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Do Gender Differences in Undergraduate Engineering Orientations Persist when Major is Controlled?

Harriet Hartman and Moshe Hartman

Rowan University, New Jersey, USA

ABSTRACT

The question posed in this paper is how persistent are gender differences in engineering orientation and achievement, once we control for engineering discipline, cohort, and year in the program. The data come from a multi-year survey of engineering students at a mid-Atlantic public university, which has four engineering disciplines: chemical, civil/environmental, electrical/computing, and mechanical, which vary by proportion of women in them. Using multivariate analysis, we control for gender, cohort, year in the program, and major in the analysis of differences in engineering self-confidence, satisfaction with the core course and interpersonal climate, engineering grades, expectations from the undergraduate degree and long-term commitment to a career in engineering. We then are able to isolate the significant gender differences and interaction effects that persist when these other factors are held constant. We find that gender clearly matters with respect to engineering grades, self-confidence, satisfaction with the core course, and commitment to the engineering career, even when major, year, and cohort (and grades, for all of the other dependent variables) are controlled. However, gender differences with regard to peer integration are insignificant; and there are few remaining gender differences with regard to expectations from an engineering degree. Suggestions for further research are proposed.

KEYWORDS

Gender; Major; Engineering self-confidence; Academic achievement; Commitment to Engineering.

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INTRODUCTION

Women's under-representation in engineering is a well-documented phenomenon, both within the United States (Adelman, 1998; CAWMSET, 2000; NSF, 2008), and elsewhere (Bagilhole, 2002; Dryburgh, 1999; Franzway, et. al., 2009; Gill et. al., 2008; Nguyen, 2000; Van Langen and Dekkers, 2005). Concern about this under-representation stems from the demand side, in terms of a national need for more engineers and recognition that a diverse labor base enriches the profession, and from the supply side, in that women should have equitable accessibility to a lucrative and growing occupation (CAWMSET, 2000). Nevertheless, in the United States at least, women's representation has actually been on the decline after a slight increase during the 1990's. Reasons for the under-representation have been explored, and include differential socialization and aspirations along gender lines, which is related to differential attraction to engineering in general and more specifically to the various fields of engineering, as well as different educational and professional climates for the genders in these various disciplines. According to Gibbons (2006), because women are disproportionately enrolled and employed in areas of engineering that are smaller and have less growth, the overall proportion of women enrolled and employed in engineering is likely to continue to decline unless this tendency is addressed. In 2006, for example, women earned 34.5% of the bachelor's degrees in chemical engineering in the United States, 22.7% of those in civil engineering, but only 13.0% and 13.1% of those in electrical engineering and mechanical engineering, respectively (NSF, 2008). While women made up 22.2% of the employed environmental engineers in 2000, they represented only 14.4% of the employed chemical engineers; 10.1% of the employed civil engineers; 8.7% of the employed electrical engineers; and, 6.5% of the employed mechanical engineers (U.S. Bureau of the Census, 2000). Yet among these engineering fields it is precisely electrical and mechanical engineering which are the largest disciplines in engineering and are experiencing the greatest growth (Gibbons, 2006).

According to data collected by the American Society for Engineering Education,

> [Women] are well represented in disciplines such as agricultural, biomedical, chemical, environmental, industrial/manufacturing, and metallurgical and materials engineering. Women account for between 32 and 43 percent of bachelor's degrees in each of these fields…Women are less interested in the largest disciplines, including aerospace, computer, computer science, electrical, electrical/computer, and mechanical engineering. Female students range from 11 to 17 percent representation in these fields. These six disciplines make up 63 percent of all [engineering] bachelor's degrees. The solution to attracting more women to engineering will certainly require a review of this equation.
> (Gibbons, 2006, p.1)

The growth of computer engineering, in which men received over 87% of the bachelor's degrees awarded in 2005, is a major contributing factor to the decline in women's overall representation in engineering degrees, even though their absolute numbers in engineering are growing (Gibbons, 2006).

