	158	0.13	0.62	0.34	0.33	0.08
Civil & Construction	225	0.02	0.57	0.21	0.19	0.09
Computer	244	0.02	0.48	0.11	0.10	0.06
Electrical & Electronic	282	0.02	0.38	0.12	0.11	0.06
Engineering Management	16	0.10	0.43	0.25	0.23	0.09
Engineering Science	59	0.02	1.00	0.24	0.21	0.15
Environmental	60	0.20	0.76	0.42	0.39	0.14
General Engineering	93	0.04	1.00	0.21	0.18	0.15
Manufacturing	17	0.05	0.43	0.18	0.14	0.11
Industrial, All Other	101	0.07	0.50	0.29	0.30	0.10
Marine	15	0.04	0.22	0.14	0.13	0.05
Materials & Metallurgical	59	0.07	0.60	0.24	0.22	0.10
Mechanical	272	0.02	0.37	0.11	0.11	0.05
Mining, Mineral, Geological	19	0.05	0.39	0.17	0.16	0.09
Nuclear	17	0.09	0.42	0.18	0.15	0.09
Other	116	0.04	0.56	0.20	0.18	0.11
Petroleum & Natural Gas	16	0.09	0.28	0.15	0.15	0.05
Pre Engineering	29	0.06	0.30	0.17	0.16	0.07
Systems	19	0.03	0.46	0.21	0.21	0.13
PACE School Majors						
Aerospace	14	0.08	0.18	0.14	0.15	0.02
Biological	17	0.29	0.47	0.39	0.38	0.05
Chemical	18	0.18	0.41	0.32	0.31	0.06
Civil	20	0.11	0.31	0.22	0.24	0.06
Computer	17	0.03	0.19	0.08	0.07	0.04
Electrical	21	0.06	0.18	0.11	0.10	0.03
Industrial	15	0.24	0.46	0.32	0.30	0.07
Materials Science	11	0.20	0.38	0.28	0.26	0.06
Mechanical	21	0.06	0.23	0.13	0.13	0.04
Undecided	14	0.14	0.26	0.20	0.20	0.04

Across all majors, the minimum proportion of women is smaller for the national data than for the PACE data. Additionally, for all majors, the maximums are larger for the national data than for the PACE data. This is not unexpected given the sample size of the PACE study. However, given these differences in the minimums and maximums, I find it interesting that the means are mostly the same, within zero to three percentage point differences between the national and PACE numbers for each of the majors. This provides additional evidence that the PACE averages are representative of the larger engineering population. However, means, minimums and maximums do not tell the whole story.

In order to provide a visual representation the national distributions of the proportion of women in the nine most popular engineering majors, I provide a matrix of scatterplots (Figure 4.4). The x-axis (0.0 to 1.0) is the proportion of women in the major and the y-axis (0 to 10000) is the total number of students in the engineering college. Smaller engineering colleges show greater variation in the proportion of women in the major. Aerospace engineering, in particular, shows comparatively little variation in the proportion of women in the major. The scatterplots show that proportion of women in engineering majors is not normally distributed, exhibiting skewness, kurtosis and outliers.

In examining the outliers, an interesting trend emerges. Massachusetts Institute of Technology (MIT) accounts for outliers in four majors: aerospace, bioengineering, civil and mechanical. The remaining outliers are all from other schools; no other school has outliers in more than one major like MIT does. Only one of the outliers represents a major with a very small number of students (n=10). The other schools with outliers represent majors with more than 50 students. Clearly MIT has a different environment and perhaps even different policies and programs than some of these other schools, which contributes to their high proportion of women. I have heard others discount the success of schools like MIT by saying that “they are nothing like us--we cannot learn from them because they have more money/staffing/prestige and we do not.” However, a case study on MIT or other similar schools might help illuminate the commonalities that exist to encourage others to push for improvements.

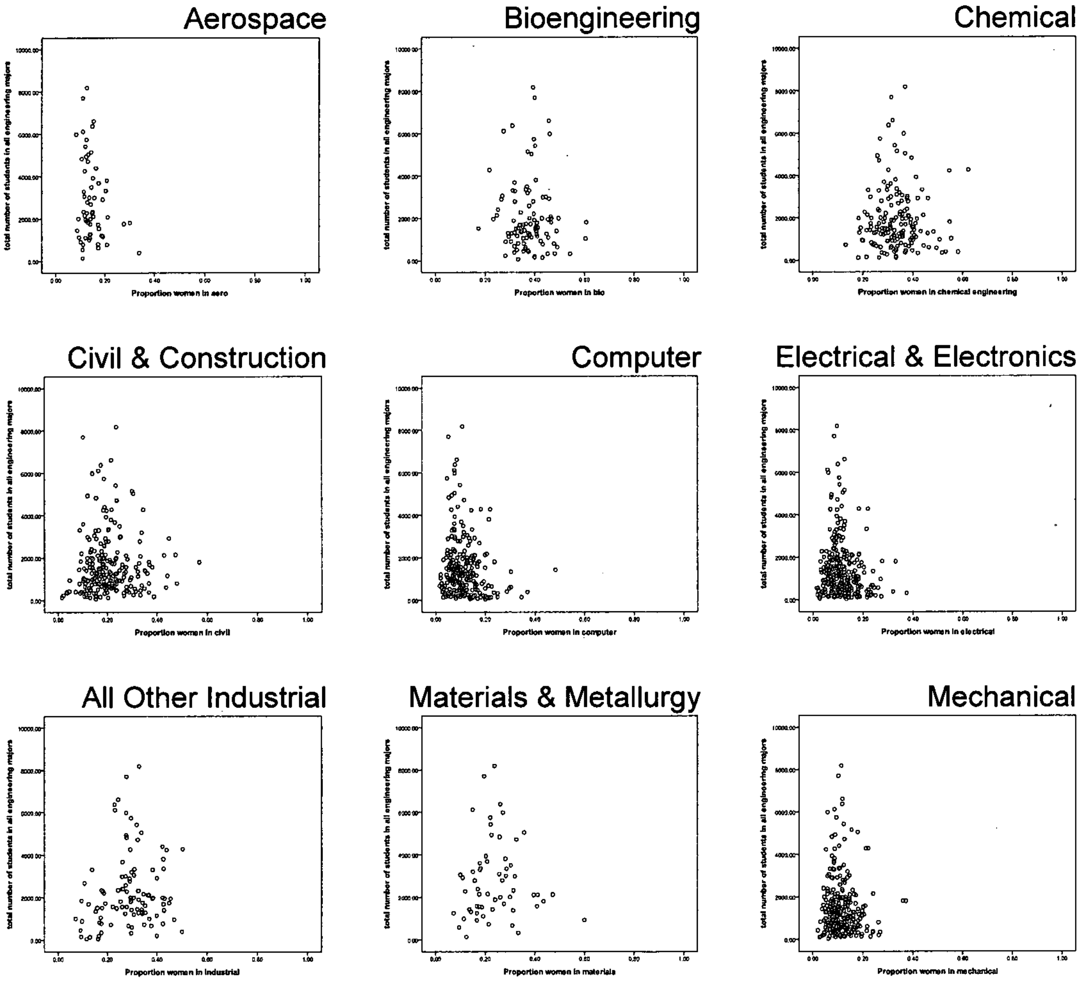
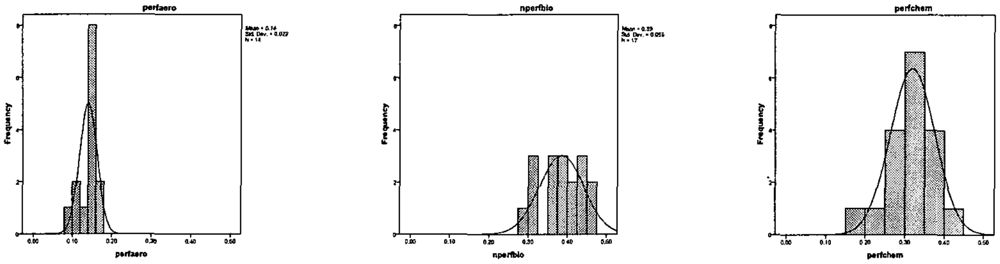


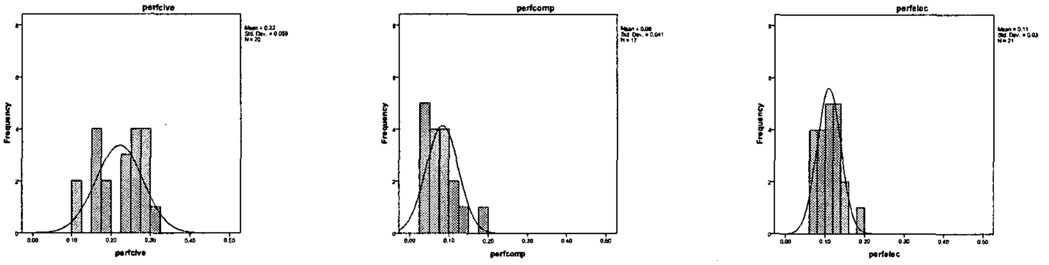
Figure 4.4 Scatterplots of Proportion Female in a Major by Size of Engineering College (EWC data)

Because of the small number of schools involved in the PACE data, scatterplots for the proportion of females in the major by size of the engineering school generally look randomly distributed. Thus, in Figure 4.5, I provide histograms of the proportion of women in each of 9 majors at PACE schools. The scales are the same for all the histograms: they begin at 0.0 and end at .50 on the X axis representing the proportion female in the major and start at 0 and end at 8 on the Y axis, which represents the frequencies.


Aerospace

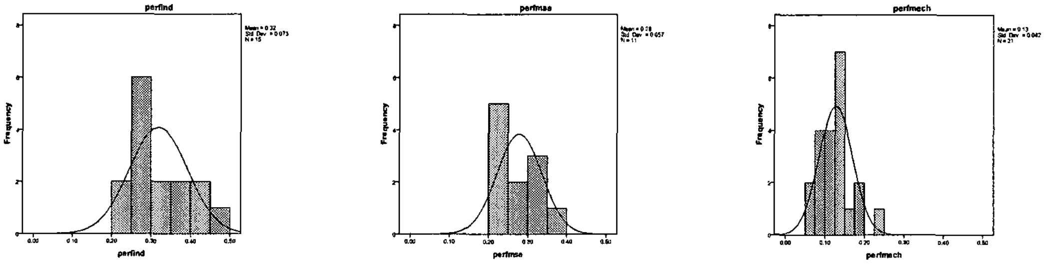
Biological

Chemical


Civil

Computer

Electrical


Industrial

Materials Science

Mechanical

Figure 4.5 Histograms of Proportion Female in Major (PACE data)

Based on an examination of the histograms and statistics on skewness and kurtosis, none of the nine most common majors at the PACE schools are normally distributed or symmetrical. A little more than half of the majors are positively (right) skewed. I expected the lack of normality, especially given the national data distributions which has much greater numbers.

4.3.2 Representation Ratio

The Representation Ratio (RR) is the second most common segregation metric used in international segregation studies (Anker 1998). The RR compares the representation of women in a particular sub-field with the representation of women in all sub-fields combined. Therefore, for the occupational segregation context, it can be interpreted as the extent to which women are over-represented or under-represented in a field relative to their participation in the labor force overall. Scholars have used this measure to describe the extent of feminization in an occupation (Queneau 2006). Like the Proportion measure, the Representation Ratio can be measured at the level of both the major and the school, with slightly different interpretations. Calculating the RR at the level of the school does not provide as much information as when it is calculated at the level of the major. At the level of the school, it only indicates how well women are represented in engineering compared to how well they are represented among all undergraduates at that school, which is not of primary interest here.

For a more enlightening measure in the context of this study, I slightly modify the RR to work in the undergraduate engineering milieu by calculating the proportion of women within a particular engineering major divided by the proportion of women in all of engineering, where

F is the number of women in all of engineering and M is the number of men in all of engineering, and all other terms are defined as above.

$$RR_j = \left(\frac{F_j}{F_j + M_j}\right) \Big/ \left(\frac{F}{F + M}\right)$$

Scores below one indicate a lower proportion of women in a particular major than in the engineering school overall (under-representation). Scores above one indicate a greater proportion of women in the major than in the engineering school overall (over-representation). See Table 4.2 for descriptive statistics of this measure.

To provide an interpretation example, a school with 23 percent women in civil engineering and 16 percent women in engineering overall would have a RR score of 1.44 indicating that there are 44 percent more female students in civil engineering than in engineering overall. Female students are over-represented in civil engineering compared to the entire engineering college. Similar to the proportion measure, strengths of this measure include its simplicity and ease of interpretation.

Interestingly, only seven of the 24 EWC majors, on average, have lower representation of women in their major than in engineering overall (RR<1). As seen by the minimum and maximum values, aggregating the RR into an average obscures the dispersion that exists across schools. As with the proportion measure, an analysis of the minimum and maximum values provides more detail. Each of the 24 majors in the EWC data has at least one school with a greater proportion of women in the major than the proportion of women in all of engineering. At all schools with architectural and ceramic engineering, women comprise a greater proportion in each of those majors than they do in engineering overall, as indicated by the minimum and maximum RR above 1.0. These two majors, though, are not highly represented at engineering schools nationwide.

Table 4.2 Descriptive Statistics for Representation Ratio (EWC and PACE Data)

Discipline	N	Min.	Max.	Mean	Median	S.D.
EWC Majors						
Aerospace and Related	62	0.53	1.39	0.83	0.79	0.18
Agricultural	16	0.21	2.48	1.32	1.23	0.67
Architectural	19	1.02	2.51	1.70	1.69	0.40
Bioengineering	103	0.89	4.40	2.12	2.03	0.63
Ceramics	5	1.00	2.45	1.42	1.08	0.62
Chemical	158	0.71	3.43	1.88	1.81	0.48
Computer	244	0.08	3.72	0.70	0.64	0.35
Civil & Construction	225	0.16	1.89	1.19	1.16	0.28
Electrical & Electronic	282	0.11	2.00	0.70	0.67	0.27
Engineering Science	59	0.11	4.94	1.20	1.02	0.76
Environmental	60	0.93	4.51	2.35	2.29	0.69
General Engineering	93	0.29	5.75	1.23	1.03	0.74
Engineering Management	16	0.84	3.73	1.36	1.11	0.72
Manufacturing	17	0.35	2.54	1.10	1.00	0.60
All Other Industrial	101	0.51	3.28	1.80	1.85	0.59
Marine	15	0.59	1.57	1.02	1.00	0.21
Materials & Metallurgical	59	0.39	7.01	1.37	1.27	0.87
Mechanical	272	0.23	1.47	0.69	0.67	0.20
Mining & Mineral & Geological	19	0.48	2.06	1.06	0.96	0.46
Nuclear	17	0.42	2.17	0.99	0.86	0.47
Other	116	0.31	3.77	1.09	0.96	0.51
Petroleum & Natural Gas	16	0.46	1.47	0.88	0.89	0.25
Pre Engineering	29	0.38	1.36	0.95	1.00	0.22
Systems	19	0.20	1.70	1.00	1.06	0.44
PACE School Majors						
Aerospace	14	0.63	1.14	0.76	0.75	0.14
Biological	17	1.55	3.16	2.14	2.11	0.43
Chemical	18	1.11	2.31	1.77	1.72	0.29
Civil	20	0.71	1.57	1.20	1.22	0.24
Computer	17	0.17	0.89	0.45	0.42	0.20
Electrical	21	0.33	0.88	0.59	0.54	0.14
Industrial	15	1.27	2.21	1.77	1.71	0.34
Material Science	11	1.35	1.83	1.55	1.47	0.18
Mechanical	21	0.40	1.44	0.68	0.68	0.21
Undecided	14	0.84	1.43	1.06	1.02	0.16

As with the proportion measure, the values of the Representation Ratio, in both the EWC or PACE data, are not normally distributed; most exhibit positive (right) skewness. Most of the distributions also have heavier than normal concentrations in the tails, as indicated by a positive kurtosis value (graphs available from the author).

The Representation Ratio statistics indicate that women are consistently over-represented across all PACE schools in biological engineering, chemical engineering, industrial engineering, and materials science engineering (minimum and maximum values both above 1.0). Additionally, the minimum and maximum numbers indicate significant variation in women's representation across the PACE schools in aerospace engineering, civil engineering, and mechanical engineering. The only majors in which women are consistently under-represented are computer engineering and electrical engineering.

In comparing the mean Representation Ratio values for PACE and national data, alignment exists between the values because if one is above or below 1.0, the other is also above or below 1.0. For the Representation Ratio means, the differences between the PACE and national EWC data vary from .01 to .25. The majors with the biggest gaps are computer engineering (.25 point gap), materials science engineering (-.17 point gap), chemical engineering (.11 point gap) and electrical engineering (.11 point gap).

4.3.3 Index of Dissimilarity

The Index of Dissimilarity (D) was created by Duncan and Duncan (1955) and is the most commonly used measure of segregation, utilized primarily in the measurement of workforce sex segregation (Anker 1998). This measure implicitly weights large fields more than it weights small fields. That is, large engineering majors are more influential on D than small engineering majors, regardless of their levels of segregation. Additionally, D does not change when the proportions of women in the entire population change. While ubiquitous in sex segregation studies, D has been criticized for being margin dependent because it varies based on the sizes of the groups, such as undergraduate engineering majors in this case (Charles and Grusky 1995). In addition, Weeden (2004) found that D was problematic for looking at changes in occupational segregation over time (see also Frehill 2006).

Scholars continue to use D, however, partly for comparability purposes across studies and time periods and partly because it has a simple interpretation (Anker 1998; Jacobs 1993). D can vary from 0 to 1 (or 0 to 100), and higher values indicate greater sex segregation. In the most common interpretation modified for the engineering context, D describes the proportion (or percentage) of women who would have to trade engineering majors with a man to have the sex ratio in each major equal the sex ratio in the entire engineering school. However, even if women and/or men switched majors to the degree prescribed by the D value, women would still be under-represented across all engineering majors. D is measured at the level of the engineering school, not at the level of the major as with the Proportion and Representation Ratio measures.

The definition of D that follows is the same as that used in most sex segregation studies but adapted for the educational context:

$$D = \sum_{j=1}^{J} \left| \left(\frac{F_j}{F}\right) - \left(\frac{M_j}{M}\right) \right| \times 100 \times \frac{1}{2}$$

where *J* refers to the total number of majors, F_j and M_j refer to the number of women and men in the *j*th major, and F and M refer to the number of women and men in engineering at each school (all majors combined).

Of the 351 schools that grant bachelor's degrees in engineering, 305 have more than one major and at least one woman, enabling calculation of D and other segregation indices. The Index of Dissimilarity is based on different numbers of majors at different schools. In the PACE data, one school has 15 majors used to calculate D, while another has just three majors that are used for D. The rest of the schools are somewhere in between those values. On average at the PACE schools, D is calculated with about 11 majors. The EWC data used for calculation of the segregation indices include schools with a minimum of 2 to a maximum of 17 majors. On average at the EWC schools, D is calculated with about 7 majors. For these 305 schools, the mean D score on a 0-100 scale is 21.12, meaning that 21 percent of women and men would have to switch majors in order for the sex distribution to be the same across majors. The minimum D is .12, maximum is 51.60 and the standard deviation of D is 9.68. Figure 4.6 maps the distribution of D scores for the 305 applicable schools.

Clearly, there is wide variation in the sex segregation levels among engineering schools as measured by D. In the EWC data, 21 percent of the women in engineering majors would have to trade places with men in other majors to result in a sex distribution equal to that in engineering overall. The Index of Dissimilarity is fairly normally distributed. The EWC data distribution has a very slight positive skew (skewness = .15) and slightly heavy tails (kurtosis = .14), which are fairly small and not a big concern. A skewness value of zero indicates a completely symmetrical distribution, and a kurtosis value of 0 indicates normality in the concentration of cases in the tails of the distribution.

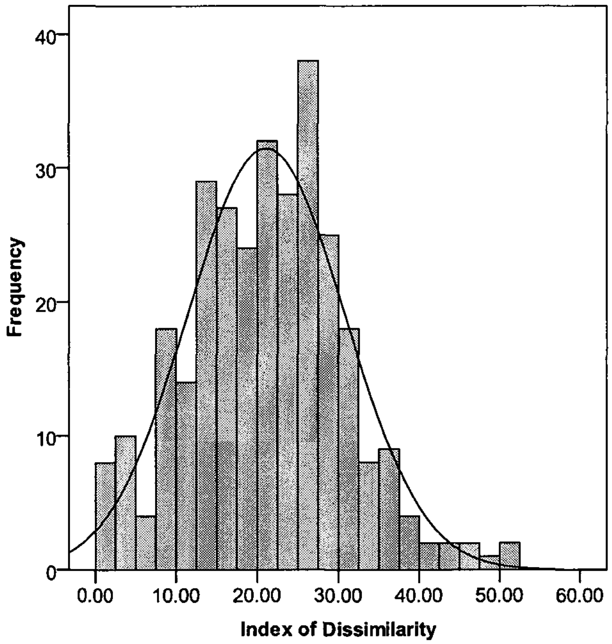


Figure 4.6 Histogram of Index of Dissimilarity at 305 EWC schools

The PACE data tells a similar story. On average 24 percent of the women in engineering majors would have to change majors with men, indicating that the PACE schools are slightly more sex segregated, as measured by the Index of Dissimilarity. The minimum D value is 12.29 and the maximum is 35.68; the distribution has a standard deviation of 6.54. The PACE data distribution of D is basically symmetrical (skewness =.05), but has very light tails, as indicated by a negative kurtosis value of -.73.

4.3.4 Size Standardized Index of Dissimilarity

A variation on D is called the Size Standardized Index of Dissimilarity (SSD). This measure has the same interpretation as D, but it treats all majors as if they were the same size, thus solving D's margin dependence. This means that small majors have just as much influence on the overall segregation numbers as large majors (England and Li 2006), and changes in the number of students in particular majors will not affect the value of SSD. However, SSD is margin dependent in a different way from D in that its value changes depending on the gender composition of students in engineering overall.

SSD is defined by the following equation, where all terms are as defined before:

$$SSD = \sum_{j=1}^{J} \left\| \left[\left(\frac{F_j}{M_j + F_j} \right) \div \sum_{j=1}^{J} \left(\frac{F_j}{M_j + F_j} \right) \right] - \left[\left(\frac{M_j}{M_j + F_j} \right) \div \sum_{j=1}^{J} \left(\frac{M_j}{M_j + F_j} \right) \right] \right\| \times 100 \times \frac{1}{2}$$

Again, 305 Engineering Workforce Commission schools have more than one engineering major and at least one woman and thus are included in SSD. At these schools, the mean value of SSD is 24.92, meaning that about 25 percent of women and men would have to switch majors to have an equal distribution by sex across majors. The minimum SSD is .14, maximum is 52.59, and the standard deviation is 9.54. Figure 4.7 shows that the distribution of SSD for the 305 schools demonstrates positive kurtosis (.29) indicating a greater concentration of cases in the tails of the distribution, and a slight negative skew (skewness = -.29).

For comparison purposes, Table 4.3 compares the percentiles for D and SSD from the national data. The mean and median shifted higher for SSD from D, indicating a slight increase in the mid-point of the distribution, which is apparent when comparing the histograms (Figures 4.6 and 4.7).

The mean value of SSD in the PACE data is 28.12. The SSD minimum is 18.61, the maximum is 37.10 and the standard deviation is 5.70. Similar to the national sample, in the PACE data, the mean value for SSD is a few percentage points higher than the Index of

Dissimilarity mean. The distribution of SSD exhibits slight positive skew (skewness =.18) and strong negative kurtosis (kurtosis = -1.24) which indicates a light concentration of cases in the tails of the distribution.

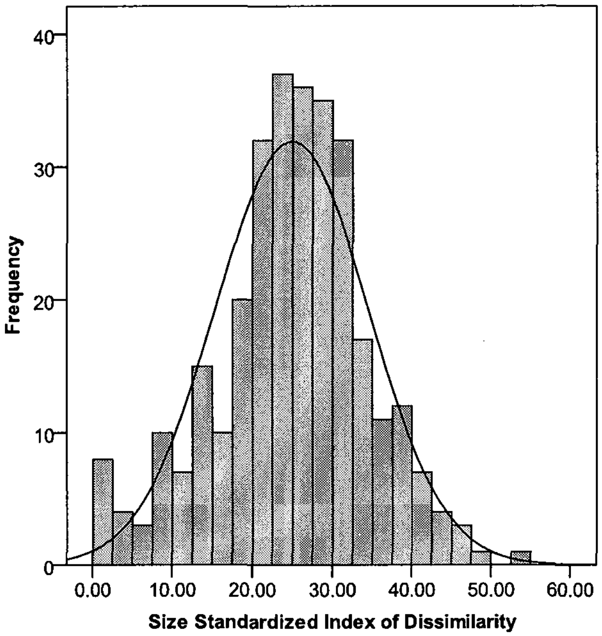


Figure 4.7 Histogram of Size Standardized Index of Dissimilarity at 305 EWC schools

Table 4.3 Comparison of Values on Index of Dissimilarity and Size Standardized Index of Dissimilarity (EWC data)

Percentiles	D	SSD
10	8.55	12.17
20	13.09	18.04
25	14.16	19.82
30	15.83	21.13
40	18.57	23.54
50	21.43	25.90
60	23.71	27.70
70	26.43	29.33
75	27.23	30.54
80	28.17	32.18
90	32.52	37.24

4.3.5 Index of Association

As a result of their dissatisfaction with the conventional modeling of sex segregation, Grusky and Charles (1998) created the Index of Association (A) to be invariant to the changes in the proportions in the overall population, and weight all fields equally. The margin-free measure fixes the margin dependencies of D and SSD, instead of trading one type of margin dependency for another. The Index of Association is measured at the level of the engineering school like D and SSD. This index results in a one number summary score, even though Grusky and Charles describe that as a weakness of D and SSD and the measurement of segregation overall (1998).

The computation of A can be problematic when there are empty cells in the contingency table, requiring substitutions of small numbers and therefore producing somewhat inaccurate segregation estimates (Frehill 2006; Watts 1998). This is not a problem with D because empty cells do not require number substitutions, resulting in more reliable data. Another weakness of A is that there is no ready interpretation for the value generated by the calculations (Watts 1998). A is defined by the following equation, where all terms are as defined before.

$$A = \left(\frac{1}{J} \times \sum_{j=1}^{J} \left\{ \ln\left(\frac{F_j}{M_j}\right) - \left[\frac{1}{J} \times \sum_{j=1}^{J} \ln\left(\frac{F_j}{M_j}\right) \right] \right\}^2 \right)^{\frac{1}{2}}$$

The mean value of A across the 305 EWC schools is 3.25 with a standard deviation of 1.19. The minimum value is .26 and a maximum value is 6.19. Figure 4.8 shows the distribution of A across EWC cases (skewness = -.10), which is more normal than SSD and slightly more normal than D. The EWC data distribution of A exhibits a negative kurtosis (-.55) indicating a lightness in the tails of the distribution.

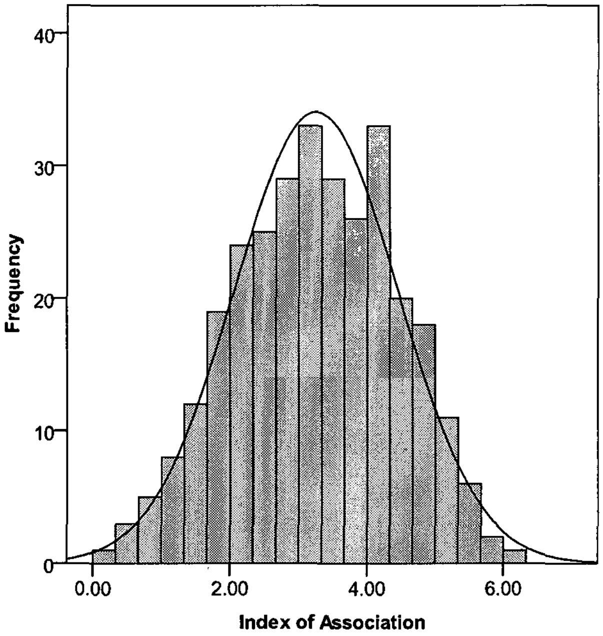


Figure 4.8 Histogram of Index of Association at 305 EWC schools

The mean value of A in the PACE data is 4.1 with a standard deviation of 1.05. The minimum and maximum values are 1.92 and 5.99, respectively. The PACE data displays an almost symmetrical A distribution (skewness = .09), and some negative kurtosis (-.29) indicating lightness in the tails.

Using each of the three segregation indices as the measures of interest, the PACE schools have higher levels of segregation than the national data does (Table 4.4). Women's engineering representation in the PACE schools, as measured by the proportion of women in engineering, is slightly higher than in the national data.

Table 4.4 Comparison of Mean Values of Standard Segregation Measures

Data Source	D	SSD	A	Proportion Female
PACE	24.3	28.1	4.1	.19
EWC	21.1	24.9	3.3	.17

There are large gaps in values for some of the PACE schools in their D and SSD values. For example, schools 7, 15 and 16 each have a difference in value of more than ten percentage points (Table 4.5).

Table 4.5 Standard Sex Segregation Measures for 21 PACE Schools

School Code	D	SSD	A	Proportion Female
1	32.71	36.16	5.24	0.15
2	33.60	33.62	4.45	0.20
3	19.98	25.39	4.09	0.23
4	33.70	35.91	3.33	0.22
5	26.33	21.11	4.13	0.17
6	28.34	29.48	3.83	0.19
7	14.31	25.57	5.99	0.14
8	12.29	18.61	2.73	0.21
9	20.60	21.65	1.92	0.16
10	29.72	31.76	5.55	0.16
11	26.68	36.11	3.69	0.22
12	25.77	23.19	3.54	0.21
13	26.67	24.74	3.55	0.24
14	18.57	25.25	5.61	0.15
15	23.42	37.10	3.10	0.20
16	16.91	28.10	3.73	0.17
17	35.68	33.68	4.14	0.15
18	17.92	22.16	5.05	0.18
19	22.15	23.22	3.74	0.19
20	22.01	30.12	3.86	0.19
21	22.90	27.89	5.62	0.15

The trends drastically differ between A and the two versions of the index of dissimilarity. In fact, of the four schools with the lowest values on A, two are also among the schools with the four lowest levels of segregation on SSD or D (School 8 and 9). Only one school overlaps between A, SSD and D's lowest segregation score schools: School 8. No overlap occurs between the highest scores for A and either D or SSD. D and SSD overlap on schools 1 and 4 which are in the top four highest scores for both indices.

Figure 4.9 shows the information from Table 4.5 in a graphical format. This makes seeing the variation across schools easier. On each of these measures, D and SSD track each other fairly well with a few exceptions, while the values of A do not seem to differ very much by school when viewed on this scale. However, when viewed on its own scale, the Index of Association shows the same sort of variation seen with the D and SSD values (Figure 4.10).

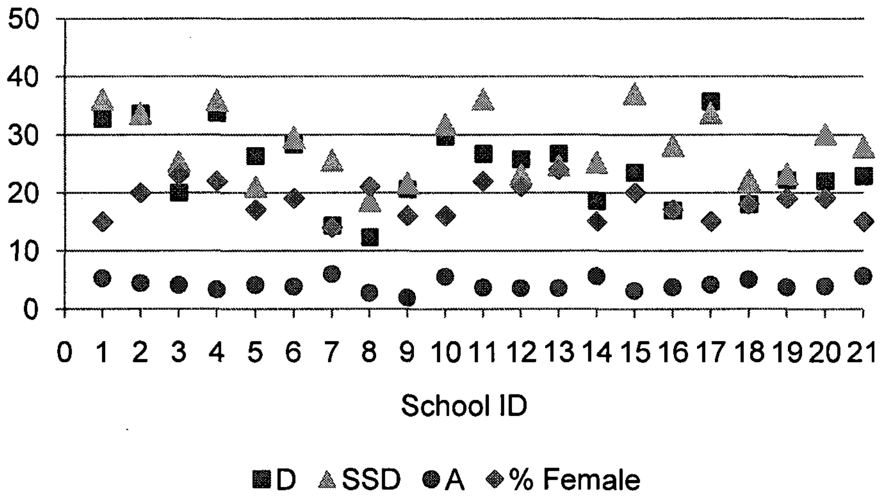


Figure 4.9 Scatterplot of Segregation Indices (PACE data)

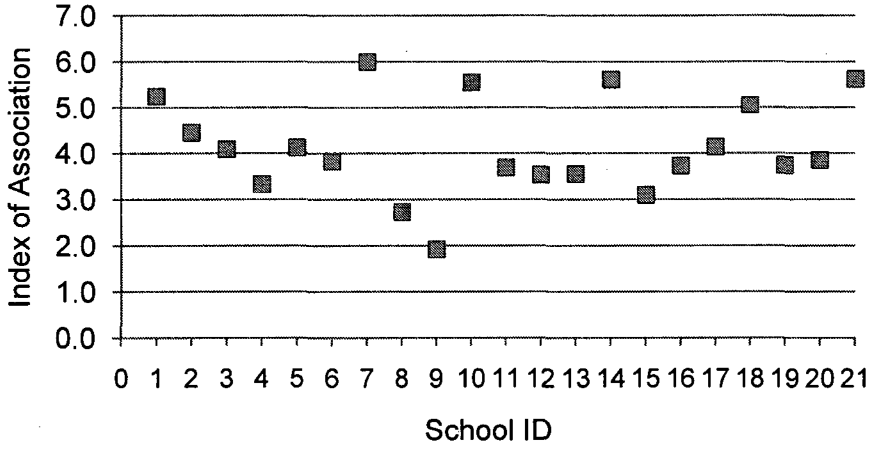


Figure 4.10 Scatterplot of Index of Association Values (PACE data)

Another way of looking at the relationships between the segregation indices is with correlations. Table 4.6 shows the Pearson correlations between each of the four college level segregation measures. There are high levels of association between D and SSD as well as between A and the Proportion Female. The relationship between D and SSD is positive so that when D increases, so does SSD. But the relationship between A and the Proportion Female is negative: when A increases, the proportion of women in engineering decreases. The proportion of women in engineering is not significantly associated with levels of segregation, as measured by D and SSD.

Table 4.6 Pearson Correlations of Segregation Indices (PACE Data, 21 Schools)

	D	SSD	A
D			
SSD	0.672 ***		
A	0.026	0.126	
Proportion Female	0.056	0.012	-0.578 **

***p<=0.001, **p<=0.01, *p<=0.05, +p<=0.10

4.4 Institutional Correlates of Sex Segregation

Because this chapter takes a broad view of sex segregation in engineering, to try to understand what macro level factors affect levels of sex segregation, I next analyze the bivariate relationships between institutional characteristics and sex segregation values. The national level data linked with Carnegie Classification data provides an unprecedented opportunity to gain a better understanding of sex segregation in engineering, particularly with respect to demand-side factors.

To assess the extent to which characteristics of institutions, such as enrollment size, research orientation and representation of female faculty, relate to levels of segregation, I perform Pearson correlations of four measures of segregation. Each measure of segregation is at the level of the engineering school, with 11 covariates taken from the Carnegie Classification and the American Society for Engineering Education data archives (Carnegie Foundation 2009, ASEE 2008). Descriptive statistics for these variables are in Table 4.7. I only include schools with more than one major and at least one woman in these analyses.

Eight of the institutional characteristics are dichotomous. *Private* is coded one if the school is under private control. Two of the newer Carnegie Classifications, *RUVH* (research university-very high research activity) and *RUH* (research university- high research activity) are each coded one if the school is in that category. *Has Fem Majors* is coded one if the school has at least one of five majors that on average have greater than or equal to 25 percent female students (architectural, bio-engineering, chemical, industrial, and environmental). *Large City* is coded one if the school is classified by the Carnegie Foundation as located in a large city. *Mid-size City* is coded one if the school is classified by the Carnegie Foundation as located in a mid-size city. *US News Top 50* and *US News Top 100* are each coded one if the engineering college is ranked in the top 50 or top 100, respectively, by the *US News & World Report* (2009).

Table 4.7 Descriptive Statistics for Engineering Workforce Commission Schools

	N	**Min**	**Max**	**Mean**	**SD**
Dependent Variables					
D	305	.12	51.60	21.12	9.68
SSD	305	.14	52.59	24.92	9.54
A	305	.26	6.19	3.25	1.19
Proportion female students	305	.03	0.38	0.17	0.06
Independent Variables					
Enrollment size	304	229	50995	15640	11512
Private	304	0	1.00	0.37	0.48
RUVH	305	0	1.00	0.28	0.45
RUH	305	0	1.00	0.26	0.44
Has Fem Majors	305	0	1.00	0.71	0.45
Large City	305	0	1.00	0.30	0.46
Mid-size City	305	0	1.00	0.34	0.48
US News Top 50	305	0	1.00	0.16	0.37
US News Top 100	305	0	1.00	0.32	0.47
Number Female Faculty	294	0	60.00	9.71	10.11
Proportion Female Faculty	279	0	0.36	0.12	0.06

Enrollment Size of the entire university, *Number Female Faculty* in engineering and *Proportion Female Faculty* in engineering are interval level variables. Enrollment size utilizes Carnegie Classification fall 2005 enrollment numbers for all levels of the university. The two female faculty variables contain only tenured and tenure-track engineering faculty from the ASEE data archives.

While differences in statistical significance exist across the segregation indices, six of the eleven variables have relationships with at least three of the segregation measures (Table 4.8). Schools with both very high research activity and high research activity are associated with higher levels of segregation as measured by D and A. Very high research activity universities are also associated with higher proportions of female undergraduates in the engineering school, while high research activity universities are also associated with higher segregation as measured by SSD.

Table 4.8 Pearson Correlations of Institutional Characteristics with Segregation Measures

	D	SSD	A	Proportion
Enrollment Size (N=304)	0.087	0.064	0.370 ***	0.039
Private (N=304)	0.031	0.027	-0.364 ***	0.309 ***
RUVH (N=305)	0.128 *	0.091	0.174 **	0.356 ***
RUH (N=305)	0.137 *	0.141 *	0.170 **	-0.057
Has Fem Majors (N=305)	0.371 ***	0.439 ***	0.370 ***	0.280 ***
Large City (N=305)	-0.062	-0.121 *	-0.168 **	0.156 **
Mid-size City (N=305)	0.106 +	0.082	0.085	-0.029
US News Top 50 (N=305)	0.042	-0.004	0.085	0.398 ***
US News Top 100 (N=305)	0.196 ***	0.137 *	0.251 ***	0.344 ***
Number Female Faculty (N=294)	0.183 **	0.192 ***	0.343 ***	0.275 ***
Proportion Female Fac. (N=279)	0.103 +	0.085	-0.033	0.106 +

***p<=0.001, **p<=0.01, *p<=0.05, +p<=0.10, two-tailed tests.

As expected, if a school has one of five majors that have the highest representation of women (*Has Fem Majors),* there is a fairly strong positive relationship with the segregation index measures, and is also positively associated with the proportion female in engineering. Being located in a large city is associated with lower levels of segregation as measured by

SSD and A; it is also associated with a greater proportion of females in engineering. Being in a top 100 *US News* ranked engineering school is associated with higher segregation levels (D, SSD and A) and a higher proportion of female engineering undergraduates.

The number of female engineering faculty at a school is also significantly related to segregation. Greater numbers of female faculty in engineering are associated with higher levels of segregation on all three segregation indices and greater proportions of female undergraduates in engineering. It is possible that the number of female faculty is endogenous—that is, while the number of female faculty is assumed to affect the proportion of female students, it is also possible that the proportion of female students affects the number of female faculty, in that the major or college brings in more female faculty to increase the number of female students.

Five variables have fewer than three significant relationships with the segregation measures: *Enrollment Size, Private, Mid-size City, US News Top 50* and *Proportion Female Faculty.* Large schools are associated with higher levels of segregation but only on the Index of Association measure. Privately controlled schools are associated with lower levels of segregation as measured by the Index of Association and higher proportions of female undergraduates in engineering. The association between schools located in mid-size cities and levels of segregation is marginally significant only for the Index of Dissimilarity. Schools ranked in the top 50 of *US News* are associated with higher proportions of female undergraduates in engineering. Lastly, the proportion of female faculty at a school is marginally related to D and the proportion of female undergraduates, but the relationship is weak at R=.10, p=.08 and R=.11, p=.08, respectively.

4.5 Outcomes of Segregation Indices Analysis

In general, common indices used for modeling or estimating sex segregation suffer from issues of marginal dependence. The most widely used, the Index of Dissimilarity (D) (Duncan and Duncan 1955) is sensitive to variability in the relative sizes of majors. The Size Standardized Index of Dissimilarity is margin dependent in that it is sensitive to changes in the gender composition of students in engineering. Based on the analysis above comparing index values, the trends for the national and PACE data are very similar for each index.

A newer index, called the Index of Association (A) is not margin dependent (Charles and Grusky 2004). Examining the trends for A indicate that it provides a different picture of segregation than the D and SSD indices. Frehill (2006) found reporting D, A, and the Representation Ratio as a set of indicators useful for providing a well-rounded picture of occupational sex segregation. In addition, England and Li (2006) reported values of D, SSD and A with regard to the sex segregation of baccalaureate degrees in the United States. Because SSD and D follow each other so closely and D is reported more often than SSD in the segregation literature, continuing to report D remains important, even with its flaws, for comparability with other research in the sex segregation field. In addition, because the results of A were different from D and SSD, reporting A is important as well.

For the purposes of the subsequent chapters, the Representation Ratio and Proportion allow for measurement at the level of the major, which is essential for answering what individual and institutional characteristics are related to women's representation in certain majors. Chapter 5 uses the proportion of women in the major to divide students into majors with the highest and lowest female representation. Chapter 6 uses the natural log of the

Representation Ratio in an analysis of the meso-level characteristics impacting women's over- or under-representation in an engineering major.

If there had been very little variation across schools on these segregation measures, this might imply that supply-side factors could be at work, such as pre-college experience or a student's self-confidence. If that were the case, segregation levels would be "set" long before students get to college as a result of supply-side factors. Demand-side institutional factors would then be of little use for decreasing segregation. However, the significant difference in segregation across schools implicates institutional conditions or demand-side factors as an important cause of undergraduate engineering sex segregation. This suggests that segregation in engineering is not as "sticky" as one might think. Changing climate/culture, policies and programs is easier than going back in time to provide additional training or different socialization.

4.6 Structure of Sex Segregation in Engineering Majors

Occupational sex segregation is complex, such that characterizing it only by its amount and not measuring it in a more complex way has hampered research and understanding of this type of social stratification (Charles and Grusky 2004). As I have already shown in this chapter, there is variation in segregation by degree, but whether the structure of segregation across institutions varies remains unclear. This analysis shows the complexity of segregation in undergraduate engineering majors, rather than boiling segregation down to one parameter.

Describing segregation using multiple indicators is useful, but to really understand the structure of segregation in undergraduate engineering, a different type of institutional analysis is needed. Horizontal segregation and vertical segregation characterize the structure of occupational segregation (Grusky and Charles 1998). Horizontal segregation is the disproportionate distribution of women into certain types of occupations, such as manual and non-manual labor, and is upheld by an ideology of gender essentialism (Charles and Grusky 2004). Vertical segregation is upheld through the ideology of male primacy, and describes how women and men are separated into different fields based on a ranking of fields, so that males fill the more lucrative, prestigious fields (Charles and Grusky 2004).

In higher education, horizontal segregation is defined as the separation of women and men into different, non-ranked fields. Vertical segregation in higher education is often defined as differences in the amount of education one receives (e.g. BA, MA, PhD) (Charles and Bradley 2009). Thinking about what horizontal and vertical segregation mean within a field such as engineering provides some opportunities to think broadly about what gender essentialism and male primacy mean for the distribution of women and men across engineering majors. Given that horizontal segregation is based on an ideology of gender essentialism, it remains unclear whether all engineering fields are considered more appropriate for men, or whether some fields are designated as appropriate for women. In engineering, male primacy would mean men are more likely to be in fields providing greater remuneration and prestige, resulting in vertical segregation. Understanding these two types of segregation is important for two reasons. First, because vertical segregation has been more responsive to social pressures, greater understanding of it could result in faster improvements in women's representation in particular majors (Charles and Grusky 2004). Second, other authors suggest that horizontal segregation should be examined carefully since access to higher education (vertical segregation) for women and men has reached parity (Gerber and Cheung 2008).

Because there are no current measures for the gender appropriateness of particular engineering majors, horizontal segregation for engineering undergraduates measures segregation among unranked disciplines. Vertical segregation measures the segregation among ranked disciplines, since these types of measures do exist. Following Charles and Grusky (2004), I assess the fit of six different underlying sex segregation structures (margin-invariant to margin-varying forms) using log-linear analysis. The data for this analysis come from the PACE student level survey data. I include students who report only one major to bypass the noise of double or triple major students, who most likely are different types of students than those with only one major. The valid N for this analysis is 7600, removing missing cases list-wise.

To assess the structure of segregation, I use log-linear analysis, a type of analysis for multi-way contingency tables. Log-linear analysis allows the researcher to determine whether there is a simple underlying structure of association across the variables of interest, by comparing the observed cell counts to those that would be expected (Long 1997). It uses the counts in each cell as the dependent variable, with the assumption that all observations are independent. All factors involved in this type of analysis must be categorical. I examine the distributions of frequencies across three factors: Sex, Major, and School. Sex is coded one if the respondent is male, zero if the respondent is female. Major has nine categories, one for each of the most common majors from the survey. School has 21 categories for each of the 21 schools eligible for this analysis. This results in a 378 cell table.

To test a model of vertical segregation that includes a variable with the nine majors categorized into two larger categories, I calculate three different grouping variables and test the effect of each one. I rank engineering disciplines by prestige, starting salary after graduation, and critical mass of women (Davies and Guppy 1997). Prestige scores and starting salary are fairly straightforward in terms of the reason for their inclusion. I include a variable for the critical mass of women in a field, since prior research has indicated that the prestige and salary of the field decrease as women enter a field in large numbers (Reskin and Roos 1990). *Critical Mass* is coded one if the major has a national average of 30 percent or more women. Biological, chemical and industrial engineering are coded one. *Prestige* is coded one for the majors with occupational prestige scores at 68 or above (Nakao and Treas 1990) and zero for engineering fields with occupational prestige scores below 67. The most prestigious engineering fields are: chemical, computer science, aerospace, and civil engineering. Biological engineering was not an occupational field at the time these prestige scores were calculated, so it is coded zero to group with the lower prestige fields, as a conservative estimate. *Valued* is based on starting salaries for bachelor's degrees in different engineering fields and is coded one if the average starting salary for a student with a bachelor's degree from Spring 2009 was above $58,000 (NACE 2009). The average salary values for biological engineering and materials science engineering are based on n's of 4 and 11, respectively, indicating low reliability in the measurement of starting salary for these majors. The highest paid engineering fields are biological, chemical, computer, mechanical and industrial engineering.

Log-linear analysis is appropriate when the question of interest focuses on the associations between variables rather than the effect of one variable on another (Agresti and Finlay 1997). I use a Poisson distribution, weighted data and add interactions to allow certain frequencies to be more likely to show up than is expected if they were independent. SPSS produces maximum likelihood estimates of parameters by means of the Newton-Raphson algorithm (Haberman 1988).

As indicated in Table 4.9, the likelihood ratio and the associated p-values indicate that none of the models fit the data well. The saturated model (not shown), as expected, fits the data perfectly. Sex, college and area of study are not independent. While no likelihood ratio statistics indicate a good model fit with a non-significant p-value, the smallest log likelihood and a subsequent examination of the observed by expected residual plot (Figure 4.11) indicates that the universal association model (Model 4) fits the data second best to the saturated model.

Table 4.9 Log-Linear Sex Segregation Models

Model	**L^2**	**p**	**df**
0. Conditional Independence (C+A+S)	18882	0.000	348
1. Complete Similarity (C + A*S)	16252	0.000	340
2. Demand-Side Similarity (S*C + A*S)	15164	0.000	320
3. Supply-Side Similarity (A*C + A*S)	1608	0.000	180
4. Universal Association (S*C + A*C + A*S)	757	0.000	160
5. Multilevel model (S*C+A*C+A*S+G*S*C)	50152 to 67009	0.000	496

Notes: S=Sex, C=College/University, A=Detailed area of study/major, G=Grouped major

Model 4 of universal association indicates that there is no conditional independence, and that each pair of variables is associated while controlling for the third variable. That is, while controlling for the appropriate third variable, associations exist between sex and college, area of study and college, and area of study and sex. Interestingly, adding in a ranking variable in Model 5 (*Critical Mass, Prestige* or *Valued*) results in a worse fit than the universal association model. The likelihood ratios for the ranking models are: *Critical Mass* L^2=50152, *Prestige* L^2=64256 and *Valued* L^2=67009, each with 496 degrees of freedom in a 756 cell table.

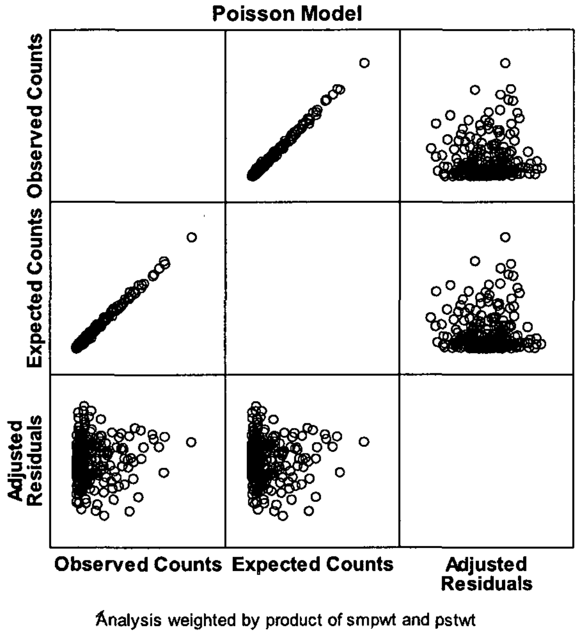


Figure 4.11 Plot of Adjusted Residuals and Expected by Observed Counts for Model of Universal Association.

Based on this analysis, vertical sex segregation (the segregation of students into majors based on ranking of those majors) is not at work in undergraduate engineering majors. The ranking variables (prestige of the major, critical mass and starting salary after graduation) show no association with the other variables. A different formulation of these ranking variables could possibly lead to a different conclusion. The log-linear analysis shows that the relationships between sex, college and major are complex, and there is no simple underlying structure to the data.

4.7 Conclusion

The disproportionate distribution of women and men across engineering majors is relevant for a couple of reasons. First, in the context of a discipline where women are already under-represented in general, understanding whether the popularity of certain majors with women holds across schools can lead to a better understanding of sex segregation. The extent to which sex segregation in engineering majors is "sticky" has implications for whether one can expect to see future decreases. The results show that sex segregation in engineering can vary widely across schools, suggesting that organizational factors play an important role in drawing women to certain majors.

Second, having evidence of the heterogeneity existing within engineering in terms of women's representation can lead to important consequences for future practices in engineering. For example, in the past a chair of a chemical engineering department might have thought that female students are drawn to chemical engineering to the same extent at all engineering schools. But the data I provide shows clearly that there is a significant amount of variation at schools across the country in the proportion of women in chemical engineering. Now that chair will know to assess their performance in terms of women's representation with regard to other chemical engineering departments. In addition, because the correlation analysis showed that certain organizational characteristics are associated, at least at the bivariate level, with measures of women's representation, that chair can obtain data on similar types of schools and be able to rank their department within that category.