In their seminal study of undergraduate engineering and the engineering workplace, McIlwee and Robinson (1992) suggest that the engineering culture varies by discipline and by setting (academia, workplace) in ways that interact with gender to affect persistence, identity, self-efficacy, power and feelings of belongingness or comfort that they fit in this major or career. Such variance suggests that rather than lumping all "women in engineering" in one category, we might be able to better understand women's under-representation by focusing on particular disciplines, either those successful in recruiting more women or those particularly weak in doing so. Nevertheless, most studies of gender differences in engineering, or that specifically focus on women's persistence in engineering, have not distinguished between the various engineering disciplines in any depth (Campbell and Howey, 2003; CAWMSET, 2000; Seymour and Hewitt, 1997), although some research acknowledges that this avenue of inquiry is important (Jawitz and Scott, 1997). McIlwee and Robinson (1992) suggested that the academic culture does not vary as much by discipline as the workplace culture, and that this is due to the overriding status in academic culture being derived from academic achievement, which women succeed at as well as men. Other studies have suggested, however, that even in an academic context women face disadvantages due to the overwhelming masculinity of the engineering culture which forces women to choose between 'undoing' their gender or being perceived by themselves and others as 'other' (Franzway et. al., 2009; Tonso, 1999).

These differences in the discipline go beyond the question of the proportion of women in the particular discipline, although this is not an insignificant consideration. Williams and Emerson (2001), quoted in Madill et al (2007), suggest that the effect of being a minority is not eliminated until a 'critical mass' of 30% is reached, and as the statistics above show, there are few engineering disciplines where more than 30% of the undergraduates are women. Nevertheless, this is one significant way in which engineering disciplines vary, which may affect the gendered patterns of persistence and experience. Other ways are the extent to which socialization that includes 'tinkering' or hands-on experimenting with mechanical and technical activities and ease doing such 'tinkering' activities are valued.

Ask female engineering undergraduates whether they notice differences between themselves and their male counterparts, and they are likely to deny any or trivialize those they see. In part this reflects their demonstrable conforming to the engineering culture (Dryburgh, 1999; Tonso, 1999), but also this reflects only minor differences in their pre-college qualifications and their academic performance. Nevertheless, gender differences are apparent and persist in engineering self-confidence; satisfaction with engineering programs; expectations from the engineering degree; and, commitment to a future in engineering (Hartman and Hartman, 2003). The research has also shown that both men and women vary in their engineering orientations by engineering discipline. Engineering students in different disciplines vary in their perceived strengths in engineering, which is related to their satisfaction with engineering as a suitable fit for them, and they also vary in terms of what they expect to be the returns on their engineering degree (Hartman and Hartman, 2007). However, in at least one study, gender differences in engineering grade point averages (GPA's) (women's being higher) disappeared when major was controlled (Hartman, Hartman and Kadlowec, 2008). Therefore, another reason to consider gender differences by engineering discipline is the possibility that observed gender differences among engineering students or professionals may be camouflaged or inflated because of the differential distribution of the genders across engineering disciplines. Studying the variation in gender differences by engineering discipline may help us to better identify, and thereby address, the precise nature of gender difference.

The question addressed in this paper is:

- To what extent does the distribution of undergraduate men and women across engineering disciplines contribute to gender differences in engineering?

More specifically, we ask:

1. Are gender differences in grades; engineering self-confidence; satisfaction with engineering major; satisfaction with peers; and, commitment to engineering as a career diminished or eliminated when the specific engineering discipline is controlled?
2. How much variation in these variables is there between majors (for women or men)?
3. Is there an interaction between gender and major, so that women and men in the same major have different orientations to and achievements in engineering?

DATA

Data were collected in surveys conducted during 2002 – 2008 as part of an ongoing study of all engineering students at a public university on the East Coast of the United States in a mid-Atlantic state. During each of these years, students participated in one survey at the beginning of the fall semester and one at the end of the following spring semester. The aggregated data increases the sample size and hence the reliability of the findings, although the single site of data collection does present some questions of generalizability that will be addressed in the concluding discussion.

The data reported in this paper are taken from the responses to the spring surveys of students that queried, among other topics, attitudes toward engineering; self-confidence in engineering; satisfaction with the major and the career; commitment to a future in engineering; and, expectations from a degree in engineering.

This study is exemplary in its inclusion of over 85% of the students in any given semester, as surveys were distributed in courses required of each student majoring in engineering. Both men and women were surveyed enabling differences between majors and other characteristics of students to be compared both within and across genders.