The descriptive exploratory analysis indicates that nationally there is significant variation in the representation of women across engineering majors. While common knowledge holds that certain majors have greater or lesser female representation, I provide new information on how much the representation of women differs within majors and across schools. The Proportion and Representation Ratio measures clearly show that even within majors that are traditionally considered highly male oriented--such as mechanical engineering--some schools have greater than 30 percent female undergraduates, resulting in a critical mass. While no majors have reached parity at a national level, as defined by an average of 50 percent female students, there are "pockets of parity" within majors at certain schools. Certain schools are more successful at attracting women to their majors, which has implications for improvements in women's representation across the board in engineering.

The disproportionate representation of women across majors is a defining feature of undergraduate engineering. This chapter shows that important variations occur across engineering colleges and majors. Similar to studies of occupational sex segregation in which important variations are obscured when we examine occupations and ignore job-level segregation, examining the detail at the level of the major and not just the college remains necessary.

One observable fact in the occupational segregation literature is the distribution of women into less prestigious and less well-paying jobs and occupations. I examine the extent to which a similar phenomenon of vertical segregation might be happening in engineering majors. The log-linear analysis with status/ranking variables suggests that these factors are not at play in engineering. The main issue in engineering majors remains horizontal segregation. However, an analysis with different status or ranking variable formulations might provide a different perspective on vertical segregation in undergraduate engineering majors. Future research should examine whether some other ranking system results in vertical segregation in engineering.

The Pearson correlation analysis concludes that higher sex segregation is associated with very high and high levels of research activity, ranking in the top 100 of *US News*, having at least one major with greater than 25 percent female students and greater numbers of female faculty. As a bivariate correlation analysis, this is an extremely broad view, and other variables may moderate the relationship between an organizational characteristic and the level of segregation. This broad view does, however, provide some sense of the conditions under which sex segregation is sustained. Many of the organizational characteristics above are not ones that can be changed, or that someone would want to change, as in the case of a top 100 *US News* ranking.

The index calculations, which measure segregation at the level of the college, result in the majority of the cases grouping around the mean. The Index of Dissimilarity and the Size-Standardized Index of Dissimilarity track each other fairly well with only a few deviations and are significantly associated with one another. Comparisons of the PACE data with the national EWC data using the five different segregation measures indicate that the means are fairly similar but the minimum and maximum values show greater deviations. As expected, the national data's larger standard deviations indicate a wider spread of cases over the possible values. Compared to the national data, the PACE data slightly over-estimate the values of D, SSD, A, and proportion female.

No simple underlying sex segregation structure exists in undergraduate engineering majors, as evidenced by the log-linear analysis. The only model that fits the data is the saturated model. A student's sex, major and the school they attend inter-relate completely. This is not a complete surprise given the amount of variation seen in the proportion female within majors and across schools. The implication of this finding is that context matters.

Overall, I find that the environment in which students learn and study is important for channeling them into certain fields, as indicated by the variation across colleges and majors. This variation is also important because while women are, on average, under-represented in engineering, certain engineering majors at certain schools are more successful at recruiting a gender diverse student body. Improvements are possible, and future research should examine these successful departments in detail. Never before has this level of detail within the engineering discipline been analyzed with regard to sex; this dissertation contributes to the *literature with ground-breaking data analysis of heretofore unanalyzed data*. While this chapter has shown that demand-side factors are clearly important for women's representation, the analysis in this chapter does not rule out the importance of supply-side factors. This chapter provides an important step forward in our understanding of the impact of supply and demand factors on women's representation in engineering.

CHAPTER 5: ANALYSIS OF FACTORS INFLUENCING SEX SEGREGATION AND ALTERNATIVE EXPLANATIONS OF MAJOR CHOICE

5.1 Introduction

In Chapter 4, I showed that the vast under-representation of women in engineering majors may be amenable to change because of the wide variations of female representation in majors across schools. The organizational context matters. But supply-side factors may still play an important role in women's representation in engineering majors. The enduring inequality in engineering provides a firm background from which I examine the differences between majors. Again, I take a roundabout approach; multiple angles on the question help me converge on an understanding of how supply-side factors are associated with women's representation in certain majors.

This chapter describes the individual and institutional factors affecting the sorting of undergraduate engineering students into majors with high and low levels of female representation and into particular engineering majors. It focuses on both supply and demand factors while controlling for school level variation. As described in Chapter 4, significant variation exists across majors and colleges in terms of sex segregation. This chapter examines how these individual-level effects occur in the context of institutional level effects, by using a multilevel analysis. Research questions guiding this chapter include: Are students in the most segregated majors significantly different than students in the least segregated engineering majors? Do certain factors differentially impact men and women's location in a highly segregated major? Are there effects of being in a particular major that are separate from effects of being in a major with high or low levels of sex segregation?

This chapter focuses on differences between students in engineering departments with high levels of sex segregation and departments with low levels of sex segregation. In an attempt to disentangle the relationship between a particular major and its level of segregation, I perform three analyses. Using data from the Project Assess Climate in Engineering (PACE), I examine the factors that influence participation in engineering majors with varying levels of sex segregation. First, I use t-tests and chi-square analysis to explore the bivariate relationships between human capital, status belief and hostile climate variables and a student being in a major with a certain level of segregation. In a multilevel logistic regression framework, I then examine the impact of these theoretical perspectives on a student's choice of major in the highest or lowest quartile of percent female in the major. Lastly, I continue to utilize the multilevel logistic model, but attempt to understand the association between supply and demand factors and a student's choice of a particular engineering major, compared to a biological engineering major.

Drawing on the literature regarding occupational sex segregation and educational gender gaps, I focus on three main theoretical orientations within the framework of supply and demand to explain the importance of each for a student's choice of a major. Human capital, status beliefs and discrimination perspectives focus the analysis. No research has looked within the field of engineering to assess the relative differences among nine engineering subfields and the students within. These analyses provide important insight into the push and pull factors that impact the major choice of male and female engineering students.

Results indicate mixed support for human capital and status beliefs, and more support for the demand side discrimination and hostile climate perspectives. In addition, less variation is explained by the modeling of proportion women in the major than by the modeling of student location in a particular major, indicating that the defining characteristic of a particular engineering major is not the proportion of women in that major. More than two-thirds of the variation in the proportion female in the major analysis is at the school level; this is true for all students and male students. The female-only analysis indicates that only 30 percent of the total variation is attributable to the variation between schools, suggesting that school level characteristics are less important for women's choice of major than other individual, interactional or environmental characteristics.

5.2 Perspectives on Differences between Engineering Departments

Very little research exists on the differences between fields of engineering, specifically with regard to how the proportion of women in each of these fields might impact the experiences of students and to how student characteristics are related to choices to specialize in particular majors with particular proportions of women. One study examined this topic in limited way, by comparing two majors where women are under-represented (mechanical and electrical/computer engineering) to two majors where women are better represented (chemical engineering and civil/environmental engineering). They found that there were few differences between women in different engineering majors with the exception that women in the most under-represented majors had higher levels of engineering self-confidence than women in the comparison group of chemical and civil/environmental engineering, which the authors interpreted as women choosing majors in which they felt they had strengths (Hartman, Hartman and Kadlowec 2007).

Research suggests that women's educational experiences differ considerably from those of men, even when they attend the same institutions and the same classes (Hall and Sandler 1982; Pascarella et al. 1997; Whitt et al. 1999). This dissertation uses three explanations to try to understand if and how educational experiences differ not just by gender, but also by the student's choice of major.

5.2.1 Implications of Human Capital

Human capital theory provides one explanation for the differential representation of women in certain engineering majors. As described in Chapter 2, human capital theory predicts that women choose certain fields to minimize the depreciation of their skills, and that those fields are most likely to be female-dominated fields that enable easy exit and re-entry to the labor force. This could be extended to college majors such that women would choose majors that do not require high start-up costs, and will enable them to maintain their skills and salary level through stop-outs from the labor force. According to human capital theory, women might also be less likely to invest in knowledge and skills that will not retain their value during stop-outs from the labor force, or they might be less likely to be given opportunities to improve their skills.

In the context of choosing engineering majors, human capital theory would predict that students with engineering experience prior to college already have an increased investment in their skills which would translate to their choice of a more "technical" and perhaps male-dominated engineering major because skill maintenance would be higher.

5.2.2 Implications of Status Beliefs

As discussed in Chapter 2, status is an important factor affecting social inequalities (Ridgeway and Erickson 2000; Weber 1968). Status value beliefs are often associated with sex or race and related to a general perception of a person's competence (Ridgeway 1991; Ridgeway and Erickson 2000). Status beliefs about gender, science, math and occupations are continually created in everyday interactions from childhood (Eccles et al. 1999; Frome and Eccles 1998; Jacobs and Eccles 1985). This process of socialization to certain beliefs has been shown to have important impacts on resulting career choices and aspirations (Correll 2001, 2004). Status beliefs are created and can be spread and diffused through interactions with others.

As a result of this perspective, I include measures of status beliefs surrounding how well women and families fit into engineering and of how positively engineers in general are perceived. Because status beliefs can be internalized (Correll 2001), I include measures of self-efficacy in terms of preparedness for a job, engineering self-confidence and an ability comparison. I expect women in highly segregated majors to have lower expectations of work/family balance than women in less segregated majors. In addition, this theory suggests that higher self-confidence and self-efficacy are associated with male-dominated majors in engineering.

5.2.3 Implications of Discrimination and Hostile Climate

Discrimination perspectives assert that students are pushed away from certain fields as a result of the behavior (either overt or passive in the case of policies, etc.) of other people or organizations. In my operationalization of discrimination, factors such as stereotyping, hostile climate and overt harassment combine to make students feel unwelcome or uncomfortable, resulting in differential distributions of students across majors.

The students in the analyses come from schools that have one-tiered admission processes. This means they admit students into engineering directly from high school or the schools provide an engineering advisor during the first year to connect the students to the engineering community. This basically eliminates statistical discrimination concerns about students being admitted to a university and then being excluded from an engineering major because of the second admission process into the major. Because actual exclusion from a major is unlikely within this sample I also include measures of experiences that might turn someone away from a major, such as hearing stereotypes, receiving poor treatment from professors or peers and harassment.

One qualification regarding discrimination is that students in the survey are those who are currently in a major and the analysis does not account for students who already left a major or plan to leave their current major. The measures of discrimination should therefore be considered only to reflect the current situation of students in a major. To some degree, this conceptualization assumes that female students hear about the hostility in a major through the grapevine, although the effect of this is unmeasured and unknown.

5.2.4 Hypotheses

Based on the literature and theory discussed above, I assert the following hypotheses related to supply- and demand-side factors:

(H0): There is no difference between students in majors with high and low female representation.

(H1): Compared to students in majors with the highest female representation, students in majors with low female representation will report a greater likelihood of having taken an engineering course before college, higher GPAs, less positive expectations about the flexibility of engineering careers, higher self confidence and more positive comparisons of own ability.

(H2): Compared to students in majors with the highest female representation, students in majors with low female representation will report more experiences with stereotypes and hostile climate.

5.3 Understanding the Impact of Sex Segregation at Different Levels

Not controlling for other factors, I perform an initial bivariate analysis that compares students in majors in the top 25 percent of female representation to students in majors in the bottom 25 percent of female representation. I then compare students in these two groups using multilevel multivariate logistic regression. By doing a third analysis focused on the choice of a biological engineering major as compared to other majors, I disentangle the effect of being in a major with either high or low sex segregation from the effect of being in a particular major compared to other majors. In Chapter 4, it became clear that majors differ across schools with regard to their level of sex segregation. This makes it important to examine whether the effects are specific to certain majors or specific to certain amounts of female representation.

5.3.1 Sample

The individual is the unit of analysis. Only students who report having one major and who report one of the nine highly represented majors are included in this analysis. The nine highly represented majors are aerospace engineering, biological engineering, chemical engineering, civil engineering, computer engineering, electrical engineering, industrial engineering, materials science engineering and mechanical engineering. Each student is assigned a value for the proportion of women in their major at their particular school.

For the bivariate and first multilevel logistic regression analysis, the values of the proportion of women in the major are divided into quartiles, and only the top and bottom quartile are examined. The majors in the lowest quartile in terms of representation of women are aerospace engineering (student n=69), civil engineering (n=125), computer engineering (n=287), electrical engineering (n=868) and mechanical engineering (n=865). The majors in the highest quartile in terms of female student representation are also not surprising. They include biological engineering (n=740), chemical engineering (n=736), civil engineering (n=100), industrial engineering (n=312), and materials science engineering (n=84). Note that civil engineering is included in both the highest quartile and the lowest quartile because there is such large variation across civil engineering departments. Not all students in each of the above majors are included in these analyses—only those with scores in the highest or lowest quartile are included. By looking at only the top and bottom quartiles in terms of the proportion of women in the major, I can easily see the differences between these two groups. This transformation of the dependent variable results in a loss of cases but it makes the differences between these two groups very apparent.

For the second multilevel logistic regression, the individual N and the group N for each analysis is slightly different depending which schools could contribute data. For example, school ten does not have aerospace engineering, but they do have biological engineering, so they cannot be included in the analysis of aerospace to biological engineerng because they would have no variation on the dependent variable. I include the number of schools and the total number of students that contribute to each analysis in the multilevel logistic regression tables. The number of schools in each analysis varies from 12 to 17 schools and the number of students varies from 432 to 1739 students.

5.3.2 Measures

I operationalize sex segregation for the first multilevel analysis as a student's location in a major that is in the top or bottom 25 percent of female representation measured by the proportion of women in a particular major. This is useful because it measures at the level of the individual rather than the level of the college, and it enables me to concentrate on the effect being in a major with an extremely low proportion of women rather than the effect of being in a particular major such as biological engineering, as these two things are not always the same. As shown in Chapter 4, the proportion of women in a major can vary across schools, such that at some schools the proportion of women in mechanical engineering is .06 while at other schools the proportion of women in that major is .23. Because the proportion of women in a major at different schools varies significantly, this suggests that the proportion of women in the major measures something different than simply knowing what major someone is in.

Table 5.1 provides the means and standard deviations for the variables employed in the analyses.

The dependent variable for the first multilevel logistic analysis is a dichotomous variable reflecting "success" as a student being in a major in the highest quartile of proportion female compared to "failure" as location in a major in the lowest quartile of proportion female. The outcome variable in multilevel models must always be at the lowest level of the model (Snijders and Bosker 1999). In this analysis, the individual is the lowest level; both of the dependent variables are at the level of the individual, as is required by multilevel analysis.

Table 5.1 Descriptive Statistics for Variables in the Analysis (PACE)

Dependent and Independent Variables	**N**	**Min**	**Max**	**Mean**	**SD**
Dependent Variables					
Highest Quartile Proportion Female	4099	0.00	1.00	0.48	0.50
Aerospace/Biological Engineering	1030	0.00	1.00	0.40	0.49
Chemical/Biological Engineering	1678	0.00	1.00	0.56	0.50
Civil/Biological Engineering	1533	0.00	1.00	0.60	0.49
Computer/Biological Engineering	830	0.00	1.00	0.35	0.48
Electrical/Biological Engineering	2020	0.00	1.00	0.63	0.48
Industrial/Biological Engineering	930	0.00	1.00	0.46	0.50
Materials Science/Biological Engr.	628	0.00	1.00	0.32	0.47
Mechanical/ Biological Engineering	2372	0.00	1.00	0.69	0.46
Controls					
Female	8456	0.00	1.00	0.44	0.50
African American	8605	0.00	1.00	0.04	0.19
Hispanic American	8605	0.00	1.00	0.12	0.33
Human Capital					
GPA (centered)	8114	-2.24	1.19	0.01	0.50
Engr Prior	8526	0.00	1.00	0.15	0.36
Status Beliefs					
Family Friendly (centered)	8113	-3.54	3.19	0.00	0.99
Positive View Engr (centered)	8113	-6.51	1.86	0.00	0.99
Engr Lack of Confidence	8559	0.00	1.00	0.13	0.34
Intend to Graduate	8545	0.00	1.00	0.88	0.32
Prepared for Job- Disagree	8432	0.00	1.00	0.08	0.28
Prepared for Job-Neutral	8432	0.00	1.00	0.15	0.35
Prepared for Job-Somewhat agree	8432	0.00	1.00	0.47	0.50
Ability Comparison- Below average	8528	0.00	1.00	0.05	0.22
Ability Comparison- Average	8528	0.00	1.00	0.40	0.49
Ability Comparison-Above average	8528	0.00	1.00	0.48	0.50
Discrimination					
Gender Stereotypes	8321	0.00	1.00	0.14	0.35
Professors Care (centered)	7686	-4.11	2.78	-0.01	0.99
Engr Community	8605	0.00	1.00	0.60	0.49
Always Help Others Succeed	8542	0.00	1.00	0.21	0.41
Singled out	8224	0.00	1.00	0.08	0.28
Sexual Harassment	8485	0.00	1.00	0.03	0.17
Carnegie Classification: RUVH	8605	0.00	1.00	0.72	0.45

For the second multilevel logistic analysis, I use eight different binary dependent variables to model a student's location in a particular major as compared to a reference category. The reference category is the major with the highest average percentage of women: biological engineering. Other reference categories were tested and this comparison was most instructive for the findings.

Female is coded one if the respondent is female. *African American* and *Hispanic American* are each coded one if the respondent indicated membership in those racial/ethnic categories. Human capital variables include two measures of competence and experience. *GPA* is the student's self-reported college grade point average which has been centered so the mean is zero. *Prior Engr Experience* is coded one if the respondent reported that they had taken any engineering courses prior to beginning college. *Prior Engr Experience* is the only educational background measure I have available and while it does not fully compensate for the lack of high school GPA or college entrance exam test scores, combining it with current GPA gives a good sense of the capabilities of students. In addition, because engineering is not a subject normally taught in high school, those students who have prior experience with it are likely to be a special group, and this variable captures that information in a way that a background variable like SAT score could not.

Status beliefs theory encompasses issues of socialization and self-confidence/self-efficacy. I create two factor variables to measure different aspects of socialization. Using principal components factor analysis with varimax rotation, I create *Family Friendly* and *Positive View Engr*, which I then center around the grand mean. Higher scores indicate a greater sense of engineering's family friendliness in terms of the extent to which a respondent believes that engineers can leave and come back to their careers more easily than can people in other professions, the extent to which a respondent agrees that engineering is a field that supports people who want to have children and continue working, the extent to which a respondent agrees that engineers can design their own work schedules, and the extent to which a respondent agrees that engineering is a field that supports a balance between work and family life (four survey items). *Positive View Engr* measures the extent to which a respondent agrees that society values the work engineers do, that engineers are well paid, and that engineering is an occupation that is respected by other people (three survey items).

Also in the status beliefs section, a measure of *Engineering Lack of Confidence* is coded one if the respondent indicated that they "strongly disagree", "somewhat disagree" or were "neutral" regarding their confidence in their ability to succeed in their college engineering courses. *Intend to Graduate* is transformed from a five point scale into a dichotomous variable; it is coded one if the respondent "strongly agrees" that they intend to complete their engineering degree, and zero for all other responses.

Prepared for Job and *Ability Comparison* are transformed from five point scales into four indicator variables. For *Prepared for Job,* "strongly disagree" and "somewhat disagree" are combined into one "disagree" category, "neutral" is the second category, "somewhat agree" is the third category and "strongly agree" is the reference (omitted) category. *Prepared for Job* is the extent to which the respondent disagrees or agrees that their engineering coursework will prepare them for an engineering job. *Ability Comparison* measures how a student sees themselves compared to their peers in terms of their engineering abilities. This measure is coded into four indicator variables: "below average", "average", "above average", and the reference (omitted) category "far above average".

Discrimination includes measures of stereotyping, passive and overt discrimination. *Gender Stereotypes* is coded one if the respondent indicated that they have heard engineering faculty express stereotypes about men and women. A factor variable called *Professors Care* is centered around the grand mean and is created with principal components factor analysis with varimax rotation. *Professors Care* factor has an eigenvalue of 6.108 and loads most highly on the following five survey questions: professors care whether you learn the course material, professors encourage you to think creatively, professors write helpful comments on the material you turn in, professors inspire you to study engineering and professors take your suggestions seriously. Other measures of passive discrimination include those related to hostile environment, such as whether students feel like they are part of an engineering community and whether engineering students help each other succeed in class. *Engineering Community* is coded one if the respondent indicated that they "usually" or "all the time" feel like part of an engineering community. *Always Help Others Succeed* is transformed from a five point scale into a dichotomous variable; those who said students "always" help each other succeed are coded one. *Singled out* is coded one if the respondent indicated that they had been unfairly singled out in class because of their gender. Lastly, *Sexual Harassment* is coded one if the student indicated that they had been sexually harassed by an engineering faculty member or engineering student.

Multiple organizational characteristics were examined in the multilevel analyses. I tested school level measures including the RUVH Carnegie Classification (Research University-Very High), prestige of the engineering college as measured by *US News* ranking, percentage of female undergraduate students in engineering and the proportion of tenured or tenure-track female faculty in engineering. These characteristics are measured at the level of the school, not at the level of the major. Only the RUVH Carnegie Classification variable is included in the final models.

5.3.3 Method

I utilize a multi-stage process to understand the differences between students in highly segregated majors and those in the least segregated majors.

First, I use an independent samples t-test and chi-square cross-tabulation analysis to compare the two groups on the questions of interest. A t-test requires a quantitative, interval level response variable and a two-category explanatory variable. T-tests assume that the observations are independent, the quantitative variable has a normal population distribution, and the observations are a random sample. However, t-tests are robust to departures from the normal population distribution assumption, and by the central limit theorem any random sample size greater than 30 has a sampling distribution of the mean that is approximately normal (Agresti and Finlay 1997). If t-test variances are unequal, I report Levene's test statistic. A chi-square test requires two categorical variables, each with two or more categories. There are no normality assumptions, but it requires large samples with more than 5 expected frequencies in each cell. I first examine the bivariate relationships among all students, then, I replicate the bivariate analysis with a female-only and a male-only sample to determine whether the initial findings are relevant for each gender. This is done to determine the extent to which men and women have different experiences in majors with different levels of segregation, while also examining how the environment might be different for all students, depending on the levels of segregation.

The second step is to conduct a multivariate multilevel logistic regression analysis of individuals nested within schools using the variables from the bivariate analysis to understand how the effect of certain variables can disappear or appear after controlling for other covariates. Multilevel modeling enables me to examine patterns of association both between and within schools. Nested data have a correlated error structure, and multilevel modeling accommodates for this correlated error structure and minimizes the variance within schools. This type of analysis enables understanding of both individual effects within school contexts as well as the impact of the school. The dependent variable for the first multilevel model is a student's location in a major in the highest quartile for proportion female in major or the lowest quartile for proportion female in major. I utilize a logistic regression which is appropriate for binary dependent variables. Logistic regression enables the calculation of odds ratios which are easy to interpret and indicate the odds of a "success": the success is always the category coded one rather than zero. Linear regression is not appropriate for this type of analysis because the distribution of the dependent variable violates assumptions of Ordinary Least Squares (OLS) regression. The multilevel logistic regression is performed three times: for all students, for women only and for men only. Level one, or the lowest level of the multilevel analysis is the individual and level two is the school.

The third step is to use a different two-level multilevel model with individuals nested within schools. Because the outcome variable must be at the lowest level, I model the odds a student is in a particular major compared to a reference major as the dependent variable. To assist in the interpretation of the models, I create eight new binary variables that are each compared to the same reference category. The reference category is biological engineering because it has the highest percentage of women undergraduates and is often used in informal conversations as the de facto comparison. Thus, I model the choice of a student to be in aerospace engineering as compared to biological engineering, and so on for chemical, civil, computer, electrical, industrial, materials science and mechanical engineering. A separate multilevel logistic regression is performed for each of the eight majors compared to biological engineering (BIOE).

I use Stata 10 to perform the multilevel analyses using the command xtmelogit. Stata 10 does not allow weighting in the xtmelogit command. Raudenbush and Bryk (2002, pg 267) recommend using only one level two variable for every 10 groups in the data, although they indicate that this rule may be too liberal. I use the deviance statistic and the Bayesian Information Criterion (BIC) to measure improvement in model fit from the empty model, and for each block of variables (Raftery 1995).

While a multilevel multinomial regression would be more efficient for the analysis of the choice of major, estimation and interpretation would be more difficult. For this reason I use a multilevel logistic regression which is less efficient, but is easier to estimate and interpret.

5.4 Results

The results show some support for each of the theoretical perspectives described above. Looking at women's under-representation using different dependent variables affords a better understanding of the processes and mechanisms supporting under-representation. To begin, I report the means of the independent variables for each category of the dependent variable used in the bivariate analysis and first multilevel model (Table 5.2).

Without doing any statistical significance tests, the variables that seem to be most different between the two groups are prior engineering experience and engineering community.

Students in majors in the lowest quartile of proportion women in the major have higher levels of prior engineering experience (19 percent compared to nine percent). Engineering community works the opposite direction. Students in majors with the highest proportion of women report a greater sense of engineering community (63 percent compared to 53 percent).

Table 5.2 Descriptive Statistics by Quartile of Proportion Women in Major

	Lowest Quartile Proportion Women		Highest Quartile Proportion Women	
	Mean	**SD**	**Mean**	**SD**
Interval				
GPA (centered)	-0.01	0.49	0.08	0.49
Family Friendly (centered)	-0.01	0.98	0.05	1.01
Positive View Engr (centered)	-0.03	0.99	-0.04	1.02
Professors Care (centered)	-0.10	1.02	0.03	0.98
Dichotomous				
Prior Engr Experience	0.19	0.39	0.09	0.29
Engr Lack of Confidence	0.12	0.33	0.15	0.36
Intend to Graduate	0.89	0.31	0.86	0.35
Prepared for Job- Disagree	0.10	0.30	0.08	0.27
Prepared for Job-Neutral	0.16	0.37	0.14	0.35
Prepared for Job-Somewhat Agree	0.47	0.50	0.47	0.50
Ability Comparison- Below Average	0.05	0.22	0.05	0.22
Ability Comparison- Average	0.38	0.48	0.40	0.49
Ability Comparison-Above Average	0.49	0.50	0.48	0.50
Gender Stereotypes	0.13	0.33	0.14	0.35
Engr Community	0.53	0.50	0.63	0.48
Always Help Others Succeed	0.19	0.39	0.21	0.41
Singled Out	0.06	0.23	0.09	0.29
Sexual Harassment	0.02	0.14	0.03	0.18

5.4.1 Bivariate analysis of highest and lowest quartiles

The bivariate comparison of students in the most sex segregated majors with students in the least sex segregated majors results in statistically significant relationships (Table 5.3). Among human capital variables, both GPA and prior engineering experience are associated with a student's choice of a major with a very high proportion of women or a very low proportion of women. This association persists after gender is held constant. Specifically, compared to students in the lowest quartile of proportion of women, students in majors with the highest proportion of female students have higher GPA's. Students in majors with the lowest proportion of students are more likely to have had an engineering course prior to college, compared to the reference category.

Under the status belief variables, perceived family friendliness, a positive view of engineering, a lack of engineering confidence, intention to graduate and the relative ability comparison show some association with the proportion of women in a major. For all students, being in a major in the highest quartile of female representation is associated with less confidence and a weaker intent to graduate. Among women only, those in the majors in the highest quartile are more likely to indicate a greater perception of the family friendliness of engineering. Among men only, those in the majors in the highest quartile of female representation are more likely than male students in the lowest quartile to perceive engineering to be family-friendly. In addition, men in the majors in the highest quartile have a less positive view of the impact engineering has on society, a weaker intent to graduate and are less likely to indicate that they consider themselves average amongst their peers, relative to students who say they are far above average.

Table 5.3. T-test and Chi-square Analysis between Students in Majors with the Highest Proportions of Women and Students in Majors with the Lowest Proportions of Women

	All Students	**Female**	**Male**
Interval	**t**	**t**	**t**
GPA	-5.78 ***	-2.36 *	-4.28 ***
Family Friendly	-1.89	-1.96 *	-2.91 **
Positive View Engr	0.47	1.87	2.12 *
Professors Care	-3.94 ***	-0.62	-5.04 ***
Dichotomous	**X^2**	**X^2**	**X^2**
Prior Engr Experience	73.44 ***	31.03 ***	23.68 ***
Engr Lack of Confidence	7.54 **	1.40	0.02
Intend to Graduate	7.28 **	1.64	5.37 *
Prepared for Job—Disagree	2.67	0.01	0.98
Prepared for Job—Neutral	2.18	1.06	0.42
Prepared for Job—Somewhat Agree	0.04	0.18	0.77
Ability Comparison—Below Avg.	0.00	2.79	0.15
Ability Comparison—Avg.	1.64	0.21	6.72 *
Ability Comparison—Above Avg.	0.04	0.49	3.56
Gender Stereotypes	2.98	9.84 **	0.24
Engr Community	40.85 ***	10.02 **	5.84 *
Always Help Others Succeed	1.54	0.06	0.00
Singled Out b/c Gender	17.86 ***	14.66 ***	13.50 ***
Sexual Harassment	6.35 *	0.88	0.41

***p<=.001, **p<=.01, *p<=.05, +p<=.10, two-tailed tests

There is also bivariate evidence for the discrimination and hostile climate perspectives, although some of the findings conflict. In particular, students in majors with the highest proportion of females are more likely to indicate that professors care about student learning, perceive a sense of community in their engineering department, report being singled out more often and report more sexual harassment. Among women only, the findings differ a bit. There is an additional finding that women in the highest quartile of female representation are more likely to indicate that they heard gender stereotypes from faculty. In addition, *Professors Care* is not significant among women only. The effects of *Engr Community* and

Singled Out b/c Gender are in the same direction as for all students. For the bivariate analysis among men only, male students in the highest quartile majors for women's representation are more likely to indicate that professors care about student learning and that they have been singled about because of their gender. The variable about engineering community operates in the opposite direction for men than it does for women and all students. That is, men who are in the majors in the highest quartile of female representation indicate a lower sense of community in engineering than men in the most male dominated majors.

5.4.2 Multilevel model of highest and lowest quartiles of proportion women in major

The second step of the analysis uses what was learned from the bivariate analysis and puts it into a multivariate context. For this analysis, I use the top and bottom quartiles of the proportion female in the major as my dichotomous dependent variable. The highest quartile of proportion female is coded one and the lowest quartile of proportion female is coded zero. All but three covariates are as defined earlier. For this analysis I add in *Female*, *African American* and *Hispanic American* as controls, each of which is coded one if the respondent represents the category name. I conduct multilevel logistic regression analyses for three populations: all students, women and men. The odds ratios and standard errors from the analyses are reported in Table 5.4.

Table 5.4 Odds Ratios from Multilevel Logistic Regression of Covariates on Highest Quartile of Proportion Female in Major (PACE)

	All Students	**Female**	**Male**
	OR (se)	OR (se)	OR (se)
Human Capital			
Female	5.95 (.67) ***	---	---
African American	1.03 (.27)	0.83 (.33)	1.28 (.47)
Hispanic American	1.10 (.22)	0.82 (.31)	1.24 (.29)
GPA (centered)	1.15 (.14)	0.90 (.17)	1.31 (.22)
Prior Engr Experience	0.44 (.07) ***	0.35 (.09) ***	0.48 (.10) ***
Status Beliefs			
Family Friendly (centered)	1.11 (.06) *	1.03 (.08)	1.21 (.09) *
Positive View Engr (centered)	0.97 (.06)	1.03 (.10)	0.91 (.07)
Engr Lack of Confidence	1.21 (.22)	1.05 (.26)	1.31 (.34)
Intend to Graduate	0.72 (.12) *	0.62 (.16)	0.85 (.19)
Prepared for Job—Disagree	0.80 (.18)	0.84 (.30)	0.79 (.24)
Prepared for Job—Neutral	0.88 (.17)	0.88 (.26)	0.95 (.23)
Prepared for Job—Somewhat Agree	0.88 (.11)	0.96 (.19)	0.86 (.14)
Ability Comparison—Below Avg.	0.54 (.17)	0.44 (.22)	0.68 (.31)
Ability Comparison—Avg.	0.84 (.18)	0.75 (.28)	0.89 (.24)
Ability Comparison—Above Avg.	0.86 (.16)	0.67 (.23)	1.04 (.24)
Discrimination			
Gender Stereotypes	0.69 (.11) *	0.71 (.15)	0.64 (.18)
Professors Care (centered)	1.12 (.06) *	1.04 (.09)	1.16 (.08) *
Engr Community	1.28 (.14) *	1.62 (.29) **	1.12 (.17)
Always Help Others Succeed	1.09 (.14)	1.11 (.21)	1.06 (.20)
Singled Out b/c Gender	0.97 (.21)	0.77 (.19)	6.76 (4.6) *
Sexual Harassment	1.59 (.54)	1.54 (.60)	0.62 (.51)
Random Effects			
School ID Variance	8.84 (6.4)	1.43 (1.6)	6.98 (5.1)
RUVH Variance	3.41 (9.3)	7.46 (5.2)	2.41 (7.3)
Model Fit			
Deviance	2520	1091	1464
Empty Model Deviance	4071	1646	2022
BIC	2712	1256	1635
Intraclass Correlation Coefficient	0.73	0.30	0.68
R^2-dichotomous	0.08	0.06	0.02
Number of Schools	21	21	21
N	2991	1282	1709

***p<=.001, **p<=.01, *p<=.05, two-tailed tests

Interestingly, there are fewer differences between women in the highest and lowest quartile majors than between men in these majors. Among women only, a woman is less likely to be in a major in the highest quartile compared to the lowest quartile if she has prior engineering experience, and women in the highest quartile of proportion women in the major are about 62 percent more likely than women in the lowest quartile to indicate a sense of engineering community.

Among men only, a man is also less likely to be in a major with the highest quartile of proportion women if he has prior engineering experience. In addition, compared to men in majors in the lowest quartile of female representation, men in majors in the highest quartile of female representation are 21 percent more likely to see engineering as family friendly, 16 percent more likely to believe professors care and about 600 percent more likely to indicate they have been singled out because of their gender.

Based on the differences between the deviance scores of each, these models all offer significantly better fit than the empty model with no explanatory variables, and each block of variables representing a different theoretical perspective offers significantly better fit than the one before (results not shown). Following Snijders and Bosker (1999), I calculate a R^2 value for each of the models, using a formula specifically for dichotomous dependent variables. Overall, the R^2 values are very low. For all students, the R^2 value stays the same from .06 for human capital variables only, to .06 for human capital and status beliefs, and increases to .08 for the full model including measures of discrimination. For women, the human capital variables explain only one percent (R^2 =.01) of the variation in the dependent variable, and even with the addition of the status beliefs variables, the R^2 only increases to .02. With the addition of the discrimination measures, the R^2 reaches .06, indicating that the model explains only 6 percent of the variation in the dependent variable. The amount of variation explained is even smaller for men only, increasing from an R^2 of .01 for human capital to .02 for the full model including discrimination measures. Given this, the demand-side measures are most important for explaining student choice of a major in the highest or lowest quartile of proportion women in the major.

The intraclass correlation coefficient (ICC) values indicate that 30 to 73 percent of the total variation is attributable to the variation between schools. The ICC for the female only model is .30 while the male only model is .68 and the full model for all students has an ICC of .73. Even though the R^2 values for all students, women and men, did not differ by a lot, the ICC values do, with the reasons for women choosing a major in the highest quartile of proportion women having less to do with differences at the school level than at the individual level.

5.4.3 Multilevel model predicting choice of major

The third step in the analysis is a multilevel model that examines the same independent variables as the first multilevel analysis but uses different dependent variables. The dependent variables compare students in one of the eight majors to students in biological engineering majors. For each of the eight dependent variables I ran an empty model with only the dependent variable and the random intercept. Using the deviance, I compared the empty model with the full model reported in table 5.5 and all models show clear improvements in model fit and immense statistical significance ($D_0 - D_1$, X^2 22 df).

Table 5.5 reports the odds ratios and standard errors for the multilevel logistic regression of student choice of major. This is a varying intercept model. I include gender as a predictor in the model, and it is significant across seven of the eight majors, indicating what was already known about the concentration of women across majors. This analysis focuses on how the attractors or detractors to majors are different across majors. The analysis in Table 5.5 includes all students and shows the differences across majors.

Controlling for all other variables, in comparison to the reference category of biological engineering (BIOE), females are less likely to be in aerospace, chemical, civil, electrical, computer, materials science, and mechanical engineering. There are no significant associations with race. The effect of GPA is in the same direction across all eight majors. Aerospace, chemical, civil, computer, electrical, industrial, materials science, and mechanical engineering students have lower GPA's than students in biological engineering. Students who had taken an engineering course prior to college are more likely to be found in aerospace, computer, electrical, industrial or mechanical engineering than in BIOE.

Within the status beliefs section, students who hold more positive views of engineering's family friendliness are less likely to be in aerospace, civil, materials science or mechanical engineering than BIOE. But those students who hold positive views of the impact engineering can have on society are more likely to be found in aerospace, chemical, civil, computer, electrical and mechanical engineering than in biological engineering. Specifically, every standard deviation increase in *Positive View Engr* results in a 19 to 41 percent increase in the likelihood that a student is majoring in one of the six majors mentioned above rather than biological engineering. Students who lack confidence in their ability to succeed in engineering are about 41 percent less likely to be in civil engineering than biological engineering. Students in aerospace and civil engineering are more likely than students in BIOE to indicate they strongly agree they intend to graduate with an engineering degree.

Table 5.5 Multilevel Models Predicting Student Major with Fixed and Random Effects (Reference Category: Biological Engineering)

	Aero	Chem	Civil	Comp	Elec	Indust	MSE	Mech
	OR (se)	OR (se)	OR (se)	OR (se)	OR (se)	OR (se)	OR (se)	OR (se)
Human Capital								
Female	0.18***	0.58 ***	0.42***	0.13 ***	0.14 ***	0.75	0.47 **	0.17***
	(0.04)	(0.09)	(0.07)	(0.04)	(0.02)	(0.18)	(0.14)	(0.02)
African American	0.56	0.97	0.55	0.47	1.88	1.58	0.60	0.97
	(0.33)	(0.42)	(0.26)	(0.38)	(0.78)	(0.88)	(0.53)	(0.41)
Hispanic American	0.60	0.67	1.20	0.59	0.83	0.74	0.65	0.72
	(0.21)	(0.20)	(0.34)	(0.36)	(0.22)	(0.33)	(0.39)	(0.19)
GPA (centered)	0.20***	0.55 ***	0.29***	0.48 *	0.44 ***	0.11***	0.45 *	0.42***
	(0.05)	(0.10)	(0.06)	(0.17)	(0.08)	(0.03)	(0.14)	(0.07)
Engr Prior	2.62**	1.00	1.59	5.58 ***	2.77 ***	2.41**	2.00	2.66***
	(0.85)	(0.27)	(0.40)	(2.60)	(0.64)	(0.81)	(0.80)	(0.58)
Status Beliefs								
Family Friendly (centered)	0.73**	0.94	0.76***	0.87	0.87	0.82	0.63 ***	0.80***
	(0.07)	(0.07)	(0.06)	(0.13)	(0.06)	(0.09)	(0.08)	(0.05)
Positive View Engr (centered)	1.26*	1.41 ***	1.20*	1.41 *	1.19 *	1.12	1.21	1.30***
	(0.14)	(0.12)	(0.11)	(0.22)	(0.10)	(0.14)	(0.18)	(0.10)
Engr Lack of Confidence	0.98	1.26	0.59*	1.25	1.01	0.65	1.30	0.87
	(0.32)	(0.30)	(0.16)	(0.71)	(0.23)	(0.23)	(0.57)	(0.19)
Intend to Graduate	3.34***	0.97	1.82*	2.01	1.23	1.85	1.34	1.16
	(1.14)	(0.21)	(0.44)	(0.92)	(0.27)	(0.63)	(0.55)	(0.24)
Prepared for Job-Disagree	0.23***	0.24 ***	0.37**	0.37	0.67	0.18***	0.50	0.36***
	(0.10)	(0.08)	(0.12)	(0.23)	(0.19)	(0.09)	(0.28)	(0.10)
Prepared for Job-Neutral	0.44*	0.60 *	0.52*	0.48	0.81	0.62	0.55	0.91
	(0.15)	(0.16)	(0.14)	(0.26)	(0.21)	(0.24)	(0.26)	(0.21)
Prepared for Job-Somewhat agree	0.58*	0.70 *	0.83	0.62	0.88	0.67	0.66	0.87
	(0.14)	(0.12)	(0.15)	(0.23)	(0.16)	(0.18)	(0.20)	(0.14)
Ability Comparison-Below average	1.35	0.79	1.23	0.68	0.72	0.47	1.04	0.90
	(0.83)	(0.37)	(0.64)	(0.66)	(0.32)	(0.34)	(0.85)	(0.38)

Table 5.5 continued

Ability Comparison-	0.82	0.64	1.08	0.93	0.55 *	0.30**	0.33 *	0.79
Average	(0.35)	(0.20)	(0.38)	(0.53)	(0.16)	(0.14)	(0.18)	(0.22)
Ability Comparison-	0.92	0.72	1.38	0.76	0.55 *	0.47*	0.64	0.70
Above average	(0.36)	(0.21)	(0.45)	(0.40)	(0.14)	(0.20)	(0.32)	(0.18)
Discrimination								
Gender Stereotypes	1.40	1.08	1.27	0.97	1.76 *	1.88*	2.08	2.01***
	(0.43)	(0.25)	(0.30)	(0.45)	(0.39)	(0.60)	(0.79)	(0.40)
Professors Care	0.84	0.80 **	0.84*	0.83	0.82 **	0.65***	1.32	0.75***
(centered)	(0.09)	(0.07)	(0.07)	(0.14)	(0.06)	(0.08)	(0.21)	(0.06)
Engr Community	1.54	1.35	1.20	0.47 *	1.12	1.61*	2.49 **	1.29
	(0.34)	(0.21)	(0.20)	(0.16)	(0.17)	(0.38)	(0.73)	(0.19)
Always Help Others	0.95	1.24	0.70	0.36 *	0.93	1.34	1.49	1.33
Succeed	(0.23)	(0.22)	(0.14)	(0.16)	(0.17)	(0.38)	(0.46)	(0.22)
Singled out	2.68*	1.03	1.36	0.94	1.11	1.37	1.66	1.42
	(1.04)	(0.29)	(0.38)	(0.58)	(0.32)	(0.54)	(0.80)	(0.35)
Sexual Harassment	0.95	0.87	0.44	0.16	0.60	0.91	0.90	0.74
	(0.54)	(0.33)	(0.20)	(0.19)	(0.26)	(0.51)	(0.52)	(0.27)
Random Effects								
Carnegie-RUVH	1.20	3.06	0.01	9.74	0.73	0.29	0.00	1.32
Variance	(2.57)	(1.65)	(0.76)	(7.72)	(0.69)	(2.49)	(0.00)	(0.66)
School ID Intercept	1.05	0.13	0.77	1.30	0.37	2.22	1.52	0.03
Variance (se)	(2.11)	(0.18)	(0.62)	(1.89)	(0.38)	(2.03)	(0.86)	(0.09)
Model Fit								
Full Model Deviance	722	1306	1192	375	1379	606	438	1603
Empty Model Deviance	1244	2042	1909	752	2470	1082	722	2736
BIC	880	1476	1360	527	1553	761	584	1782
Intraclass Corr. Coef.	0.24	0.04	0.19	0.28	0.10	0.40	0.32	0.01
R^2-dichotomous	0.30	0.12	0.18	0.35	0.28	0.25	0.19	0.28
Number of Schools	13	17	16	12	17	13	13	17
N	739	1165	1108	562	1409	639	432	1739

***p<=.001, **p<=.01, *p<=.05, two-tailed test

Compared to students who strongly agree, if a student disagrees that they will be prepared for a job after graduation, they are anywhere from 82 to 63 percent less likely to be in aerospace, chemical, civil, industrial or mechanical engineering compared to BIOE. A similar effect exists for students who indicate "neutral or somewhat agree" that they will be prepared for a job; compared to those who strongly agree they will be prepared, those who are neutral or somewhat agree are less likely to be in aerospace, chemical, or civil engineering in comparison to biological engineering. Compared to students who rate themselves "far above average", students who rate themselves "average" are less likely to be in electrical, industrial or materials science engineering than in BIOE. Those who rate themselves "above average" compared to those who rate themselves "far above average" are less likely to be in electrical and industrial engineering than biological engineering.

Students who indicate they hear faculty express gender stereotypes are 76 percent more likely to be in electrical engineering than biological engineering, 88 percent more likely to be in industrial engineering than BIOE, and 101 percent more likely to be in mechanical engineering than BIOE. Students who think their professors care about them are anywhere from 16 to 35 percent less likely to be in chemical, civil, electrical, industrial or mechanical than biological engineering. The effect of *Engineering Community* on the odds of location in a particular major differs in direction between majors. A greater sense of engineering community results in a student being 53 percent less likely to be in computer engineering than BIOE, while it results in a student being 61 percent and 149 percent more likely to be in industrial and materials science engineering than in BIOE, respectively. Students who indicate that engineering students always help each other succeed in class are 64 percent less likely to be in computer engineering than BIOE. Students who indicate being singled out in class because of their gender are 168 percent more likely to be in aerospace engineering than biological engineering. There is no association between sexual harassment and location in a major, likely because the numbers reporting it are so small.

In total, the proportion of the variance explained by the full model differs greatly across the majors (R^2-dichotomous min.=.12, max.=.35). At the high end, the variables included in the model explain 35 percent of the variation in a student's decision to choose computer over biological engineering. At the low end, the variables explain 12 percent of the variation in the decision to choose chemical over biological engineering. In general, it seems that other majors with higher proportions of women have lower proportions of variance explained, compared to the overwhelmingly male-dominated majors. In particular, the value of R^2-dichotomous is lowest for chemical engineering, perhaps because chemical and biological engineering are more similar to each other than biological engineering is to any of the other majors.

The values of the intraclass correlation coefficient (ICC) indicate that 1 to 40 percent of the variation is attributable to the variation between schools across the eight majors. For the choice of mechanical engineering over biological engineering in particular, only one percent of the variation is at the school level; the ICC is also extremely small for chemical engineering (ICC=.04). On the high end, the greatest amount of variation attributable to the differences between schools is in industrial and materials science engineering (ICC=.40 and .32, respectively). Thus, the reasons for choosing mechanical over biological engineering or chemical over biological engineering have much less to do with variation at the level of the institution than variation at the level of the individual or major.

5.5 Discussion and Conclusion

The bivariate and multivariate analyses provide evidence for human capital, status beliefs and discrimination explanations of major choice. Many of the findings from the second multilevel model mirror those of the first multilevel model. This may be in part because biological engineering is on average the major with the greatest representation of females, making it highly correlated with the highest quartile of women's representation in majors. However, much less of the variation is explained by the analysis modeling student choice of majors in the highest and lowest quartiles compared to the analysis modeling student choice of specific majors.

With regard to the hypotheses posed earlier, I find mixed evidence for Hypothesis 1 (H1), which deals with both human capital and status belief explanations. The results provide mixed support for human capital theory. Human capital theory predicts that technical majors require additional skills, knowledge and experience. The most technical majors are often the ones with the lowest proportions of women. *GPA* does not support this prediction, but the *Prior Engr Experience* does. Compared to students in majors with the highest representation of women, students in majors with the lowest representation of women report a greater likelihood of having taken an engineering course before college. Prior engineering experience has a strong association with student's choice of a more male dominated major. To test whether math confidence or overall academic confidence might be important factors I added them into the logistic regression and neither had an effect on student choice of a particular major. Echoing other researcher's findings, math experience does not seem to be the gatekeeper for women's entrance into certain majors (Tyson et al. 2007). I find that prior engineering experience moderates student choice of major. Perhaps prior engineering experience provides students with a greater understanding of the diversity of work that one can do within certain engineering majors, resulting in the choice of a male-dominated major.

I did not find that students in highly male-dominated majors have higher GPA's; instead, there is evidence that students in majors with better female representation have higher average GPA's. The GPA finding may cause speculation that GPA's are higher among majors with higher proportions of women because those majors are "easier"; there is no evidence for this speculation and until good evidence can be found, this is simply another thinly veiled suggestion that women are not as smart as men. Perhaps this relationship exists because of a compositional effect such that since women compose a greater proportion of students in the highest quartile majors and women on average have higher GPA's than men (Keller, Crouse, and Trusheim 1993).

Status beliefs theory predicts that the perceptions and beliefs about engineering and one's own competence have an impact on career outcomes, including decisions about majors. There is mixed evidence here as well. The most common findings across the different analyses relate to *Family Friendly*, *Positive View Engr*, and *Intend to Graduate*. Family friendliness works in the direction expected, showing that students in majors with higher proportions of women in general have higher expectations that engineering will be family friendly. Strong evidence exists that expectations about the flexibility of engineering careers are related to both a student's choice of a major in the highest quartile of proportion women in the major and with choice of biological engineering major compared to other engineering majors. This supports the expectation laid out in Hypothesis 1 regarding flexibility of careers.

Positive view of engineering works in the opposite direction as *Family Friendly*—students with more positive views of engineering as a field that is respected and valued by society are more likely to be in six other majors compared to biological engineering. Why do students in certain majors have better views of engineering as a field that is respected, valued and well-paid? Of the majors that are associated with this variable, only newly minted chemical, computer and electrical engineers make more than $60,000 per year (NACE). There does not seem to be a close relationship between actual starting salaries and the majors in the lowest quartile. The perceptions of students may be different than reality, and people within their departments may be teaching students those perceptions.

The evidence for self-efficacy, as measured by differences in intention to graduate, indicates that among all students, those in majors with the highest representation of women have a weaker intent to graduate than students in majors with the lowest proportion of women. In addition, two specific majors (aerospace and civil) are significantly related to a strong intent to graduate, compared to biological engineering. Whether students enter these majors with a stronger intent or whether it is learned in the major remains unknown.

There is limited evidence that higher self-confidence is associated with a student's choice of a major with the lowest representation of women, and with the choice of a civil engineering major compared to biological engineering. More positive comparisons of one's own ability are related to choice of an electrical, industrial or materials science engineering major compared to a biological engineering major. This last finding does not provide strong support for H1, in that industrial and materials science are not generally considered to be more male-dominated majors. Given that there is limited support for the confidence measures, I disagree with the findings of Hartman, Hartman and Kadlowec that higher confidence is associated with women's location in majors in which females are under-represented (2007). The relationship is more nuanced, and seems to be associated with student choice of certain majors rather than their choice of a major with an especially high or low proportion of women.

Hypothesis 2 (H2) proposed that students in the most male-dominated majors would be more likely to experience discrimination and hostile climates. Almost all the evidence provides support for this hypothesis, with one clear exception. Male engineering students who report being singled out because of their gender are more likely to be in a major with the highest proportion of women. This finding is highly unexpected. In all other cases, students in majors with the highest proportion of women report a greater sense their professors care, of engineering community, and fewer instances of gender stereotypes and being singled out. An interesting finding that does not necessarily refute H2 is that students in industrial engineering generally report a greater sense of community than students in biological engineering. The direction of this finding is different from that of the other variables in the discrimination section.

Two moderating factors for the singled out finding may be that only eight percent of respondents included in these analyses indicating being singled out because of their gender. This does not create much variation on which to model decision-making consequences. The second thing that may influence this finding is that being singled out may have its largest impact on the exit rate from a major. Because I only have current engineering students in my sample, I cannot model the decision to leave an engineering major for a different engineering major or non-engineering major.

It is unknown whether students learn these sorts of beliefs from their peers and professors in their major or whether they enter into the major with certain beliefs. For example, every standard deviation increase in sense of family friendliness is associated with an 11 percent increase for all students in the likelihood someone is in the highest quartile of majors classified according to female representation, and a 21 percent increase among males only. Do students choose these majors because they believe they will be more family friendly or do they enter the major for other reasons and then learn the major is more family friendly? Do they see their professors working all hours of the day and night in their labs or do there seem to be reasonable expectations about the work hours professors and students are expected to keep?