The engineering college has four engineering disciplines: chemical, civil/environmental, electrical/computer, and mechanical. These disciplines vary by proportion of women, and sometimes that proportion varies considerably by cohort as well (Table 1). It should be noted that while the representation of women in chemical engineering compares favorably with national representation, women are underrepresented in comparison with national averages of degrees awarded in the other disciplines, especially in electrical and computer engineering.

Table 1: Percentage of Women Students in Major by Year of Survey (n)

	Chemical	**Civil/ environmental**	**Electrical/ computer**	**Mechanical**
Spring 2002	26.7 (60)	29.7 (74)	4.7 (107)	13.4 (97)
Spring 2003	35.5 (62)	23.1 (52)	8.2 (97)	10.2 (127)
Spring 2004	29.2 (65)	29.3 (75)	6.3 (95)	11.0 (109)
Spring 2005	31.6 (76)	15.0 (80)	7.4 (81)	9.6 (94)
Spring 2006	28.8 (73)	11.8 (85)	4.5 (66)	11.0 (91)
Spring 2007	28.2 (85)	16.1 (87)	7.2 (69)	9.7 (93)
Spring 2008	31.6 (76)	11.9 (84)	4.2 (72)	15.7 (102)
Total % (n)	31.4 (497)	19.0 (537)	6.1 (587)	11.5 (713)

Dependent Variables.

Dependent variables are the indicators for which we try to determine the sources of variation. In this section, we introduce each of the indicators we use by describing the questions by which the variable was measured in the survey and how we created indices from multiple questions measuring the same variable. Unless otherwise noted, the survey questions were phrased in such a way that the students could respond with the extent to which they agreed or disagreed with a statement using a scale of 1-5, from strongly disagree to strongly agree. Where there were multiple questions for a variable, the data were reduced into a smaller number of indicators using factor analysis, a technique which clusters indicators into a small number of factors based on the similarity of their variation. In our analyses, all factor analyses were performed using the principal components Varimax rotation method. Analysis verified that the factors that emerged were identical in content between the genders, and over the years of the program. The reliability test was also performed over multiple groups to make sure that the index worked similarly for all subgroups in the analysis. The reliability of the resulting indices can be expressed by the percentage of variance explained by the factor and the reliability Chronbach coefficient, which we give in parentheses.

Engineering grades.
Students self-reported their grade point average (GPA) in their engineering courses.

Engineering self-confidence.
Students rated themselves in terms of how well they thought they 'fit' in engineering. They were asked to respond to statements about how well-suited they were for their choice of college major and chosen career; whether they considered themselves mechanically inclined, technically inclined and good at designing things; and, whether they felt competent in the skills required for their major. The factor resulting from these statements explained 62.8% of the variance (Chronbach α=.879). The overall mean of the factor score is 0, with lower scores indicating less self-confidence, and higher scores indicating greater self-confidence.

Satisfaction with the core engineering course.
All students are required to take a common core course each semester, and this forms a foundational part of this engineering program. As such, we focused on the students' satisfaction with this course. Since teamwork is integral to this course (Farrell, et. al., 2001), it is of particular interest in terms of gender; teamwork is widely considered to be the favored pedagogy of women as compared to men (Rosser, 1991), and yet teamwork can at times work to women's disadvantage (Felder et. al., 1995). While factor analysis resulted in two factors of the statements, we focused on the first factor, which explained 37.5% of the variance in the items (Chronbach α=.824). The five items with high loading on this factor were: the course provides realistic experiences like in the work world; the course provides useful hands-on experiences; the interdisciplinary nature of the course enables me to connect things from different disciplines; the course unifies students in the same class but from different majors; and, overall the course experience is beneficial. The overall mean of the factor score is 0, with lower scores indicating less satisfaction, and higher scores indicating greater satisfaction.

Satisfaction with peers.
Students were asked to respond to a series of 13 statements about their peers. Items with high loading on the first factor (which explained 57.8% of the variance in the statements, with Chronbach α=.905) include: engineering students are approachable, supportive, friendly, help each other, listen, respect me, care about me, are proud to be engineering students, and feel a sense of community in the engineering college. The overall mean of the factor score is 0, with lower scores indicating less satisfaction with peers, and higher scores indicating greater satisfaction with peers.