The goal of this chapter was a gain a sense of the supply- and demand-side characteristics that impact a student's location in a specific major or a specific type of major—one with the highest proportion or lowest proportion of women. This chapter, while providing evidence for the importance of human capital, status beliefs and discrimination perspectives in the study of the women's representation across engineering majors, has brought up more questions than answers. The conflicting evidence for each of the theories leaves gaps in our understanding of the process of sex segregation in undergraduate engineering majors.

There is value in examining the importance of individual effects, as indicated by the significance of the logistic regression coefficients regarding human capital and status beliefs. However, the relatively high intraclass correlation coefficients for many of the models indicate that there are significant similarities between students at the same schools, lending importance to the use of a multilevel model to control for between school associations. For the analysis of the highest and lowest quartiles of proportion women in the major, the intraclass correlation coefficients were extremely high for all students and for men only. This indicates that much of what is happening with those particular analyses is actually at the level of the school, not at the individual level.

In order to test the relative contributions of each theoretical perspective, I calculate the deviance score for the model with human capital variables only, human capital and status belief variables and human capital, status belief and discrimination variables. The difference between the deviance for the empty or restricted model and the deviance for the model with additional parameters follows a chi-square distribution with degrees of freedom equaling the number of additional parameters added to the model. In this case, each successive block of variables added provides improved model fit as indicated by the statistical significance of the deviance differences. Each theoretical perspective adds to our understanding of how supply and demand factors are related to sex segregation.

By combining the effects of individual and institutional characteristics in understanding the choices of students to be in certain majors, this study answers the call for research on links between micro and macro level phenomena (ex. see Van der Lippe and van Dijk 2002). Human capital factors exhibit push and pull characteristics, and a subset of the status belief variables are related to the type of major a student is in. However, discrimination and hostile climate variables show the strongest findings in terms of the effects occurring in the same direction as expected. These findings have implications for how much we can expect the gender composition of these fields to change over time. While some of the factors related to women's choice of a particular engineering major are related to their own personal skills and beliefs which are difficult to change, a good portion of the factors are at the level of the organization, and can be improved to create a welcoming climate for under-represented students.

CHAPTER 6: PROPERTIES OF SEGREGATION AT THE MESO LEVEL

6.1 Introduction

In spite of the enduring gender inequality in engineering overall, women have made inroads into certain engineering disciplines. In undergraduate engineering majors, women are most likely to be found in bioengineering, chemical or industrial engineering, although they are still far from equality even in those disciplines. These circumstances create an interesting case study of sex segregation. Because sex segregation within engineering is relatively un-studied, I continue my roundabout approach to the issue by examining sex segregation from yet another perspective. Chapter 4 examined the organizational characteristics associated with sex segregation, Chapter 5 examined the individual level characteristics associated with sex segregation and this chapter examines the characteristics of the major that are associated with sex segregation in engineering.

That is, what explains segregation at the meso (major) level? How do group level processes and properties impact the representation of women in engineering majors? In majors where women are over-represented compared to the total engineering population do students experience a greater sense of community? Are the majors where women are over-represented more likely to be related to lower paying occupations? This analysis sheds light on how the context of a major is related to the composition of the students within.

I use weighted least squares regression to examine the questions above. I aggregate data from the PACE survey to create variables to measure human capital, status beliefs and discrimination at the level of the major. In addition, I add in a measure of prestige of the major via average salary post-graduation and the *US News* rank of the major, and I control for two institutional characteristics. The dependent variable is the Representation Ratio, a measure of the over- or under-representation of women in an engineering major compared to women's average representation in all of engineering.

Results indicate that demand-side explanations provide the most purchase for explaining sex segregation. In general, more welcoming, caring, collaborative environments are associated with majors with higher than average participation of women. This conforms to expectations based on the discrimination/hostile climate perspectives. But two other variables, including a demand-side climate variable, do not match expectations. The two measures of prestige of the major have significant but very small associations with the Representation Ratio value, leaving equivocal support for the influence of prestige of the major.

6.2 Theoretical Expectations

The framework of supply and demand is relevant for this analysis, although the variables are no longer measured at the individual level. As discussed in Chapter 2, human capital theory provides an explanation of why women choose certain fields for work and study. According to this theory, women are less likely to invest in human capital that loses its value during breaks from the labor force. For this reason, I include two measures: the average GPA of students in the major, and the proportion of students in the major who have taken an engineering course before college. These approximate the constructs of skill and investment of time.

Status belief theory predicts that interactions with others create a sense of expectations which then can impact career aspirations (Correll 2004; Ridgeway 1997, 2000). Socialization, self-confidence and self-efficacy are important measures of the processes underlying status belief theory. Socialization to the view that engineering supports work-family balance and engineers makes positive contributions to society might lead a woman to choose a major that other women have chosen, with the assumption that the need for balance and making contributions must be easier in that particular major. In addition, status beliefs about appropriate careers for women are also related to a sense of self-confidence and self-efficacy. At the aggregate level, status belief theory suggests that majors with a high proportion of students who believe that engineering can support work-family balance will enroll a greater proportion of women than the average in the engineering college. It also suggests that majors with a higher proportion of students with high levels of confidence and self-efficacy will be in majors where women are under-represented compared to the engineering college. It is unknown the extent to which these aggregated micro-level processes will be able to explain the over- and under-representation of women among engineering majors.

On the demand side of the equation, the theories suggest more macro-level processes at work. Stereotyping, discrimination and hostile climate provide alternative explanations of major choice. When these individual level variables are aggregated to the level of the major, different processes may emerge to help understand the uneven distribution of women across engineering majors. The demand-side constructs offer a few hypotheses about this phenomenon. Majors with a higher proportion of women than the engineering college average will be associated with higher average perceptions of the engineering community and that faculty care about student learning, and lower perceptions of gender stereotypes or being singled out because of gender.

In addition, organizational characteristics at the level of the major, engineering college and university are important for understanding the context of female representation across engineering majors. I expect prestigious majors at specific schools (as measured by the *US News* ranking for the department) will have lower proportions of women than the engineering college overall since the demand for these majors is likely high and schools have more latitude with their admission and retention standards, and thus gender discrimination may occur. Based on occupational segregation research, a higher starting salary for students in certain majors, a measure of prestige and value, may also be associated with majors that have lower than average female representation.

6.3 Methodology

6.3.1 Sample

The unit of analysis is the major. The PACE survey data are aggregated up to the level of major for the nine majors that are most common across the schools, which results in 148 cases. Every school does not have each of the nine majors; removing cases that are not highly represented results in five majors across 13 schools for a total of 65 cases. The five majors in the reduced data file are biological, chemical, civil, electrical and mechanical engineering.

6.3.2 Measures

Table 6.1 provides the means, standard deviations, minimums and maximums for the variables employed in the analysis. For the dependent variable, I use the natural log of the Representation Ratio (RR) score of each major, to correct for skewness in the distribution of the untransformed RR. The Representation Ratio describes the extent to which women are over or under-represented in a major compared to the engineering school at large; the scale moves from lower values (indicating under-representation) to higher values (indicating over-representation).

Table 6.1 Descriptive Statistics for Variables in the Analysis (N=65)

Dependent and Independent Variables	Min	Max	Mean	SD
Dependent Variable				
ln(Representation Ratio of Major)	-.92	1.15	0.10	0.57
Human Capital				
GPA	3.02	3.71	3.28	0.14
Engineering Prior	0.00	0.31	0.13	0.07
Status Beliefs				
Family Friendly	-0.55	0.37	0.01	0.17
Positive View	-0.57	0.51	-0.02	0.22
Engineering Confidence	3.97	4.56	4.25	0.12
Prepared for Job	3.29	4.41	3.93	0.22
Ability Comparison	3.29	3.95	3.58	0.13
Discrimination / Hostile Climate				
Engineering Community	2.82	3.95	3.57	0.23
Professors Care	-0.64	0.33	-0.05	0.21
Help Others Succeed	3.33	4.22	3.79	0.17
Gender Stereotypes	0.00	0.56	0.16	0.09
Singled Out b/c Gender	0.00	0.27	0.09	0.06
Sexual Harassment	0.00	0.11	0.03	0.03
Prestige and Controls				
Starting Salary	51793	68000	60309	5831
Majors *US News* Ranked	2.00	100.00	34.09	28.25
Number of Students in Major	78.00	1216.00	432.95	265.35
Proportion Female in Major	0.06	0.47	0.22	0.12
Top 20 *US News*	0.00	1.00	0.46	0.50
Carnegie RUVH	0.00	1.00	0.78	0.42

The independent variables are a mixture of derived and group level variables. The derived variables are created by aggregating individual level survey responses to the level of the major at each school. The group level variables are measures already at the level of the major, and come from other data sources but are matched to the PACE aggregated survey data.

For human capital measurement, I include the averages of cumulative GPA and the proportion of students who had taken an engineering course prior to college. Measures of status beliefs include averages of: the perception of family friendliness of engineering, the perception of engineering as a positive field where engineers are valued, level of confidence in engineering skills, perception of whether one will be prepared for a job when they graduate and the perception of one's own ability in comparison to classmates.

Discrimination and hostile climate are measured by the averages of survey items regarding: the perception of being part of an engineering community, the perception that professors care and the perception that students help each other succeed in class. Also included in the discrimination measures is the proportion of students reporting that faculty express gender stereotypes, the proportion of students reporting being singled out because of their gender, and lastly, the proportion of students indicating they were sexually harassed by engineering faculty or students. Each of these variables was included in Chapter 5 and is described in detail there.

The group level variables focus on two measures of prestige, size of the major at that particular school and the proportion of females in the major. Each year, *US News & World Report* provides rankings of specific engineering departments, as well as engineering colleges overall (2008). If an engineering school is in the top 25 for a discipline in 2008, they are coded with their rank for that major and if they were not in the top 25 they are coded either with their overall engineering rank if that rank is above 25 or coded 30 if their overall rank is under 25. Lower values indicate better rank: a rank of 1 is the best a school can achieve. I include values for average starting salaries for each of the five majors in the analysis (NACE 2009). The salary values do not vary across schools, only across majors.

For controls, the number of students in each major at a particular school is included, since there is reason to expect that the errors associated with each school's measurement are related to the size of the school and the number of respondents to the survey. Number of students in each major is the weighting variable that I use. Proportion female in the major is included as a control as well. While proportion female in the major is highly correlated with the Representation Ratio dependent variable (r=0.92), preliminary analysis showed that statistical effects in the model were actually related to composition of the students in that major, not necessarily to the under- or over-representation of women in the major. Majors with higher Representation Ratio scores have greater proportions of women in them than the engineering average. If women in engineering are more likely than men to indicate that they have been singled out, majors with more women will have higher averages on this variable, resulting in a relationship at the macro-level that does not have an individual level correlate.

Specifically, in an early analysis without proportion female in the major, higher values on *Singled Out* and *Sexual Harassment* seemed to be related to majors with higher proportions of women. Women in majors with greater proportions of women are not actually singled out more than women in majors with lower proportions of women, there are just more women in those majors, and since the responses are aggregated to the level of the major for this analysis, an association appears to exist even though it does not exist at the individual level.

I control for two institutional variables: whether the school overall is ranked in the top 20 of all engineering schools and research universities with very high levels of research activity (*Carnegie RUVH*). Top 20 *US News* is included to determine whether there is an effect of the ranking of a particular major apart from the prestige of the entire engineering college.

6.3.3 Method

I use a weighted least squares model to analyze the variation of the Representation Ratio. I tested whether a multilevel linear regression model is appropriate and the result indicates that in this case a hierarchical linear regression model is no better than a one-level linear regression model (X^2=2.54, 1 df, p=.06). I first run an Ordinary Least Squares (OLS) analysis; an examination of residual variance plots indicates that the OLS model I use has problems with hetereoskedasticity. Regression using OLS assumes that the variance of the residual errors is constant (homoskedastic). While heteroskedasticity does not affect the point estimates, it does affect the standard errors and thus the hypothesis tests. The homoskedasticity assumption of OLS does not hold in the case in the PACE data. The number of students in a major exhibits non-constant residual error variance with the dependent variable, so I weight proportional to the log of the residuals squared of *Number of Students in Major.* I use the WLS0 program in Stata 10, which allows for different types of weighting. The weighting corrects for the heteroskedasticity.

6.4 Results

At the level of the major, there is no support for human capital explanations, minimal support for the status belief explanations, but significant indication that hostile climate/discrimination perspectives explain the most at the meso level (Table 6.2). The status belief variable, *Positive View,* is significantly related to women's representation in engineering majors.

Higher proportions of students in a major who believe that society values the work of engineers are related to women's over-representation in a major, compared to engineering overall. This is somewhat contrary to Chapter 5 findings at the individual level which found that a student's positive view of engineering was associated with the choice of many majors over biological engineering.

Table 6.2 Weighted Least Squares Regression Predicting the Representation Ratio (n=65)

	B		**se**	**95% Conf. Interval**	
Human Capital					
GPA	0.12		0.18	-0.25	0.48
Engineering Prior	0.52		0.28	-0.03	1.08
Status Beliefs					
Family Friendly	-0.02		0.13	-0.28	0.24
Positive View	0.53	***	0.13	0.26	0.80
Engineering Confidence	-0.20		0.26	-0.73	0.32
Prepared for Job	-0.27		0.24	-0.76	0.22
Ability Comparison	0.39		0.21	-0.03	0.81
Discrimination / Hostile Climate					
Engineering Community	-0.31	*	0.14	-0.60	-0.02
Professors Care	0.60	***	0.16	0.27	0.93
Help Others Succeed	0.45	**	0.16	0.14	0.76
Gender Stereotypes	0.33		0.59	-0.85	1.51
Singled Out b/c Gender	-0.59		0.68	-1.95	0.77
Sexual Harassment	0.63		1.73	-2.86	4.12
Prestige and Controls					
Starting Salary	-0.00	**	0.00	-0.00	-0.00
US News Rank of Major	-0.01	*	0.00	-0.01	-0.01
Number of Students in Major	-0.00		0.00	-0.00	0.00
Proportion Female in Major	5.25	***	0.40	4.45	6.05
Top 20 *US News*	-0.10		0.06	-0.22	0.03
Carnegie RUVH	-0.64	***	0.17	-0.99	-0.29
Constant	0.79		1.57	-2.37	3.95
Model Fit : Adjusted R-Squared	0.98				

***p<=.001, **p<=.01, *p<=.05, two-tailed tests

More significant evidence exists for the demand-side explanations, although not all conform to expectations. Surprisingly, a greater average perception of the community in engineering is related to majors with lower than average proportions of women, which is divergent from Chapter 5 findings. This is also surprising because at the individual level, women are more likely than men to indicate that they feel like part of an engineering community. Further research should be conducted to understand this finding and test whether it holds true in other contexts.

In a "warmer" educational climate, majors where students, on average, are more likely to believe that their professors care about student learning or that students in class help each other succeed, have a greater Representation Ratio value. This conforms to expectations based on the discrimination and hostile climate perspectives. Women are over-represented, compared to engineering overall, in majors in which students feel that classmates and faculty are working together to help students succeed.

Salary and the rank of the department a student is in are both related to women's representation in engineering majors—higher salaries are associated with lower female representation while departments that are low in prestige based on rankings also have lower female representation, although the effect size is very small for both variables. The salary finding is similar to that found in the occupational sex segregation literature (Reskin and Roos 1990), but the department ranking finding does not conform to expectations. One possible explanation for this is that highly ranked departments are resource rich which enables them to recruit more women to their departments. Vertical segregation generally occurs such that men are in fields with higher prestige and salary, as those are sometimes synonymous, and women are fields with lower prestige and salary. The findings from this weighted least squares regression do not provide a clear answer to how vertical segregation might be operating in engineering.

As expected, the proportion of women in the major is related to the over- or under-representation of women in a major compared to engineering overall. I include the proportion of women in the major in the analysis because it controls for the compositional effects that occur as a result of the aggregation to the level of the major. The Representation Ratio is calculated using the proportion of women in the major, so the close association between these two variables, and the resulting adjusted R^2 of the model (R^2=.98), are expected.

I included university level characteristics to determine what impact, if any, they have on the Representation Ratio. There is no association between a school's ranking in the top 20 of engineering schools overall and the over- or under-representation of women in particular engineering majors. However, the analysis shows that universities with very high levels of research activity (Carnegie Classifications=RUVH) are associated with majors with lower than average proportions of women. Even in this analysis of majors, there are institutional effects. In this case, this provides further evidence for the importance of context. The five majors included in this analysis are common across schools. At research intensive universities, the Representation Ratio's in those five majors are likely to be lower than at the less research-heavy universities.

6.5 Conclusion

When one observes a pattern in women's representation such as that within engineering, knowing that the pattern exists is not sufficient. It is imperative to gain an understanding of the causes, or at the very least, the characteristics correlated with the pattern. This is all the more important because the trends in women's enrollment in higher education show parity. This dissertation uses multiple viewpoints, but one consistent theoretical framework, to examine the patterns in women's engineering representation. The current chapter focuses on the meso level, or the level of the major, to assess the extent to which departmental characteristics impact women's representation. Some new information is learned, and new questions also arise from the analysis.

Overall, demand-side characteristics of the major are more influential on women's representation than supply-side characteristics. Because supply-side variables focus at the level of the individual and their preferences and desires, it is unsurprising that these supply-side variables, when aggregated to the level of major, had little explanatory power for the question at hand. It is vital that these findings not be extrapolated to the level of the individual, as that is not the unit of analysis and to make such conclusions would be committing an ecological fallacy.

There are expected and unexpected findings in this chapter. Variables regarding professors caring about student learning and students helping other students succeed had expected effects. A perception that one is part of an engineering community, in the aggregate, was not related to the Representation Ratio in the direction expected.

In direct conversation with the occupational segregation literature, I included two measures of occupation prestige: starting salary and departmental rank. The results were not clean; while both variables showed significant relationships with the dependent variable, the effects were small and contradictory. The relationship of salary to the Representation Ratio was in the direction expected, but the rank of the department did not follow expectations. One possibility is that these two variables are not both measures of prestige, but instead measure two different concepts.

At the level of the major, supply and demand explanations each provide some purchase for explaining the uneven distribution of women across engineering majors. The analysis in this chapter results in additional understanding of the meso-level context of sex segregation across engineering majors. At the level of the major, demand-side processes operate more than supply-side processes, but not all the results were in the direction expected, suggesting that future research should consider how prestige and salary are related for undergraduate engineering majors, and should establish whether one is more important than another for student choice of engineering major.

CHAPTER 7: DISCUSSION AND CONCLUSION

7.1 The Big Picture

Gender inequality in engineering persists in spite of women reaching parity in college enrollments and degrees granted. After many years of research on women's under-representation in engineering, women still lag far behind men in engineering enrollments and degrees granted, and the factors affecting women's under-representation are still not fully understood. As many other researchers have shown, women are disproportionately represented across aggregate fields of study in higher education, with the lowest representation in engineering (Jacobs 1995, 1996). To move beyond traditional methods of studying the long-standing stratification by field of study in higher education, I look deeper to explore gender stratification within one field: engineering. Within a traditionally male-dominated field such as engineering, why do some engineering disciplines exhibit a greater representation of women than other disciplines? What individual and institutional factors encourage or inhibit women's under-representation?

Individual and institutional factors are both associated with women's representation in particular engineering majors, but the results point to demand-side factors as the most important. Each of the analyses showed fairly strong evidence for organizational effects, including experiences with discrimination and hostile climate. There is mixed evidence regarding the impact of human capital and status beliefs theories. I find more evidence explaining why students are in specific majors than explaining why they are in majors with a high proportion of women. This suggests that the proportion of women enrolled is not a defining feature of a major, and that across the nine majors examined in this dissertation, there are important differences between them that are negated when the majors are aggregated into larger groups.

Previous research on women's under-representation in engineering does not examine students' contextual experiences within particular majors, resulting in gross inaccuracies when their general engineering findings are applied to particular engineering majors. It is perhaps this generalization of engineering experiences that has hampered more full understandings of the causes of women's under-representation. It is common knowledge among engineering faculty and researchers that women are distributed across engineering disciplines unequally. For example, women are much more likely to be found in biological or chemical engineering than in electrical or mechanical engineering. This dissertation takes this common knowledge and examines it in-depth to gain understanding of the variation of women's representation across engineering majors, and the factors associated with women's representation in particular majors. By utilizing a supply and demand framework with relevant theoretical approaches, I examine individual and institutional factors affecting women's uneven distribution across engineering majors.

7.2 Review of findings

I examined the influence of three alternative explanations for women's uneven distribution across engineering majors. Human capital theory, status beliefs and discrimination are explanations often used in the occupational sex segregation literature, and I tested their usefulness for explaining sex segregation in undergraduate engineering majors. None of these explanations found full support without some discrepancies, although discrimination perspectives showed the most promise. This suggests that the processes governing occupational sex segregation and the processes governing engineering sex segregation are not exactly the same. At the meso level, discrimination and hostile climate seem to be more important predictors of women's representation in a major than human capital and status beliefs. At the level of the individual, human capital explains some of the variation in women's representation but it does not always operate in the direction expected. Prior engineering experience fits well with the expectations of human capital theory, but the relationship of GPA with women's representation does not.

From an individual level perspective, a student's educational background and skills, socialization, self-efficacy and experiences with educational culture operate to pull or push students from certain engineering fields. Prior experience with engineering pulls students toward highly male-dominated majors such as computer, electrical and mechanical engineering. A lack of self-efficacy and socialization about the family-friendliness of engineering pushes students out of certain fields, relative to biological engineering. Positive climates pull students into certain majors, generally those that have higher proportions of women.

From an organizational or institutional level perspective, the context matters for women's representation. Given prior research indicating that women are less well represented at elite, selective colleges and universities (Hearn 1991; Jacobs 1999a), it was somewhat surprising to see that women's representation is higher in top ranked engineering colleges (Chapter 4), and that at the level of the major, the more prestigious the major is in terms of ranking, the higher female representation is in that major relative to engineering overall (Chapter 6). A school's classification as a Carnegie Research University with Very High research activity (RUVH) has an overall dampening effect on women's representation in a major relative to engineering overall.

I examined various measures of undergraduate engineering sex segregation to provide an unprecedented picture of women's distribution across engineering majors in Chapter 4. The results in this chapter revealed a complex structure of sex segregation in engineering majors. I examined five different measures of sex segregation: three index measures quantify the equality of dispersion across majors by gender, and two non-index measures quantify women's representation either in the entire engineering college and/or in a particular engineering major. I provided hard evidence of the wide variation in women's representation across engineering majors and across schools, which suggests that organizational factors play a role in the patterns of sex segregation.

There are significant and persistent correlations between high sex segregation index scores and schools with very high or high research activity, a greater number of female faculty, at least one engineering major with more than 25 percent female enrollment, and a *US News* ranking in the top 100 of engineering schools. The school's location in a large city is associated with lower sex segregation index scores. A higher proportion of women in engineering overall is associated with many of these same factors: high research levels, having at least one major with more than 25 percent women, high *US News* ranking, number of female faculty and location in a large city, as well as private control of the university.

Many of the measures of women's representation indicated wider dispersion than I expected. For example, even though women are highly under-represented in computer engineering nationwide, there are six schools with computer engineering majors with greater than 30 percent women. While 30 percent female representation is not parity, it is outside the normal bounds of representation in this major and should be considered an achievement. It is these “success” stories that need careful examination.

I disentangled the factors associated with student choice of a major with a very high or very low proportion of women from the factors associated with student choice of particular majors. These two different analyses in Chapter 5 were essential given the knowledge gained from Chapter 4 regarding the variation of women’s representation in particular majors across schools. One of the interesting findings is the differences in the proportion of variance explained for the two multilevel models in this chapter. The proportion of variance explained is very low for the multilevel model of student choice of major with a relatively high or low proportion of women, compared to the model predicting a specific engineering major compared to a biological engineering major. It is possible these categories of highest quartile and lowest quartile of female representation do not match with the way students think about their majors, or the aggregation of different majors into broader groups continues to obscure important differences between engineering majors. While the dichotomous R^2 that I calculated is not a true R^2 and is very sensitive to the number of cases in the analysis, the differences between the models show a trend, even if the exact numbers are not that instructive.

Each theoretical perspective is supported to some degree by the analyses in Chapter 5, although there is some mixed evidence. Consistent relationships exist between the dependent variables and engineering experience before college, the perception of family friendliness of engineering careers, and the perception that professors care about students. Students who have greater expectations that engineering will be family friendly and who perceive greater support from faculty are more likely to be in majors with greater proportions of women. Discrimination and hostile climate perspectives find the most support with relationships between female representation and gender stereotypes, professors who care, and engineering community.

In Chapter 6, I examined sex segregation from a meso-level, examining how the context of *the major and the institution influence* women's under- and over-representation in engineering majors. Demand-side processes, including the prestige of particular departments, the Carnegie research rating and the engineering climate, are highly related to women's over- or under-representation in a department. It is possible that supply-side process associations were minimized because of the use of derived variables that were aggregated to the level of the department at each school. These supply-side factors likely do not operate as strongly at the level of the major as they do at the level of the individual.

Given that a student's field of study in higher education is related to their post-college earnings, that women generally earn less than men, even with the same degrees and that fields with greater proportions of women often offer lower pay than highly male-dominated professions (Tam 1997; Reskin and Roos 1990), it was not unexpected that average starting salary of recently graduated engineering students was negatively related to the Representation Ratio values, although the small size of the effect was unexpected.

7.3 Theoretical and Methodological Implications

Throughout this dissertation, I have used the occupational sex segregation literature as both backdrop and analogy. It informed the selection of the theoretical perspectives and the variables I included in my analyses. I think that while occupational sex segregation has been useful in those respects, engineering education sex segregation presents a somewhat unique case. The first reason for this is that sex segregation within engineering, while offering variation across majors and schools, is still fairly homogenous when compared to sex segregation across occupations. Differences across the majors exist, but they are smaller in size and narrower in scope. For example, all engineers are required to have a certain level of math competence. Therefore, there are few differences in math confidence across engineering majors, but large differences in math performance across aggregate fields of study such as education, humanities, science and engineering.

The second reason engineering education is a unique case of sex segregation is that some of the primary tenets of occupational segregation are not supported by the analysis here. Specifically, women are not clustered in the low prestige fields/majors. At the macro level, top 50 and top 100 *US News* ranked engineering schools are associated with higher proportions of females in engineering overall. Similarly, departments that are highly ranked are likely to have a higher representation of women than those that are lower ranked. As mentioned in Chapter 6, this may be in part because highly ranked department have more resources to recruit and retain women in their departments.

One important theoretical contribution this dissertation makes relates to our understanding of sex segregation within schools and across schools. When looking at an entire university, prior research indicates that sex segregation is greater within schools than across schools (Jacobs 1999). Chapter 5 is especially instructive on this topic because the multilevel modeling facilitates an understanding of the amount of variation explained within schools and between schools. Of particular interest is the finding that, for women, much less of the variation in whether a student chooses a major in the highest or lowest quartile of proportion female in the major, is attributable to the variation between schools. This suggests that individual level characteristics are much more important for women's choice of major than for men's choice. From a different perspective, the choice to be in certain majors is more consistent across schools—only one percent and four percent of the variation in choosing mechanical or chemical engineering over bioengineering, respectively is the result of school variations. On the other end of the spectrum, 40 percent of the variation is attributable to the variation between schools for the choice of industrial over bioengineering. So, context matters more for the choice of industrial and materials science over bioengineering and matters almost not at all for chemical and mechanical over bioengineering.

Methodologically, this dissertation brings new information to the research community through the use of a novel dataset, statistical techniques not normally used in the field of engineering education, examination within the engineering discipline, and the examination of the research questions from multiple viewpoints to gain a broad view of sex segregation in engineering.

By matching the PACE data (which themselves are unique in terms of the types of questions that are asked and the number of respondents) with institutional data on enrollments by sex and major and Carnegie Classification data, I have created a unique data set that allows me to examine sex segregation from different perspectives. I can aggregate to the level of the institution or the level of the major, and because such a large number of schools is involved, I can make claims that the results are representative of a group of schools that are generally large, publically controlled, highly ranked and conduct very large amounts of research. Because the data are specific to engineering and contain so many students, I am able to conduct my analysis within engineering, and not just with two or three majors within engineering—I examine nine engineering majors for most of the analyses in this dissertation.

7.4 Recommendations

Researchers and educational administrators are calling more information about the differences between engineering sub-disciplines in order to assist schools in creating tailored programs and practices to improve women's representation (PACE 2010; Sonnert, Fox and Adkins 2007). Because of the strong theoretical framework and the detailed analysis looking across majors within engineering, I make the following recommendations.

- One of the consistent and strong findings was that students without prior engineering experience were much more likely to go into less technical majors with a greater proportion of women. By providing engineering information and experience during high school, and by targeting this information and experience to women, typically male-dominated majors could see an influx of qualified students, particularly of women students.
- Having a sense that one is part of an engineering community seems to be very important to students and to women in particular. Departments with greater proportions of women often have higher scores on sense of engineering community. In addition, industrial and materials science engineering seem to be doing a very good job in creating community within their majors, while computer engineering leaves much to be desired in terms of community. Departments and colleges can build a sense of community through student involvement in discipline specific clubs and societies and even getting students involved in activities for events like E-Week (engineering week).

- Gender stereotyping is more likely to occur in certain majors than in others, and this seems to be related to the representation of women in those majors. Stereotyping can have important consequences for student identity and career aspirations, in the case of stereotype threat. Faculty play a large role in this, and engineering colleges and perhaps even specific disciplines could focus on educating faculty regarding equity and the impact of stereotypes. The Implicit Association Test (IAT) could be a useful tool for detecting and educating people about stereotypes and their impact.
- Aerospace engineering seems to diverge from the other engineering departments in non-trivial ways that could impact their student population. In particular, students in aerospace engineering report more instances of being singled out than students in biological engineering, and no other major has this finding. In addition, students in aerospace engineering have a much stronger intent to graduate than students in other majors. There is also much less variation in women's aerospace representation across schools. There seems to be a particular culture in aerospace which educators and researchers should examine in order to understand ways in which it can be improved.
- Departments should recognize that their culture and climate may be the most important factor for student decisions to choose one major over another. The climate of a department can be changed, and departments may want to do self-assessments to determine what aspects of the climate are most unpleasant for students.

7.5 Limitations and Future Research

This study provides a wealth of directions for future research. Because the alternative explanations of major choice examined here had mixed support, future research should examine additional theories that might have better explanatory power. In addition, an opportunity exists for new data to be collected to include more detailed measures of human capital in order to more fully test the applicability of that theory.

There are a number of unexpected findings that need further examination. Interestingly, a number of these unexpected findings emerged when the analysis was done for men only. For example, why do men in majors with the highest proportions of women report being more often being singled out because of their gender compared to men in majors with the lowest proportions of women? Why are men in majors with the highest proportions of women more likely to perceive engineering as family friendly compared to men in majors with the lowest proportions of women? In relation to all students, why is it that highly ranked schools attract more women to engineering overall, but then those women are segregated into certain majors to a greater extent than at schools with lower proportions of women overall?

It was also surprising that there was very little evidence for the influence of self-confidence on choice of major. Prior research indicates important gender differences between men and women in engineering in self-confidence which would be expected to influence the major. Instead, self-confidence may operate not to influence the engineering major one chooses but instead whether one stays in an engineering major.

Future research should examine the associations between starting salary and engineering major with a more detailed salary measurement. Salary may have a stronger relationship to student choice of major, but the current imprecise measurement of the variable may be preventing that relationship from coming through.

The findings discussed here are not causal- the variables included in the model are not predictive of the choice of a particular major or a particular type of major. Since the data I use are a snapshot of student life, I do not know whether students come into majors with pre-conceived notions of engineering work-family balance, or whether those ideas are created during their time in that major. Longitudinal data with this level of detailed questions regarding engineering experiences is badly needed. There may be some way to approximate this by examining the strength of these notions for students in different years of school. If there are significant differences between seniors and first year students, this would tell us a bit more about how certain perceptions come into being.

Nor do these data and findings necessarily indicate what characteristics are associated with retention in engineering majors. I do not know whether some majors do a good job of initially attracting women, but a poor job of keeping them, or vice versa. Retention of students in engineering is a problem that has yet to be examined at the level of the major to understand differences between majors. Retention and recruitment are two different processes, and while related, certain factors would theoretically be less useful for explaining one process or another. For example, based on human capital theory, a person's human capital is important for getting into certain majors, jobs and occupations. But it is likely to be a less important reason for why a person stays or leaves a major, job or occupation.

Future research should also examine how sex segregation has changed over time within engineering. New fields such as bioengineering have been created, and those new fields as well as the growth of other fields could be primarily responsible for shifts in the majors that females study. If this is true, it would be parallel to findings in the occupational segregation literature and to the educational stratification literature in which the expansion of the educational system was a major influence on the declining gender gap in higher education (Buchman, DiPrete and McDaniel 2008). There is data available to examine the longitudinal trends of sex segregation in engineering, but such a task was outside the scope of this project.

7.6 Conclusion

This study of sex segregation in undergraduate engineering has provided comparisons to the occupational sex segregation literature. There is mixed evidence regarding the impact of human capital, status beliefs and discrimination perspectives on women's representation in engineering majors.

The study and practice of engineering has always been dominated by men. With the social changes seen in enrollment of women in higher education, it seems that the time is ripe to press for change in male-dominated bastions such as engineering. Because not all engineering fields have the same level of female representation, there is an opportunity to learn about the differences between these fields to better understand what is drawing women to fields such as biological engineering and chemical engineering or pushing women away from fields such as computer and mechanical engineering. As a result of the analyses in this dissertation, I made some recommendations to pull more women into engineering majors and minimize the degree to which majors push women away.

Creating a more equal distribution across engineering majors is important for a number of reasons. One reason is because social inequality in engineering enrollments can have lasting consequences for women's lifetime earnings. As families and households increasingly require two incomes to provide the necessities for their members, the specialized training individuals receive, such as in engineering, affects wages (Tam 1997). In fact, recent work concludes that the barrier of sex segregation by field of study in higher education will preclude any gender equality in earnings that might be expected as a result of women's "advantage" in higher education (Bobbit-Zeher 2007).

Equality in the distribution of students to fields of study is important because diversity of thought is essential to producing innovative and useful products (Ashcraft 2008; Page 2007a). Without women as part of the design and engineering teams for these products, inventions will at best provide little benefit to half of the population and at worst, do harm to the female half of the population (i.e., seatbelts and heart medications designed with men in mind). A recent example of the need for women to be involved in the design process is Apple's new iPad. When the iPad name was revealed, the media exploded with commentary that Apple probably had no women involved in the creation of the iPad, otherwise they surely would not have picked a name that for half the population is associated with feminine hygiene products (Mattioli and Wingfield 2010). This is an example of a design flaw that causes no harm, but one wonders whether the initial sales of the iPad would have been better if it had been named something different, enabling greater spread of this innovative technology.

The study of sex segregation is also of importance because it helps us understand why certain fields move from significant inequality to parity. For example, the field of medicine experienced a large influx of women students and practitioners in the last half-century, obliterating the horizontal segregation that had endured for hundreds of years. However, medicine still suffers from problems with vertical segregation; women doctors are not generally found in high-paying, high-prestige positions such as neurosurgery.

Engineering is an important field for our society- it keeps us safe in our houses, cars, with the products we use. Engineering innovates new products that cheaply purify water for drinking in rural areas of the world, helps disabled people grasp items with a dexterous robotic arm controlled by brain signals (Matsuoka 2007), and allows us to immediately communicate with friends, family and colleagues across the globe. As the former National Academy of Engineering president, William Wulf, said, "Sans diversity, we limit the set of life experiences that are applied, and as a result, we pay an opportunity cost,- a cost in products not built, in designs not considered, in constraints not understood, in processes not invented." (1998). There are so many things that could be invented, or improved that would help people and improve society. Imagine what could be accomplished if half the world's engineers were women.

BIBLIOGRAPHY

Acker, Joan. 1973. "Women and Social Stratification: A Case of Intellectual Sexism." *American Journal of Sociology* 78(4):936-945.

Acker, Joan. 1980. "Women and Stratification: A Review of Recent Literature." *Contemporary Sociology* 9:25-39.

Acker, Joan. 1990. "Hierarchies, Jobs, Bodies: A Theory of Gendered Organizations." *Gender & Society* 4(2):139-158.

Acker, Joan. 1999. "Gender and Organizations." Pp. 177-194 in *Handbook of the Sociology of Gender*, edited J.S. Chafetz. New York: Plenum Publishers.

Acker, Sandra and Keith Oatley. 1993. "Gender Issues in Education for Science and Technology: Current Situation and Prospects for Change." *Canadian Journal of Education* 18(3):255-272.

ACT Education. 1990. "College Outcomes Survey." Retrieved from http://www.act.org/ess/

Adams, David. 1988. "Factors Relating to the Persistence of Men and Women Engineering Freshman." Ph.D. dissertation, Department of Sociology, University of Pennsylvania.

Adelman, Clifford. 1998. *Women and Men of the Engineering Path: A Model for Analyses of Undergraduate Careers*. Washington, DC: U.S. Department of Education and The National Institute for Science Education.

Agresti, Alan and Barbara Finlay. 1997. *Statistical Methods for the Social Sciences*. Upper Saddle River, NJ: Prentice-Hall

Agresti, Alan. 1990. *Categorical Data Analysis*. John Wiley and Sons.

Allan, Elizabeth J. and Mary Madden. 2006. "Chilly Classrooms for Female Undergraduate Students: A Question of Method?" *The Journal of Higher Education* 77(4):684-711.

American Society for Engineering Education (ASEE). 2008. Data Mining Tool, 2008 Enrollment data. Accessed September 25, 2009.

Anderson, Carolyn J. and Stanley Wasserman. 1995. "Log-Multiplicative Models for Valued Social Relations." *Sociological Methods Research* 24(1):96-127.

Anker, Richard. 1998. *Gender and Jobs: Sex Segregation of Occupations in the World.* Geneva, Switzerland: International Labour Office

Archer, Louise, Anna Halsall, and Sumi Hollingworth. 2007. "Inner-City Femininities and Education: 'Race', Class, Gender and Schooling in Young Women's Lives." *Gender and Education* 19(5):549-568.

Ashcraft, Catherine and Anthony Breitzman. 2007. Who Invents IT? An Analysis of Women's Participation in Information Technology Patenting (NCWIT). Executive summary available at www.ncwit.org

Ashcraft, Catherine. 2008. NCWIT Promising Practice Sheet: Interview Strategies that Identify Functionally Diverse Perspectives (Case Study 1): One Way to Recruit Diversity that Promotes Innovation and Productivity. Available at www.ncwit.org

Astin, Alexander W. and Helen S. Astin. 1992. *Undergraduate Science Education: The Impact of Different College Environments on the Educational Pipeline in the Sciences.* Los Angeles, CA: Higher Education Research Institute.

Ayalon, Hanna. 2003. "Women and Men Go to University: Mathematical Background and Gender Differences in Choice of Field of Higher Education." *Sex Roles* 48(5/6):277-290.

Bae, Yupin, Susan Choy, Claire Geddes, Jennifer Sable, Thomas Snyder. 2000. *Trends in Educational Equity of Girls and Women.* Washington, DC: National Center for Education Statistics.

Baker, Dale, Stephen Krause, Senay Yasar, Chell Roberts, and Sharon Kurpius-Robinson. 2007. "An Intervention to Address Gender Issues in a Course on Design, Engineering, and Technology for Science Educators." *Journal of Engineering Education* 96(3):213-226.

Baron, James N. and Jeffrey Pfeffer. 1994. "The Social Psychology of Organizations and Inequality." *Social Psychology Quarterly* 57:190-209.

Becker, Gary S. 1971. *The Economics of Discrimination.* Chicago: The University of Chicago Press.

Becker, Gary S. 1993. *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education.* 3rd ed. Chicago, University of Chicago Press.

Becker, Gary. 1991. *A Treatise on the Family.* Enlarged edition. Cambridge, MA: Harvard University Press.

Beller, Andrea. 1982. "Occupational Segregation by Sex: Determinants and Changes." *Journal of Human Resources* 17:371-392.

Berggren, Caroline. 2008. "Horizontal and Vertical Differentiation within Higher Education--Gender and Class Perspectives." *Higher Education Quarterly* 62(1/2):20-39

Berryman, Sue E. 1983. *Who will do Science? Trends, and Their Causes in Minority and Female Representation among Holders of Advanced Degrees in Science and Mathematics. A Special Report.* New York: Rockefeller Foundation.

Betz, Michael and Lenahan O'Connell. 1992. "The Role of Inside and Same-Sex Influencers in the Choice of Nontraditional Occupations." *Sociological Inquiry* 62(1):98-106.

Beutel, Ann M. and Donna J. Nelson. 2005. "The Gender and Race-Ethnicity of Faculty in Top Science and Engineering Research Departments." *Journal of Women and Minorities in Science and Engineering* 11:389-402.

Beyer, Sylvia. 1999. "The Accuracy of Academic Gender Stereotypes." *Sex Roles* 40:787-813.

Bielby, William T. and James N Baron. 1986. "Men and Women at Work: Sex Segregation and Statistical Discrimination". *American Journal of Sociology* 95:616-658.

Bielby, William. 2000. "How to Minimize Workplace Gender and Racial Bias." *Contemporary Sociology* 29:120-29.

Bix, Amy Sue. 2004. "From "Engineeresses" to "Girl Engineers" to "Good Engineers": A History of Women's U.S. Engineering Education." *National Women's Studies Association Journal* 16(1):27-49.

Blossfeld, Hans-Peter and Catherine Hakim, eds. 1997. *Between Equalization and Marginalization: Women Working Part-time in Europe*. Oxford, UK: Oxford University Press.

Blumberg, Rae Lesser. 1984. "A General Theory of Gender Stratification." In *Sociological Theory*, edited by R. Collins. San Fransisco: Jossey-Bass.

Bobbitt-Zeher, Donna. 2007. "The Gender Income Gap and the Role of Education." *Sociology of Education* 80:1-22.

Bonous-Hammarth, Marguerite. 2000. "Pathways to Success: Affirming Opportunitites for Science, Mathematics, and Engineering Majors." *The Journal of Negro Education* 69(1/2):91-111.

Boulis, Anne, Jerry A. Jacobs and J. Jon Veloski. 2001. "Gender Segregation by Specialty during Medical School." *Academic Medicine* 76(10):S65-S67.

Bourdieu, Pierre. 1986. "The Forms of Capital." Pp. 241-58 In *Handbook of Theory and Research for the Sociology of Education*, edited by JG Richardson. Westport, CT: Greenwood Press.

Bradley, Karen and Maria Charles. 2004. "Choice, Self-Expression, and Sex Segregation: Engineering Programs in 44 Countries." Presented at the annual meeting of the American Sociological Association, San Francisco, CA. Retrieved July 19, 2008 (http://www.allacademic.com/meta/p108525_index.html)

Bradley, Karen. 2000. "The Incorporation of Women into Higher Education: Paradoxical Outcomes?" *Sociology of Education* 73:1-18.

Brady, Kristine L. and Richard M. Eisler. 1999. "Sex and Gender Equity in the College Classroom: A Quantitative Analysis of Faculty-Student Interactions and Perceptions." *Journal of Educational Psychology* 9(1):127-145.

Brainard, Suzanne G. and Linda Carlin. 1998. "A Six Year Longitudinal Study of Undergraduate Women in Engineering and Science." *Journal of Engineering Education* 87(4):369-375.

Brainard, Suzanne G., Susan S. Metz, and Gerald Gillmore. 1999. "WEPAN Pilot Climate Survey: Exploring the Environment for Undergraduate Engineering Students." Proceedings of the 1999 IEEE/ISTAS Conference on Women and Technology: Historical and Professional Perspectives.

Brainard, Suzanne G., Suzie Laurich-McIntyre, and Linda Carlin. 1995. "Retaining Female Undergraduate Students in Engineering and Science: 1995 Annual Report to the Alfred P. Sloan Foundation." *Journal of Women and Minorities in Science and Engineering* 2:255-267.

Breen, Richard and Jan O. Jonsson. 2000. "Analyzing Educational Careers: A Multinomial Transition Model." *American Sociological Review* 65:754-772.

Browne, Irene and Joya Misra. 2003. "The Intersection of Gender and Race in the Labor Market." *Annual Review of Sociology* 29:487-513.

Buchmann, Claudia and Ben Dalton. 2002. "Interpersonal Influences and Educational Aspirations in Twelve Countries: The Importance of Institutional Context." *Sociology of Education* 75:99-122.

Buchmann, Claudia and Thomas A. DiPrete. 2006. "The Growing Female Advantage in College Completion: The Role of Family Background and Academic Achievement." *American Sociological Review* 71:515-541.

Buchmann, Claudia, Thomas A. DiPrete, and Anne McDaniel. 2008. "Gender Inequalities in Education." *Annual Review of Sociology* 34:319-337.

Budden, Amber E., Tom Tregenze, Lonnie W. Aarssen, Julia Koricheva, Roosa Leimu, and Christopher J. Lortie. 2008. "Double-Blind Review Favours Increased Representation of Female Authors." *Trends in Ecology and Evolution* 23(1):4-6.

Canes, Brandice J. and Harvey S. Rosen. 1995. "Following in Her Footsteps? Faculty Gender Composition and Women's Choices of College Major." *Industrial and Labor Relations Review* 48:486-504.

Carnegie Foundation for the Advancement of Teaching, Carnegie Classifications Data File, June 19, 2009. Accessed http://www.carnegiefoundation.org/classifications/index.asp?key=785

Cassirer, Naomi and Barbara Reskin. 2000. "High Hopes: Organizational Location, Employment Experiences, and Women's and Men's Promotion Aspirations." *Work and Occupations* 27:438-63.

Catsambis, Sophia. 2005. "The Gender Gap in Mathematics: Merely a Step Function?" Pp. 220-245 in *Gender Differences in Mathematics: An Integrative Psychological*

Approach. Edited by Ann M. Gallagher and James C. Kaufman Cambridge, UK: Cambridge University Press.

Charles, Maria and David Grusky. 1995. "Models for Describing the Underlying Structure of Sex Segregation." *American Journal of Sociology* 100(4):931-971.

Charles, Maria and David Grusky. 2004. *Occupational Ghettos: The Worldwide Segregation of Women and Men*. Stanford, CA: Stanford University Press.

Charles, Maria and Karen Bradley. 2002. "Equal but Separate? A Cross-National Study of Sex Segregation in Higher Education." *American Sociological Review* 67:573-599.

Charles, Maria and Karen Bradley. 2008. “A Matter of Degrees: Female Underrepresentation in Computer Science Programs Cross-Nationally." Pp. 183-203 in *Women and Information Technology: Research on the Reasons for Underrepresentation*. Edited by Joanne McGrath Cohoon and Bill Aspray.. Cambridge, MA: MIT Press.

Charles, Maria and Karen Bradley. 2009. "Indulging our Gendered Selves? Sex Segregation by Field of Study in 44 Countries." *American Journal of Sociology* 114(4):924–76.

Charles, Maria. 1992. "Cross-National Variation in Occupational Sex Segregation." *American Sociological Review* 57:483-502.

Charles, Maria. 2003. "Deciphering Sex Segregation: Vertical and Horizontal Inequalities in Ten National Labor Markets." *Acta Sociologica* 46:267-287.

Charles, Maria. 2005. "Skill Profiles, Gender Ideology, and Sex Segregation: Structural and Cultural Constraints on Occupational Choice." *Social Politics* 12:289-316.

Clewell, Beatriz C. and Patricia B. Campbell. 2002. "Taking Stock: Where We've Been, Where We Are, Where We're Going." *Journal of Women and Minorities in Science and Engineering* 8:255-284.

Collins, Randall. 1971. "Functional and Conflict Theories of Educational Stratification." *American Sociological Review* 36:1002-1019.

Commission on Professionals in Science and Technology. 2009. Data derived from Engineering Workforce Commission EWC, Engineering and Technology Enrollments, 2008. Provided to UW Center for Workforce Development.

Commission on Professionals in Science and Technology. 2006. Professional Women and Minorities: A Total Human Resources Compendium. Sixteenth Edition. Prepared by Nathan Bell, Nicole DiFabio and Lisa Frehill.

Commission on Professionals in Science and Technology. 2008. Data derived from Engineering Workforce Commission EWC, Engineering and Technology Enrollments, Fall 1996 through Fall 2006. Retrieved July 20, 2008 from www.wepan.org members only site.

Constantinople, Anne, Randolph Cornelius, and Janet Gray. 1988. "The Chilly Climate: Fact or Artifact?" *The Journal of Higher Education* 59:527-550.

Corcoran, Mary E., Greg Duncan, and Michael Ponza. 1984. "Work Experience, Job Segregation, and Wages." Pp. 171-91 in *Sex Segregation in the Workplace: Trends, Explanations, Remedies*, edited by Barbara F. Reskin. Washington, DC: National Academy Press.

Corra, Mamadi. 2007. "Stereotype Threat? Male and Female Students in Advanced High School Courses." *Journal of Women and Minorities in Science and Engineering* 13:95-118.

Correll, Shelley J. 2001. "Gender and the Career Choice Process: The Role of Biased Self-Assessments." *The American Journal of Sociology* 106:1691-1730.

Correll, Shelley J. 2004. "Constraints into Preferences: Gender, Status, and Emerging Career Aspirations." *American Sociological Review* 69:93-113.

Cortese, Charles F., R. Frank Falk, and Jack K. Cohen. 1976. "Further Considerations on the Methodological Analysis of Segregation Indexes." *American Sociological Review* 41:630-637.

Council of Economic Advisors. 1998. Changing America: Indicators of Social and Economic Well-Being by Race and Hispanic Origin. Washington, DC: Council of Economic Advisors.

Couper, Mick P. and Peter V. Miller. 2008. "Web Survey Methods Introduction." *Public Opinion Quarterly* 72(5):831-835.

Couper, Mick P., Michael W. Traugott, and Mark J. Lamias. 2001. "Web Survey Design and Administration". *Public Opinion Quarterly* 65:230–53.

Crawford, Mary and Margo MacLeod. 1990. "Gender in the College Classroom: An Assessment of "Chilly Climate" for Women." *Sex Roles* 23(3/4):101-122.

Crowley, Sue, Deena Fuller, Wendy Law, Denise McKeon, Julie J. Ramirez, Keith A. Trujillo, and Eileen Widerman. 2004. "Improving the Climate in Research and Scientific Training Environments for Members of Underrepresented Minorities." *The Neuroscientist* 10(1):26-30.

Curtin, Richard, Stanley Presser, and Eleanor Singer. 2005. "Changes in Telephone Survey Non-Response over the Past Quarter Century." *Public Opinion Quarterly* 69:87-89.

Davies, Scott and Neil Guppy. 1997. "Fields of Study, College Selectivity, and Student Inequalities in Higher Education." *Social Forces* 75(4):1417-1438.

Davies, Scott. 1995. "Leaps of Faith: Shifting Currents in Critical Sociology of Education." *The American Journal of Sociology* 100(6):1448-1478.

De Leeuw, Edith, D. 2005. "To Mix or Not to Mix Data Collections Modes in Surveys." *Journal of Official Statistics* 21(2):233-255

Delavande, Adeline and Susann Rohwedder. 2008. "Eliciting Subjective Probabilities in Internet Surveys." *Public Opinion Quarterly* 72(5): 866-891.

Dillman, Don A. 2000. *Mail and Internet Surveys: The Tailored Design Method.* New York: Wiley.