Expectations.
We focused on three types of expectations students had about the type of job their degree would allow: getting a well-paying job, associating with interesting people, and being an important contributor to society. A prominent explanation for women's selective representation across engineering disciplines has been that women prefer majors in which the benefit to society is most clear (Goodman et. al., 2002; Seymour and Hewitt, 1997). The social benefits of science and technology seem to be much more important to women than to male students in similar fields (Sax, 1994). Advanced as a reason that women are less likely to choose and persist in engineering as a major in general, this preference for majors with clearer societal benefit can easily be extended to disciplines within engineering. We test this with our data.

Commitment to the engineering career.
We focused on the responses to the question of whether the student expected to be working as an engineer ten years from now (the survey date). Attrition of women engineers continues to be a greater problem than for men (Franzway et. al., 2009), and therefore this is an indicator of intentions for persistence in the engineering career even before employment begins. We had also asked what was the highest degree the student expected to achieve in engineering. We found, however, that responses reflected more the norms of the discipline, specifically how much training was rewarded or expected before getting a good job in the labor force, than the degree of long-term commitment to engineering. Students sometimes plan to attend graduate school in a field because they are unsure of their employability or employment possibilities; thus, intentions to continue on to graduate training may reflect a lack of self-confidence as an engineering professional rather than a commitment to the field.

Independent Variables
The independent variables were the indicators with which we attempted to explain the variation in the dependent variables, in order to understand how important these influences were. These influences included:
Gender.
1=men; 2=women.

Year in the program.
From 1=first-year to 4=senior.

Major: chemical, civil/environmental, electrical/computer; mechanical.
It should be noted that at this university, students are encouraged to select a major already in their first year, and there is relatively little switching during the course of the undergraduate years. Every semester of the survey, students were asked whether they had changed majors from the previous semester. Less than 5% of the women and 7% of the men reported changing majors within engineering in any given semester, and even fewer entered from non-engineering majors.

Term of Survey.
Slight changes have occurred in the program over the years; as such we introduced a control for the term the data was collected. By controlling for term in the analysis of variance, we also effectively control for the bias presented by having some of the same students in the sample for different years of the program. That is, mechanical engineering majors who began their program in 2002 as first-year students were sophomores in 2003, juniors in 2004, and seniors in 2005. If we did not control for the year in which the data was collected, we would be analyzing some of the same students four times. The model allows us to draw conclusions about whether, in any particular term (i.e., keeping term of the survey constant), year in the program affects our dependent variable. It also allows us to test whether the variation in the program (represented by term of survey) affects the dependent variable, or interacts with any of the other independent variables (gender, major, year in the program) in their relationship with the dependent variables. Alternatively, we could analyze each year in the program separately, but this would eliminate the opportunity to analyze how important year in the program was as an effect on any of our dependent variables. Or we could follow a particular cohort as they travelled through the program, and sometimes such an analysis is of interest (i.e., following a student's development in a longitudinal analysis). When we are attempting to tease out the relative importance of gender, major and year in the program, however, including the same student more than once might bias the results (e.g., for certain students, gender might make more of a difference in their attitudes than for others).

It should be noted that including both major and term of the survey effectively controls for the proportion of women in the student's immediate cohort, so we did not include a separate indicator of this.

METHOD

We realized that we needed a complex model that would handle the variations by gender, discipline, and year in the program in order to determine which explained the greatest variation once the others were controlled. We needed a method that would be able to control for the year the survey was administered, so that the presence in multiple years of the survey by any particular student would not bias the results. Not all of the independent variables could be ordered linearly (there was no a priori reason to expect one major to be more satisfied with engineering than another, for example, or to have higher/lower grades than another), and we wanted to check for interactions between the independent variables. Our method of choice was therefore analysis of variance. This method tells us the net effect of each of our dependent variables once the other variables have been controlled. For example, whether gender differences in engineering GPA are significant when we control for major, year in the program, and cohort; whether major differences in engineering GPA are significant when we control for gender, year in the program and cohort; and so on. It does not assume a linear effect of the independent variables, but actually shows us which of the categories are significantly different from others, and in what way. It also tells us whether the interaction of gender and major, for example, is significant:

whether major makes more or less of a difference for men and women's GPA. Examining the mean GPA's will tell us more about how this interaction affects GPA.