DiPrete, Thomas A. and Claudia Buchmann. 2006. "Gender Specific Trends in the Value of Education and the Emerging Gender Gap in College Completion." *Demography* 43:1-24.

Duncan, Otis D. and Beverly Duncan. 1955. "A Methodological Analysis of Segregation Indexes." *American Sociological Review* 20:210-217.

Eccles, Jacquelynne and xxx Hoffman. 1984. "Sex Roles, Socialization and Occupational Behavior." Pp. 367-420 in *Research in Child Development and Social Policy*: Volume 1, Edited by H.W. Stevenson and A.E. Siegel.

Eccles, Jacquelynne S. 1994. "Understanding Women's Educational and Occupational Choices: Applying the Eccles et al. Model of Achievement-Related Choices." *Psychology of Women Quarterly* 18:585-609

Eccles, Jacquelynne S., Bonnie Barber, and Debra Jozefowica. 1999. 'Linking Gender to Educational, Occupational, and Recreational Choice: Applying the Eccles et al Model of Achievement-Related Choices." Pp.153-91 in *Sexism and Stereotypes in Modern Society: the Gender Science of Janet Taylor Spence*. Washington D.C.: American Psychological Association.

Eccles, Jacquelynne. 2005. "Why Women Shy Away from Careers in Science and Math." Invited Address at Society for Research in Child Development, April 9. Summary available http://www.ur.umich.edu/0405/Apr11_05/06.shtml

England, Paula and Su Li. 2006. "Desegregation stalled: The Changing Gender Compositions of College Majors, 1971-2002." *Gender and Society* 20:657-677.

England, Paula, Paul Allison, Su Li, Noah Mark, Jennifer Thompson, Michelle J. Budig, and Han Sun. 2007. "Why are Some Academic Fields Tipping Toward Female? The Sex Composition of U.S. Fields of Doctoral Degree Receipt, 1971-2002." *Sociology of Education* 80(1):23-42.

England, Paula. 1981. "Assessing Trends in Occupational Sex Segregation, 1900-1976." Pp. 273-95 in *Sociological Perspectives on Labor Markets,* Edited by Ivar Berg. New York: Academic.

England, Paula. 1982. "The Failure of Human Capital Theory to Explain Occupational Sex Segregation." *The Journal of Human Resources* 17:358-370.

Etzkowitz, Henry, Carol Kemelgor, Michael Neuschatz, Brian Uzzi and Joseph Alonzo. 1994. "The Paradox of Critical Mass for Women in Science." *Science* New Series 266(5128):51-54.

Farmer, Helen S. 1997. "Women's Motivation Related to Mastery, Career salience, and Career Aspiration: A Multivariate Model Focusing on the Effects of Sex Role Socialization." *Journal of Career Assessment* 5:355-381.

Fiske, Susan T. 1998. "Stereotyping, Prejudice and Discrimination." Pp. 357-411 in *Handbook of Social Psychology*, edited by Daniel T. Gilbert, Susan T. Fiske and Gardner Lindzey. New York: McGraw-Hill

Foor, Cynthia E., Susan E. Walden, and Deborah A. Trytten. 2007. "I Wish that I Belonged More in this Whole Engineering Group: Achieving Individual Diversity." *Journal of Engineering Education* 96(2):103-115.

Fox, Mary Frank and Carol Colatrella. 2006. "Participation, Performance, and Advancement of Women in Academic Science and Engineering: What is at Issue and Why." *Journal of Technology Transfer* 31:377-386.

Freeman, Catherine E. 2004. *Trends in Educational Equity of Girls and Women.* Washington, DC. National Center for Education Statistics.

Frehill, Lisa M. 1997. "Education and Occupational Sex Segregation: The Decision to Major in Engineering." *The Sociological Quarterly* 38(2):225-249.

Frehill, Lisa M. 2006. "Measuring Occupational Sex Segregation of Academic Science and Engineering." *Journal of Technology Transfer* 31:345-354.

Frome, Pamela M. and Jacquelynne S. Eccles. 1998. "Parents' Influence on Children's Achievement-Related Perceptions." *Journal of Personality and Social Psychology* 74(2):435-452.

Gallagher, Ann M., and James C. Kaufman, Eds. 2005. *Gender Differences in Mathematics: An Integrative Psychological Approach.* Cambridge, UK: Cambridge University Press.

Gelman, Andrew and Jennifer Hill. 2007. *Data Analysis using Regression and Multilevel/Hierarchical Models.* Cambridge: Cambridge University Press.

Georges, Annie. 1999. *Keeping What We've Got: The Impact of Financial Aid on Minority Retention in Engineering.* National Council for Minorities in Engineering, Inc.

Gerber, Theodore, P. and Sin Yi Cheung. 2008. "Horizontal Stratification in Postsecondary Education: Forms, Explanations and Implications." *Annual Review of Sociology* 34:299-318.

Gianakos, Irene and Linda M. Subich. 1988. "Student Sex and Sex Role in Relation to College Major Choice." *Career Development Quarterly* 36(3):259-68.

Gibbons, Michael, T. 2008. *Engineering by the Numbers*. American Society for Engineering Education.

Glenn, Evelyn Nakano. 1999. "The Social Construction and Institutionalization of Gender and Race." Pp.3-43 in *Revisioning Gender,* edited by Myra Marx Ferree, Judith Lorber, and Beth B. Hess. Sage Publications: Thousand Oaks, CA.

Goldin, Claudia and Cecilia Rouse. 2000. "Orchestrating Impartiality: The Impact of "Blind" Auditions on Female Musicians." *The American Economic Review* 90(4):715-741.

Goldin, Claudia. 1980. "The Historical Evolution of Female Earnings Functions and Occupations." NBER Working Paper No. 529.

Goldin, Claudia. 1990. *Understanding the Gender Gap: An Economic History of American Women*. New York: Oxford University Press.

Goldrick-Rab, Sara. 2006. "Following Their Every Move: An Investigation of Social-Class Differences in College Pathways." *Sociology of Education* 79(1):61-79.

Goodman, Irene F., Christine M. Cunningham, Cathy Lachapelle, Meredith Thompson, Katherine Bittinger, Robert T. Brennan, and Mario Delci. 2002. Final Report of the Women's Experiences in College Engineering Project. Cambridge, UK: Goodman Research Group.

Goyette, Kimberly A. and Ann L. Mullen. 2006. "Who Studies the Arts and Sciences? Social Background and the Choice and Consequences of Undergradute Field of Study." *Journal of Higher Education* 77:497-538.

Grandy, Jerilee. 1994. *Gender and Ethnic Differences Among Science and Engineering Majors: Experiences, Achievement, and Expectations*. RR-94-30. Princeton, NJ: Educational Testing Service.

Granovetter, Mark S. (1995). *Getting a Job: a Study of Contacts and Careers*. The University of Chicago Press, Chicago.

Granovetter, Mark. (1988). "The Sociological and Economic Approaches to Labor Market Analysis: A Social Structural View." Pp. 187-216 In *Industries, Firms and Jobs: Sociological and Economic Approaches*, edited by George Farkas and Paula England. New York, Plenum Press.

Grodsky, Eric and Devah Pager. 2001. "The Structure of Disadvantage: Individual and Occupational Determinants of the Black-White Wage Gap." *American Sociological Review* 66:542-567.

Gross, Edward. 1968. "Plus Ça Change...? The Sexual Structure of Occupations over Time." *Social Problems* 16:198-208.

Grusky, David B. and Charles, Maria. 1998. "The Past, Present, and Future of Sex Segregation Methodology." *Demography* 35:497-504.

Haberman, Shelby, J. 1988. "A Stabilized Newton-Raphson Algorithm for Log-Linear Models for Frequency Tables Derived by Indirect Observation." *Sociological Methodology* 18:193-211

Hakim, Catherine. 1992. "Explaining Trends in Occupational Segregation: The Measurement, Causes and Consequences of the Sexual Division of Labour." *European Sociological Review* 8:127-152.

Hall, Roberta M. and Bernice R. Sandler. (1982). *The Classroom Climate: A Chilly One for Women?* Report published by Project on the Status and Education of Women, Association of American Colleges. Washington DC.

Harris, Betty J., Teri Reed Rhoads, Susan E. Walden, Teri J. Murphy, Reinhild Meissler and Anne Reynolds. 2004. "Gender Equity in Industrial Engineering: A Pilot Study." *National Women's Studies Association Journal* 16(1):186-193.

Hartman, Harriet and Moshe Hartman. 2006. "Leaving Engineering: Lessons from Rowan University's College of Engineering." *Journal of Engineering Education* 95(1):49-61.

Hartman, Harriet and Moshe Hartman. 2007. "The Gender Impact of Different Engineering Majors." Presented at the First International Conference on Research in Engineering Education.

Hartman, Harriet and Moshe Hartman. 2009. "Do Gender Differences in Undergraduate Engineering Orientations Persist when Major is Controlled?" *International Journal of Gender, Science and Technology* 1(1). Http://genderandset.open.ac.uk

Hartman, Moshe, Harriet Hartman and Jennifer Kadlowec. 2007. "Gender Across Engineering Majors." Presented at the American Society for Engineering Education Annual Conference.

Hearn, James C. 1991. "Nonacademic Influences on the College Destinations of 1980 High School Graduates." *Sociology of Education* 64:158-171.

Hearn, James C. and Susan Olzak. 1981. "The Role of College Major Departments in the Reproduction of Sexual Inequality." *Sociology of Education* 54:195-205.

Heerwegh, Dirk and Geert Loosveldt. 2008. "Face-to-face versus web surveying in a high-internet-coverage population: Differences in response quality." *Public Opinion Quarterly* 72(5):836-846.

Heilman, Madeline, E. 1995. "Sex Stereotypes and Their Effects in the Workplace." *Journal of Social Behavior and Personality* 10:3-26.

Hout, Michael, Raftery, Adrian E., and Eleanor O. Bell. 1993. "Making the Grade: Educational Stratification in the United States, 1925-1989." Pp 25-50 in *Persistent Inequality: Changing Educational Attainment in Thirteen Countries*, edited by Yossi Shavit and Hans-Peter Blossfeld. Boulder, CO: Westview Press.

Howe, Kenneth R. 1988. "Against the Quantiative-Qualitative Incompatibility Thesis or Dogmas Die Hard." *Educational Researcher* 17(8):10-16.

Huang, Gary, Nebiyu Taddasse and Elizabeth Walter. 2000. *Entry and Persistence of Women and Minorities in College Science and Engineering Education* (NCES 2000-061). Washington, DC: U.S. Government Printing Office.

Huang, Penelope M. and Suzanne G. Brainard. 2001. "Identifying Determinants of Academic Self-Confidence Among Science, Math, Engineering, and Technology Students." *Journal of Women and Minorities in Science and Engineering* 7:315-337.

Huber, Joan. 1990. "Macro-Micro Links in Gender Stratification: 1989 Presidential Address." *American Sociological Review* 55(1):1-10.

Jackson, Shirley A. 2005. "The Quiet Crisis and the Future of American Competitiveness." Speech given at American Chemical Society ACS Fall National Meeting. Available at: http://www.rpi.edu/president/speeches/ps082905-acs.html

Jacobs, Janis E. 2005. "Twenty Five Years of Research on Gender and Ethnic Differences in Math and Science Career Choices: What Have we Learned?" *New Directions for Child and Adolescent Development* 110:85-94.

Jacobs, Janis E. and Jacquelynne S. Eccles. 1985. "Gender Differences in Math Ability: The Impact of Media Reports on Parents." *Educational Researcher* 14:20-25.

Jacobs, Janis E., Laura L. Finken, Nancy Lindsley Griffin, and Janet D. Wright. 1998. "The Career Plans of Science Talented Rural Adolescent Girls." *American Educational Research Journal* 35:681-704.

Jacobs, Jerry A. 1985. "Sex Segregation in American Higher Education." Pp. 191_214 in *Women and Work: An Annual Review*, edited by Laurie Larwood, Ann H. Stromberg, and Barbara Gutek. Beverly Hills, CA: Sage Press.

Jacobs, Jerry A. 1986. "The Sex Segregation of Fields of Study: Trends During the College Years." *The Journal of Higher Education* 57(2):134-154.

Jacobs, Jerry A. 1987. "The Sex Typing of Aspirations and Occupations: Instability During the Careers of Young Women." *Social Science Quarterly* 68(1):122-37.

Jacobs, Jerry A. 1989. *Revolving Doors: Sex Segregation and Women's Careers*. Stanford, CA: Stanford University Press.

Jacobs, Jerry A. 1992. "Introduction to the Special Issue on Sex Segregation and Gender Stratification." *Special Issue of Work and Occupations* 19(4):339-341.

Jacobs, Jerry A. 1993. "Theoretical and Measurement Issues in the Study of Sex Segregation in the Workplace: Research Note." *European Sociological Review* 9(3):325-330.

Jacobs, Jerry A. 1995. "Gender and Academic Specialties: Trends Among Receipients of College Degrees in the 1980s." *Sociology of Education* 68(2):81-98.

Jacobs, Jerry A. 1996. "Gender Inequality and Higher Education." *Annual Review of Sociology* 22:153-185.

Jacobs, Jerry A. 1999a. "Gender and the Stratification of Colleges." *Journal of Higher Education* 70(2):161-87.

Jacobs, Jerry A. 1999b. "Sex Segregation of Occupations: Prospects for the 21st Century." Pp. 125-141 in *Handbook of Gender in Organizations*, edited by Gary Powell. Thousand Oaks, CA: Sage Publications.

Jacobs, Jerry A. 2001. "Evolving Patterns of Sex Segregation." Pp. 535-550 in Sourcebook on Labor Markets: Evolving Structures and Processes, edited by Ivar Berg and Arne Kalleberg. New York: Plenum.

Jacobs, Jerry A. 2003. "Detours on the Road to Equality: Women, Work and Higher Education." *Contexts* 2(1):32-41.

Jacobs, Jerry A. and Suet T. Lim. 1992. "Trends in Occupational and Industrial Sex Segregation in 56 Countries, 1960-1980." *Work and Occupations* 19(4):450-486.

Jaynes, Gerald David and Robin Murphy Williams. 1989. *A Common Destiny: Blacks and American Society*. Washington, DC: National Academy Press.

Joy, Lois. 2003. "Salaries of Recent Male and Female College Graduates: Educational and Labor Market Effects." *Industrial Labor Relations Review* 56:600-621.

Kanter, Rosabeth Moss. 1977. "Some Effects of Proportion on Group Life: Skewed Sex Ratios and Responses to Token Women." *American Journal of Sociology* 82:965-990.

Kanter, Rosabeth Moss. 1977. *Men and Women of the Corporation*. New York: Basic Books.

Kaplowitz, Michael D., Timothy D. Hadlock, and Ralph Levine. 2004. "A comparison of web and mail survey response rates." *Public Opinion Quarterly* 68:94-101.

Kaufman, Robert L. 2001. "Race and Labor Market Segmentation." Pp. 645-668 in *Sourcebook of Labor Markets: Evolving Structures and Processes*, edited by Ivar Berg and Arne L. Kalleberg. New York: Kluwer Academic/Plenum Publishers.

Keller, Dana, James Crouse, and Dale Trusheim. (1993). "Relationships among Gender Differences in Freshman Course Grades and Course Characteristics." *Journal of Educational Psychology* 85:702–709.

Kilbourne, Barbara, Paula England, and Kurt Beron. 1994. "Effects of Individual, Occupational, and Industrial Characteristics on Earnings: Intersections of Race and Gender." *Social Forces* 72(4):1149-1176.

Kilgore, Deborah, Cynthia J. Atman, Ken Yasuhara, Theresa J. Barker, and Andrew Morozov. 2007. "Considering Context: A Study of First-Year Engineering Students." *Journal of Engineering Education* 96(4):321-334.

Koch, James V. 1972. "Student Choice of Undergraduate Major Field of Study and Private Internal Rates of Return." *Industrial and Labor Relations Review* 26(1):680-685.

Kreuter, Frauke, Stanley Presser, and Roger Tourangeau. 2008. "Social Desirability Bias in CATI, IVR, and Web Surveys: The Effects of Mode and Question Sensitivity." *Public Opinion Quarterly* 72(5):847-865.

Kuh, George D., Robert M. Gonyea, Kelly E. Kish, Richard N. Muthiah, and Auden D. Thomas. 2003. College Student Experiences Questionnaire: Norms for the 4th Edition. Bloomington, IN: Center for Postsecondary Research and Planning, Indiana University.

Kwak, Nojin and Barry Radler. 2002. "A Comparison Between Mail and Web Surveys: Response Pattern, Respondent Profile and Data Quality." *Journal of Official Statistics* 18:257-273.

Lackland, Anne, C and Richard De Lisi. 2001. "Students' Choices of College Majors that are Gender Traditional and Nontraditional." *Journal of College Student Development* 42(1):39-47.

Lareau, Annette and Elliot B. Weininger. 2003. "Cultural Capital in Educational Research: A Critical Assessment." *Theory and Society* 32(5-6):567-606.

Lee, Valerie E. and Anthony S. Bryk. 1989. "A Multilevel Model of the Social Distribution of High School Achievement." *Sociology of Education* 62:172-192.

Lennox, Terri L., Charles R. Woratschek, and Gary A. Davis. 2008. "Exploring Declining CS/IS/IT Enrollments." *Information Systems Education Journal* 6(44):3-11.

Lent, Robert W., Hung-Bin Sheu, Daniel Singley, Janet A. Schmidt, Linda C. Schmidt, Clay S. Gloster. 2008. "Longitudinal Relations of Self-Efficacy to Outcome Expectations, Interests and Major Choice Goals in Engineering Students." *Journal of Vocational Behavio*r 72:328-335.

Lent, Robert W., Steven D. Brown, Hung-Bin Sheu, Janet Schmidt, Bradley R. Brenner, Clay S. Gloster, Gregory Wilkins, Linda C. Schmidt, Heather Lyons, Dana Treistman. 2005. "Social Cognitive Predictors of Academic Interests and Goals in Engineering: Utility for Women and Students at Historically Black Universities." *Journal of Counseling Psychology* 52:84-92.

Lichtenstein, Gary, Heidi G. Loshbaugh, Brittany Claar, Helen L. Chen, Kristyn Jackson,and Sheri D. Sheppard. 2009. "An Engineering Major Does Not (Necessarily) an Engineer Make: Career Decision Making Among Undergraduate Engineering Majors." *Journal of Engineering Education* 98:227-234.

Lieberson, Stanley. 1980. *A Piece of the Pie: Blacks and White Immigrants Since 1880.* Berkeley and Los Angeles: University of California Press.

London Business School (2007). *Innovative Potential: Men and Women in Teams.* Executive summary available from http://www.london.edu/assets/documents/Word/Innovative_Potential_NOV_2007.pdf

Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables.* Thousand Oaks, CA: Sage Publications, Inc.

Lucas, Samuel R. 2001. "Effectively Maintained Inequality: Educational Transitions, Track Mobility, and Social Background Effects." *American Journal of Sociology* 106:1642-1690.

Manfreda, Katja Lozar and Vasja Vehovar. 2002. "Do Mail and Web Surveys Provide Same Results?" *Development in Social Science Methodology* 18:149-169.

Manfreda, Katja Lozar, Michael Bosnjak, Jernej Berzelak, Iris Haas, and Vasja Vehovar. 2008. "Web Surveys Versus Other Survey Modes: A Meta-Analysis Comparing Response Rates." *International Journal of Market Research* 50(1):79-104.

Mannon, Susan E. and Paul D. Schreuders. 2007. "All in the Engineering Family? The Family Occupational Background of Men and Women Engineering Students." *Journal of Women and Minorities in Science and Engineering* 13:333-351.

Maple, Sue A. and Frances K. Stage. 1991. "Influences on the Choice of Math/Science Major by Gender and Ethnicity." *American Educational Research Journal* 28(1):37-60.

Mare, Robert D. 1981. "Change and Stability in Educational Stratification." *American Sociological Review* 46:72-87.

Margolis, Jane and Allan Fisher. 2002. *Unlocking the Clubhouse: Women in Computing.* Cambridge, MA: MIT press.

Marini, Margaret M. and Mary C. Brinton. 1984. "Sex-Typing in Occupational Socialization." Pp. 191-232 in *Sex Segregation in the Workplace: Trends, Explanations, Remedies,* edited by B.F. Reskin. Washington, DC: National Academy Press.

Marra, Rose M., Kelly Rodgers, Demei Shen, and Barbara Bogue. 2009. "Women Engineering Students and Self-Efficacy: A Multi-Year, Multi-Institution Study of Women Engineering Student Self-Efficacy." *Journal of Engineering Education* 98(1):27-38.

Marra, Rose M., Mieke Schuurman, Cherith Moore, and Barbara Bogue. 2004."Women engineering students' self-efficacy beliefs –The longitudinal picture". Proceedings of the annual meeting of the American Society for Engineering Education Annual Conference a, 12 – 15 June, Portland, OR.

Massey, Douglas S. and Nancy A. Denton. 1989. "Hypersegregation in U.S. Metropolitan Areas: Black and Hispanic Segregation along Five Dimensions." *Demography* 26:373-93.

Massey, Douglas S., Michael J. White, and Voon-Chin Phua. 1996. "The Dimensions of Segregation Revisited." *Sociological Methods and Research* 25:172-206.

Matsuoka, Yoky. MacArthur Fellows 2007. MacArthur Foundation. Retrieved April 10, 2010. www.macfound.org

Mattioli, Dana and Nick Wingfield. 2010. "Apple's 'iPad' Name Draws Snickers." Wall Street Journal Online, January 27, Retrieved April 10, 2010.

Mau, Wei-Cheng, Margaret Dominick, and Randolph A. Ellsworth. 1995. "Characteristics of Female Students who Aspire to Science and Engineering or Homemaking Occupations." *Career Development Quarterly* 43:323-37.

May, Gary S. and Daryl E. Chubin. 2003. "A Retrospective on Undergraduate Engineering Success for Underrepresented Minority Students." *Journal of Engineering Education* 92(1):27-39.

McCall, Leslie. 2001. "Sources of Racial Wage Inequality in Metropolitan Labor Markets: Racial, Ethnic, and Gender Differences." *American Sociological Review* 66(4):520-541.

Mcllwee, Judith S. and J. Gregg Robinson. 1992. *Women in Engineering: Gender, Power, and Workplace Culture.* Albany: State University of New York.

Mendez, Guillermo, Trent D. Buskirk, Sharon Lohr, and Susan Haag. 2008. "Factors Associated with Persistence in Science and Engineering Majors: An Exploratory Study using Classification Trees and Random Forests." *Journal of Engineering Education* 97(1):57-70.

Morgan, Glenn and David Knights. 1991. "Gendering Jobs: Corporate Strategy, Managerial Control and the Dynamics of Job Segregation." *Work, Employment and Society* 5:181-200.

Mullen, Ann L. 2001. "Gender, Race and the College Science Track: Analyzing Field Concentrations and Institutional Selectivity." *Journal of Women and Minorities in Science and Engineering* 7:285-300.

Mullen, Ann L. and Jayne Baker. 2008. "Gender, Race and Ethnic Segregation of Science Fields in U.S. Universities." *Journal of Women and Minorities in Science and Engineering* 14(2):159-176.

Muller, Chandra. 1998. "Gender Differences in Parental Involvement and Adolescent Mathematics Achievement." *Sociology of Education* 71:336-356.

Murphy, Teri J., Randa L. Shehab, Teri Reed-Rhoads, Cindy E. Foor, Betty J. Harris, Deborah A. Trytten, Susan E. Walden, Mary Besterfield-Sacre, M. Susan Hallbeck, and William C. Moor. 2007. "Achieving Parity of the Sexes at the Undergraduate Level: A Study of Success." *Journal of Engineering Education* 96(3):241-252.

Nakao, Keiko and Judith Treas. 1990. "Computing 1989 Occupational Prestige Scores". *GSS Methodological Report #70*

National Academies. 2007. Committee on Prospering in the Global Economy of the 21st Century Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, National Academy of Sciences, National Academy of Engineering, Institute of Medicine. *Rising above the Gathering Storm: Energizing and Employing America for a Bright Economic Future:* National Academies Press, Washington DC. 2007.

National Academies. 2007. "Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering." Committee on Maximizing the Potential of Women in Academic Science and Engineering, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine.

National Action Council for Minorities in Engineering. 2008. *Confronting the 'New' American Dilemma, Underrepresented Minorities in Engineering: A Data-Based Look at Diversity*. Executive Summary

National Association of Colleges and Employers (NACE). 2009. *Salary Survey. A Study of 2008-2009 Beginning Offers.* www.naceweb.org

National Center for Education Statistics. 2008. Table 191. College Enrollment and Enrollment Rates of Recent High School Completers, by Sex: 1960 through 2006. *Digest of Education Statistics.*

National Survey of Student Engagement. (2002). *National Benchmarks of Effective Educational Practice.* Bloomington: Indiana University Center for Postsecondary Research and Planning.

Nauta, Margaret M. and Douglas L. Epperson. 2003. "A Longitudinal Examination of the Socio-Cognitive Model Applied to High School Girls' Choices of Nontraditional College Majors and Aspirations." *Journal of Counseling Psychology* 50(4):448-457.

Nauta, Margaret M., Douglas L. Epperson, and Jeffrey H. Kahn. 1998. "A Multiple-Groups Analysis of Predictors of Higher Level Career Aspirations among Women in Mathematics, Science and Engineering Majors." *Journal of Counseling Psychology* 45(4):483-496.

Neckerman, Kathryn, M. and Florencia Torche. 2007. "Inequality: Causes and Consequences." *Annual Review of Sociology* 33:335-57.

Nelson, Donna J. 2005. The Nelson Diversity Surveys Norman: OK, http://chem.ou.edu/~djn/djn.html. Accessed 2009.

Newman, Jerry M. 1978. "Discrimination in Recruitment: An Empirical Analysis." *Industrial and Labor Relations Review* 32(1):15-23.

Okamoto, Dina and Paula England. 1999. "Is There a Supply Side to Occupational Sex Segregation?" *Sociological Perspectives* 42:557-582.

Orenstein, Peggy. 1994. *Schoolgirls: Young Women, Self-Esteem, and the Confidence Gap.* NY: Doubleday.

Ott. Mary Diederich. 1978. "Retention of Men and Women Engineering Students." *Research in Higher Education* 9:137-50.

Page, Scott. 2007a." Diversity Powers Innovation." Centers for American Progress January 26, 2007. retrieved May 10, 2010. http://www.americanprogress.org/issues/2007/01/diversity_powers_innovation.html

Page, Scott. 2007b. *The Difference: How the Power of Diversity Helps Create Better Groups, Firms, Schools, and Societies.* New Jersey: Princeton University Press.

Pannekoek, Jeroen. 1985. "Log-Multiplicative Models for Multiway Tables." *Sociological Methods Research* 14:137-153.

Pascarella, Ernest T., Elizabeth J. Whitt, Marcia I. Edison, Amaury Nora, Linda Serra Hagedorn, Patricia M. Yeager, Patrick T. Terenzini. 1997. "Women's Perceptions of a "Chilly Climate" and Their Cognitive Outcomes During the First Year of College." *Journal of College Student Development* 38(2):109–124.

Paterson, Lindsay and Cristina Iannelli. 2007. "Social Class and Educational Attainment: A Comparative Study of England, Wales, and Scotland." *Sociology of Education* 80(4):330-358.

Peng, Samuel S. and Jay Jaffe. 1979. "Women who Enter Male-Dominated Fields of Study in Higher Education." *American Educational Research Journal* 16:289-93.

Perdue, Charles W., John F. Dovidio, Michael B. Gurtman and Richard B. Tyler. 1990. "'Us' and 'Them': Social Categorization and the Process of Intergroup Bias." *Journal of Personality and Social Psychology* 59:475-86.

Peterson, Karen L. and Bruce Roscoe. 1983. "The Home Economics Undergraduate as Seen in Demographic Profiles." *Journal of Home Economics* 75(2):38-40.

Pike, Gary R. and George D. Kuh. 2006. "Relationships among Structural Diversity, Informal Peer Interactions and Perceptions of the Campus Environment." *The Review of Higher Education* 29(4):425-450.

Polachek, Soloman W. 1979. "Occupational Segregation among Women: Theory, Evidence, and a Prognosis." Pp. 137-157 in *Women in the Labor Market*, edited by Cynthia Lloyd, Emily Andrews, and Curtis Gilroy. New York: Columbia University Press,

Polachek, Soloman W. 1981. "A Supply-Side Approach to Occupational Segregation." Annual Meeting American Sociological Association, Toronto.

Polachek, Solomon William. 1978. "Sex Differences in College Major." *Industrial and Labor Relations Review* 31:498-508.

Polachek, Solomon William. 1981. "Occupational Self-Selection: A Human Capital Approach to Sex Differences in Occupational Structure" *Review of Economics and Statistics* 63:60-69.

Polachek, Solomon William. 1985. "Occupation Segregation: A Defense of Human Capital Predictions." *The Journal of Human Resources* 20(3):437-440.

Powell, Brian and Jerry A. Jacobs. 1984. "Gender Differences in the Evaluation of Prestige." *Sociological Quarterly* 25:173-90.

Project to Assess Climate in Engineering (PACE). 2010. PACE Workshop on Organizational Transformation. March 17-18, 2010 at the American Association for the Advancement of Science in Washington DC. Personal Communication.

Queneau, Hervé. 2006. "Is the Long-Term Reduction in Occupational Sex Segregation Still Continuing in the United States?" *The Social Science Journal* 43(4):681-688.

Raftery, Adrian E. 1986. 'Choosing Models for Cross-Classifications". *American Sociological Review* 51(1):145-146.

Raftery, Adrian E. 1995. "Bayesian Model Selection in Social Research." *Sociological Methodology* 25:111-163.

Ramirez, Francisco, O. and Christine Min Wotipka. 2001. "Slowly but Surely? The Global Expansion of Women's Participation in Science and Engineering Fields of Study, 1972-92." *Sociology of Education* 74:231-251.

Raudenbush, Stephen W. and Anthony S. Bryk. 2002. *Hierarchical Linear Models: Applications and Data Analysis Methods*. Thousand Oaks, CA: Sage Publications, Inc.

Rayman, Paula and Belle Brett. 1995. "Women Science Majors: What Makes a Difference in Persistence after Graduation." *Journal of Higher Education* 66(4):388-414.

Reay, Diane, Miriam E. David, and Stephen J. Ball. 2005. Degrees of Choice, Social Class, Race and Gender in Higher Education. Staffordshire, England: Trentham Books Limited.

Reskin, Barbara F. 1988. "Bringing the Men Back in: Sex Differentiation and the Devaluation of Women's Work." *Gender and Society* 2(1):58-81.

Reskin, Barbara F. 1993. "Sex Segregation in the Workplace." *Annual Review of Sociology* 19:241-270.

Reskin, Barbara F. 2000. "The Proximate Causes of Discrimination: Research Agenda for the Twenty-First Century." *Contemporary Sociology* 29:319-29.

Reskin, Barbara F. and Heidi Hartmann. 1986. *Women's Work, Men's Work: Sex Segregation on the Job*. Washington, D.C.: National Academy Press.

Reskin, Barbara F. and Irene Padavic. 1994. *Women and Men at Work*. Thousand Oaks: Pine Forge Press.

Reskin, Barbara F. and Patricia A. Roos. 1990. *Job Queues, Gender Queues: Explaining Women's Inroads into Male Occupations*. Philadelphia: Temple University Press

Reskin, Barbara F., Debra B. McBrier, and Julie A. Kmec. 1999. "The Determinants and Consequences of Workplace Sex and Race Composition." *Annual Review of Sociology* 25:335-61.

Ridgeway, Cecilia L. 1991. "The Social Construction of Status Value: Gender and other Nominal Characteristics." *Social Forces* 70(2):367-386.

Ridgeway, Cecilia L. 1997. "Interaction and the Conservation of Gender Inequality: Considering Employment." *American Sociological Review* 62(2):218-235.

Ridgeway, Cecilia L. and Kristan Glasgow Erickson. 2000. "Creating and Spreading Status Beliefs." *American Journal of Sociology* 106:579-615.

Ridgeway, Cecilia L. and Lynn Smith-Lovin. 1999. "The Gender System and Interaction." *Annual Review of Sociology* 25:191-216

Riegle-Crumb, Catherine, George Farkas, and Chandra Muller. 2006. "The Role of Gender and Friendship in Advanced Course Taking." *Sociology of Education* 79(3):206-228.

Robinson, J.Gregg and Judith S. McIlwee. 2005 "Men, Women and the Culture of Engineering." *The Sociological Quarterly* 32(3):403-421.

Robst, John, Jack Keil, and Dean Russo. 1998. "The Effect of Gender Composition of Faculty on Student Retention." *Economics of Education Review* 17:429-439.

Rosenfeld, Rachel A. and Gunn Elisabeth Birkelund. 1995. "Women's Part-Time Work: A Cross-National Comparison." *European Sociological Review* 11:111-134.

Sax, Linda. 1994. "Retaining Tomorrow's Scientists: Exploring the Factors that Keep Male and Female College Students Interested in Science Careers." *Journal of Women and Minorities in Science and Engineering* 1:45-61.

Sax, Linda. 1996. "The Impact of College on Post-College Commitment to Science Careers: Gender Differences in a Nine-Year Follow-up of College Freshmen." Presented at the Annual Meeting of the Association for the Study of Higher Education.

Seymour, Elaine. and Nancy M. Hewitt. 1997. *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, Co: Westview Press.

Shauman, Kimberlee A and Yu Xie. 2003. *Women in Science: Career Processes and Outcomes.* Cambridge: Harvard University Press

Shauman, Kimberlee A. 2006. "Occupational Sex Segregation and the Earnings of Occupations: What Causes the Link among College-Educated Workers?" *Social Science Research* 35:577-619.

Shavit, Yossi, Richard Arum, Adam Gamoran, Gila Menachem. eds. 2007. *Stratification in Higher Education.* Stanford: Stanford University Press.

Sills, Stephan J. and Chunyan Song. 2002. “Innovations in Survey Research: An Application of Web Surveys.” *Social Science Computer Review* 20:22–30.

Snijders, Tom and Roel Bosker. 1999. *Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling.* London: Sage Publications.

Snyder, Karrie, A. and Adam I. Green. 2008. "Revisiting the Glass Escalator: The Case of Gender Segregation in a Female Dominated Occupation." *Social Problems* 55(2):271–299.

Snyder, Thomas D., Sally A. Dillow and Charlene Hoffman. 2007. *Digest of Educational Statistics* 2006. Washington DC: National Center for Education Statistics.

Solnick, Sara J. 1995. "Changes in Women's Majors from Entrance to Graduation and Women's and Coeducational Colleges." *Industrial Labor Relations Review* 48:505-514.

Sonnert, Gerhard, Mary Frank Fox, and Kristen Adkins. 2007. "Undergraduate Women in Science and Engineering: Effects of Faculty Fields, and Institutions over Time." *Social Science Quarterly* 88(5):1333-1356.

Sonnert, Gerhard. 1995. *Gender Differences in Science Careers.* New Brunswick, NJ: Rutgers University Press.

Spencer, Steven J., Steele, Claude M. and Diane Quinn. 1999. "Stereotype Threat and Women's Math Performance." *Journal of Experimental Social Psychology* 35(1)4-28.

Steele, Claude M and Aronson, Joshua. 1995. "Stereotype Threat and Intellectual Task Performance of African Americans." *Journal of Personality and Social Psychology* 69:797-811.

Steele, Claude M. 1997. "A Threat is in the Air: How Stereotypes Shape Intellectual Identity and Performance." *American Psychologist* 52(6):613-629.

Strenta, A.Christopher, Rogers Elliot, Russell Adair, Michael Matier, and Jannah Scott. 1994. "Choosing and Leaving Science in Highly Selective Institutions." *Research in Higher Education* 35:513-547.

Summers, Lawrence, H. 2005. Remarks at NBER Conference on Diversifying the Science & Engineering Workforce. Cambridge, Mass. January 14, 2005.

Tam, Tony. 1997. "Sex Segregation and Occupational Gender Inequality in the United States: Devaluation or Specialized Training?" American Journal of Sociology 102(6): 1652-1692.

Thompson, Maxine Seaborn, Karl L. Alexander, and Doris R. Entwisle. 1988. Household Composition, Parental Expectations, and School Achievement. *Social Forces* 67(2):424-451.

Thorne, Barrie. 1993. *Gender Play: Girls and Boys in School.* Rutgers University Press

Tillberg, Heather K. and J. McGrath Cohoon. 2005. "Attracting Women to the CS Major." *Frontiers* 26(1):126-140.

Tinto, Vincent. 1997. "Classrooms as Communities: Exploring the Educational Character of Student Persistence." *Journal of Higher Education* 68:599–623.

Tomaskovic-Devey, Donald. 1993. *Gender and Racial Inequality at Work: The Sources and Consequences of Job Segregation.* Ithaca, NY: ILR.

Tourangeau, Roger, Lance J. Rips, and Kenneth Rasinski. 2000. *The Psychology of Survey Response*. Cambridge: Cambridge University Press.

Toutkoushian, Robert K. and John C. Smart. 2001. "Do Institutional Characteristics Affect Student Gains from College?" *The Review of Higher Education* 25(1):39-61.

Trenor, Julie M., Shirley L. Yu, Consuelo L. Waight, Katherine S. Zerda and Ting-Ling Sha. 2008. "The Relations of Ethnicity to Female Engineering Students' Educational Experiences and College and Career Plans in an Ethnically Diverse Learning Environment." *Journal of Engineering Education* 97(4):449-465.

Turner, Sarah E. and William G. Bowen. 1999. "Choice of Major: the Changing Unchanging Gender Gap." *Industrial Labor Relations Review* 52:289-313.

Tyson, Will, Reginald Lee, Kathryn M. Borman and Mary Ann Hanson. 2007. "Science, Technology, Engineering, and Mathematics (STEM) Pathways: High School Science and Math Coursework and Postsecondary Degree Attainment." *Journal of Education for Students Placed at Risk* 12(3):243-270.

U.S. Department of Education. 2000. 1999–2000 National Postsecondary Student Aid Study (NPSAS:2000). Washington, DC: U.S. Government Printing Office.

U.S. Department of Education. 2008. National Center for Education Statistics. *The Condition of Education 2008* (NCES 2008-031), Indicator 24.

U.S. Department of Education. Lists of Postsecondary Minority Institutions. Retrieved from http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst-list.html

US News & World Report. August 21, 2009. Best Undergraduate Engineering Programs-Best Colleges-Education.

Van de Werfhorst, Herman G., Alice Sullivan, and Sin Yi Cheung. 2003. "Social Class, Ability and Choice of Subject in Secondary and Tertiary Education in Britain." *Britain Educational Research Journal* 29(1):41-62.

van der Lippe, Tanja and Liset van Dijk. 2002. "Comparative Research on Women's Employment." *Annual Review of Sociology* 28:221-241.

Vogt, Christina M. 2008. "Faculty as a Critical Juncture in Student Retention and Performance in Engineering Programs." *Journal of Engineering Education* 97(1):27-36.

Voogt, Robert J.J. and Willem E. Saris. 2005. "Mixed Mode Designs: Finding the Balance between Nonresponse Bias and Mode Effects." *Journal of Official Statistics* 21:367-387.

Walden, Susan E. and Cindy E. Foor. 2008. "What's to Keep you from Dropping Out?" Student Immigration Into and Within Engineering." *Journal of Engineering Education* 97(2): 191-205.

Watson, Karan and Jeffrey Froyd. 2007. "Diversifying the U.S. Engineering Workforce: A New Model." *Journal of Engineering Education* 96(1):19-32.

Watts, Martin. 1998. "The Analysis of Sex Segregation: When is Index Measurement Not Index Measurement?" *Demography* 35(4):505-508.

Weber, Max. 1968. *Economy and Society*, edited by G. Roth and C. Wittich and translated by E. Frischoff, et al. New York: Bedminster Press.

Weeden, Kim A. 1998. "Revisiting Occupational Sex Segregation in the United States, 1910-1990: Results from a Log-Linear Approach." *Demography* 35(4):475-487.

Weeden, Kim A. 2004. "Profiles of Change: Sex Segregation in the United States, 1910-2000" Pp. 131-78 in Occupational Ghettos, by Maria Charles and David Grusky. Stanford: Stanford University Press.

Weis, Lois. and Michelle Fine. Eds. 1993. *Beyond Silenced Voices: Class, Race and Gender in United States Schools.* Albany: SUNY Press.

Whitt, Elizabeth J., Marcia I. Edison, Ernest T. Pascarella, Amaury Nora, and Patrick T. Terenzini. 1999. "Women's Perceptions of a "Chilly Climate" and Cognitive Outcomes in College: Additional Evidence." *Journal of College Student Development* 40(2):163-177.

Williams, Christine L. 1995. *Still a Man's World: Men who do Women's Work*. University of California Press.

Williams, Joan. 2000. "Deconstructing the Ideal-Worker Norm in Market Work." in *Unbending Gender: Why Family and Work Conflict and What to Do About It*. NY: Oxford University Press.

Willis, Paul E. 1981. *Learning to Labor: How Working Class Kids Get Working Class Jobs.* New York: Columbia University Press.

Wilson, Kenneth L. and Janet P. Boldizar. 1990. "Gender Segregation in Higher Education: Effects of Aspirations, Mathematics Achievement, and Income." *Sociology of Education* 63:62-74.

Wolfe, J. and Powell, E. 2009. "Biases in Interpersonal Communication: How Engineering Students Perceive Gender Typical Speech Acts in Teamwork." *Journal of Engineering Education* January:5-15.

Wong, Raymond Sin-Kwok. 1995. "Extensions in the Use of Log-Multiplicative Scaled Association Models in Multiway Contingency Tables." *Sociological Methods Research* 23:507-538.

Wulf, William A. (1998). "Diversity in Engineering," *The Bridge* 28(4):8-13.

Wyer, Mary. 2003. "The Importance of Field in Understanding Persistence among Science and Engineering Majors." *Journal of Women and Minorities in Science and Engineering* 9:273-286.

Xie, Yu and Kimberlee A. Shauman. 1997. "Modeling the Sex-Typing of Occupational Choice: Influences of Occupational Structure." *Sociological Methods and Research* 26:233-261.

Xie, Yu and Kimberlee A. Shauman. 2003. *Women in Science: Career Processes and Outcomes*. Harvard University Press, Cambridge, MA.

Yamaguchi, Kazuo. 1995. "Editor's Introduction to the Special Issue on Log-Linear and Log-Multiplicative Models." *Sociological Methods Research* 24:3-6.

Yoder, Janice D. and Thomas L. Schleicher. 1996. "Undergraduates Regard Deviation from Occupational Gender Stereotypes as Costly for Women." *Sex Roles* 34(3/4):171-188.

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CURRICULUM VITAE

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Dissertation: Sex Segregation in Undergraduate Engineering Majors
Committee: Becky Pettit (Chair), Julie Brines, Jerry Herting, Suzanne G. Brainard
Passed General Exam 2008
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Title: "Do those who labor together stay together? The influence of specialization, perceptions of fairness and gender ideology on marital stability"

Bachelor of Arts in Communication, Illinois State University, 1998
Minors in Women's Studies and Spanish, Summa Cum Laude

RESEARCH INTERESTS

Educational Stratification, Diversity in Science and Engineering, Gender, Inequality, Institutional Transformation, Family, Workforce, Social and Ethical Issues in Nanotechnology

EMPLOYMENT

Director for Research, Center for Workforce Development (CWD), University of Washington October 2006 – Present
Current Job Responsibilities

- Project manager of Alfred P. Sloan Foundation funded National Project to Assess Climate in Engineering research study, UW ADVANCE evaluation, National Center for Women & Information Technology evaluation, National Center for Women & Information Technology-Extension Services evaluation,
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Associate Director for Research, CWD, University of Washington, February 2006-September 2006

Senior Research Associate, CWD, University of Washington, March 2005-January 2006

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Teaching Assistant, University of Washington, 2000-2003

PEER-REVIEWED PAPERS

- Yen, Joyce W., Kate Quinn, Coleen Carrigan, Elizabeth Litzler, and Eve A. Riskin. (2007) "The ADVANCE Mentoring-for-Leadership Lunch Series for

Women Faculty in STEM at the University of Washington." *Journal of Women and Minorities in Science and Engineering*, 13 (3):191-206.

- Quinn, K. & Litzler, E. (2009). "Turning away from academic careers: What does work-family have to do with it?" *The Journal about Women in Higher Education*, 2:66-90.

REFEREED CONFERENCE PAPERS

- Litzler, E., Jaros, S., Metz, S., & Brainard, S.G. (2010). "Gender and Race/Ethnicity in Engineering: Preliminary Findings from the Project to Assess Climate in Engineering." Accepted for presentation at the 2010 ASEE conference: Louisville, KY.
- Metz, S., Brainard, S.G. & Litzler, E. (2010). "Extending Research into Practice: Results from the Project to Assess Climate in Engineering (PACE)." Accepted for presentation at the 2010 ASEE conference: Louisville, KY.
- Quinn, K. & Litzler, E. (2008). "Exploring the Role of Work-Family Concerns in Graduate Students' Decisions Not to Pursue Academic Careers. American Educational Research Association (AERA) Conference.
- Blaser, B., Wheeless, A. & Litzler, E. (2007). "Enhanced Connections: Making Changes to Mentoring Programs for Science and Engineering Graduate Students." WEPAN Annual Meeting Proceedings, Orlando, FL.
- Wheeless, A., Blaser, B. & Litzler, E. (2007). "Mentoring of graduate students in STEM: Perceptions and Outcomes". ASEE Annual Meeting Proceedings, Honolulu.
- Litzler, E., Claiborne, C. & Brainard, S.G. (2007) "Five years later: the institutionalization and sustainability of ADVANCE". ASEE Annual Meeting Proceedings, Honolulu.
- Bassett, D. & Litzler, E. (2006). "Competing discourses of disruptive technologies: A case study." Society for the Social Studies of Science Conference, Vancouver, B.C. November 2006
- Litzler, E., & Lange, S.E. (2006). "Differences in Climate for Undergraduate and Graduate Women in Engineering: The Effect of Context". ASEE Annual Meeting Proceedings, Chicago, IL.
- Litzler, E., Lange, S.E., Mody, P., & Brainard, S.G. (2006). "Retention Rates and Differences between Leavers and Stayers". WEPAN Annual Meeting Proceedings, Pittsburgh, PA.
- Litzler, E., Lange, S.E. & Brainard, S.G. (2005). "Career Outcomes of Science and Engineering Graduates". WEPAN / NAMEPA Annual Meeting Proceedings, Las Vegas, NV.
- Litzler, E., Lange, S.E. & Brainard, S.G. (2005). "Climate for Graduate Students in Science and Engineering Departments". ASEE Annual Meeting Proceeding, Portland, OR.
- Litzler, E., & Brines, J. (2005). "A Fair Bargain? Breadwinning Arrangements, Interpersonal Comparisons, and the Risk of Divorce". ASA Annual Meetings, Philadelphia.

- Litzler, E. (2004). “Do those who labor together stay together? The influence of specialization, perceptions of fairness and gender ideology on marital stability”. ASA Annual Meetings, San Francisco
- Powers, E. & Litzler, E. (2004). “Gender and the Organizational Determinants of Training”. ASA Annual Meetings, San Francisco

PAPERS IN PROGRESS

- Young, J. & Litzler, E. “Investigating the Factor Structure and Invariance of Transfer Student Adjustment to College using Confirmatory Factor Analysis.” Under revision for submission to the Community College Journal of Research and Practice.
- Litzler, E., Jaros, S., Young, J., Metz, S. & Brainard, S.G. “The intersection of Gender and Race in Undergraduate Engineering Majors.” Under revision for submission to the Journal of Engineering Education.
- Blaser, B., Litzler, E., & Wheeless, A. “Enhancing relationships: Making modifications to an established mentoring program for STEM Graduate Students.” Revise and Re-submit to the Journal of Women and Minorities in Science and Engineering.
- Blaser, B., Litzler, E. & Wheeless, A. “Mentoring of graduate students in STEM: Perceptions and Outcomes.” Under revision for submission to Journal of Engineering Education
- Litzler, E., Jaros, S., Lange, S.E., Mody, P. & Brainard, S.G. “The impact of women in science and engineering programs on undergraduate retention rates in engineering.” Under revision for submission to Journal of Women and Minorities in Science and Engineering.
- Litzler, E., Jaros, S., Lange, S.E., & Brainard, S.G. “Graduate Student Climate in STEM: impact on persistence.” Under revision for submission to Journal of Engineering Education

CONFERENCES

- Metz, Susan and Litzler, Elizabeth. (2010). “Retention of Undergraduate Engineering Students: Extending Research into Practice.” A panel discussion. 2010 WEPAN/NAMEPA conference, Baltimore, MD.
- Cohoon, Joanne McGrath, Thompson, Leisa D., Goodall, Jennifer, Dohrman, Rebecca, and Litzler, Elizabeth. (2010). “Consultants on Systemic Reform for Gender Balance.” SIGCSE March 10-13, 2010, Milwaukee, Wisconsin, USA
- Hughes, C. A., Gilbert, S. G., Meischke, H. W., & Litzler, E. (2007). Perceived Risks and Hazards of Nanotechnology. Society of Toxicology Meeting, 2007

INVITED PAPERS AND PRESENTATIONS

Computing Research Association, Invited speaker to *Gender Diversity in Computing, A workshop sharing new findings on Graduate Women's Recruitment and Retention*, “Science and Engineering Climate in One Institution.” A workshop drawing from education, gender studies, and sociology to identify recruitment, admission, and retention practices that affect the gender balance in graduate computing programs, (Participants included William Aspray (Discussion Moderator), Lecia Barker, Suzanne Brainard, Rodney Brooks, J. McGrath Cohoon, Shelley Correll, Janice Cuny, Mary Frank Fox, Elizabeth Litzler, Holly Lord, Melissa Norr, Carla Romero, Louise Marie Roth, Lucinda Sanders, Sheryl Skaggs.) October 8, 2006, San Diego, CA.

GRANTS AND CONTRACTS

- Addressing university climate issues to improve retention for undergraduate engineering students, 2007-2012, Sloan Foundation grant, $354,390.40 (lead proposal writer)
- Impact of Merging WISE and MSEP Programs on Retention of Women in Engineering, 2006, Engineering Information Foundation grant, $25,000

PROFESSIONAL AFFILIATIONS

American Educational Research Association
American Evaluation Association
American Sociological Association
American Society for Engineering Education
Sociologists for Women in Society
UW Center for Research of Families
UW Center for the Study of Demography and Ecology
Women in Engineering ProActive Network

PROFESSIONAL ACTIVITIES AND SERVICE

2009-2010	Reviewer for ASEE 2010 and WEPAN/NAMEPA 2010 conferences ▪ Moderator at WEPAN/NAMEPA 2010 ▪ Co-chair of WEPAN Knowledge Center committee
2008-2009	Reviewer for WEPAN 2009 conference ▪ Reviewer for American Behavioral Scientist ▪ Consultant for National Academy of Engineering Project "GSE/Ext Engineering Equity Extension Service" (2008)
2007-2008	Reviewer for ASEE 2008 and WEPAN 2008 conferences
2006-2007	Reviewer for ASEE 2007 and WEPAN 2007 conferences
2005-2006	Reviewer for WEPAN 2006 conference
2003-2004	UW Sociology Graduate Student Association President ▪ Headed fundraising campaign to initiate a graduate student travel endowment. ▪ Sucessfully raised $25,000 to begin endowment.
2002-2003	UW Sociology Graduate Student Association Vice President and Committee Coordinator
2001-2002	UW Sociology Social Committee
2000-2001	UW Sociology Commons Committee