RESULTS

Academic Achievement (Engineering Grades).

Women have significantly higher engineering grades than men (mean engineering GPA of 3.40 compared to men's 3.23), even after we control for major, year in the program, and cohort (Table 2). There is a wider range in women's grades over major, however, resulting in a slight interaction (statistically significant only at $p<.10$) between gender and major in terms of grades: women's grades range from a low average of 3.27 in mechanical engineering to a high average of 3.52 in chemical engineering; men's grades have a narrower range from an average of 3.14 in civil engineering to 3.29 in chemical engineering.

Not unexpectedly, grades also vary by year in the program. Grades are higher among first-year students, lowest for sophomores, and then higher in the junior and senior years (though not as high as first-year). This pattern seen in the total is also true for men but not for women. Among women, grades are highest among first-year students and decline with each successive year. As a result, the widest gender gap in grades is among first-year students, with men's average engineering GPA 3.30 compared to women's, 3.52; and the narrowest gender gap in grades is among seniors, with men's average engineering GPA 3.26 and women's, 3.27.

Table 2:Analysis of Variance of Engineering Grade Point Average (GPA)

	F (df)	**Observed Means (Adjusted Means)[a]**
Main effects		
Gender	17.39 (1)*	
Men		3.23 (3.24)
Women		3.40 (3.39)
Major	6.07 (3)*	
Chemical		3.36 (3.34)
Civil/environmental		3.18 (3.18)
Electrical/computing		3.23 (3.24)
Mechanical		3.27 (3.28)
Year in Program	8.22 (3)*	
First-year		3.33 (3.34)
Sophomore		3.18 (3.18)
Junior		3.22 (3.21)
Senior		3.29 (3.29)
Covariate		
Term of survey	2.76 (1)	
Two-way interactions		
Gender x Major	2.54 (3)*	
Gender x Year	.18 (3)	
Major x Year	.57 (9)	

[a]Adjusted for other main effects and covariate (term of survey).
*p<.05

Engineering Self-confidence.
Undergraduate engineering women have significantly less confidence that they fit in engineering than do men (mean factor scores .129 for men and -.244 for women, p<.05). Rather than this difference diminishing once major, year, cohort and grades are controlled, the difference actually widens; we can see this by comparing the mean scores of men and women before and after they have been adjusted for major, year in the program, term of the survey and engineering grades, and two-way interactions of the main effects. Men's mean engineering self-confidence increases from an unadjusted .129 to .141, while women's mean self-confidence decreases from -.244 to -.308 (Table 3). Therefore, gender differences in self-confidence cannot be explained by their differential distribution across majors or any of the other differences. Nor does controlling for women's higher grades improve their self-confidence. Gender explains almost as much variance in the factor scores as do grades (while students who have higher grades are more confident that they belong in engineering, the relationship between grades and self-confidence is stronger for men than for women) (Table 4).

Table 3: Means (Observed and Adjusted)[a] of Engineering Self-Confidence, Core Course Satisfaction and Satisfaction with Peers for Gender, Major, and Year in Program. Observed Means (Adjusted Means) [a]

	Engineering Self-Confidence	**Core Course Satisfaction**	**Satisfaction with Peers**
Main effects			
Gender			
Men	.129 (.141)	.000 (.008)	.048 (.056)
Women	-.244 (-.308)	.210 (.170)	.077 (.037)
Major			
Chemical	-.024 (.015)	.068 (.065)	.044 (.045)
Civil/environmental	.061 (.097)	.023 (.029)	.099 (.107)
Electrical/computer	-.015 (-.043)	-.083 (-.074)	-.010 (.000)
Mechanical	.217 (.191)	.120 (.109)	.082 (.067)
Year in Program			
First-year	-.062 (-.097)	-.126 (-.113)	-.121 (-.130)
Sophomore	.057 (.090)	.025 (.026)	.084 (.096)
Junior	.116 (.132)	.144 (.128)	.143 (.150)
Senior	.202 (.199)	.128 (.127)	.148 (.140)

[a]Adjusted in analysis of variance for other main effects and covariates (term of survey, GPA).

Table 4: Analysis of Variance of Engineering Self-Confidence, Core Course Satisfaction, and Satisfaction with Peers (F(df))

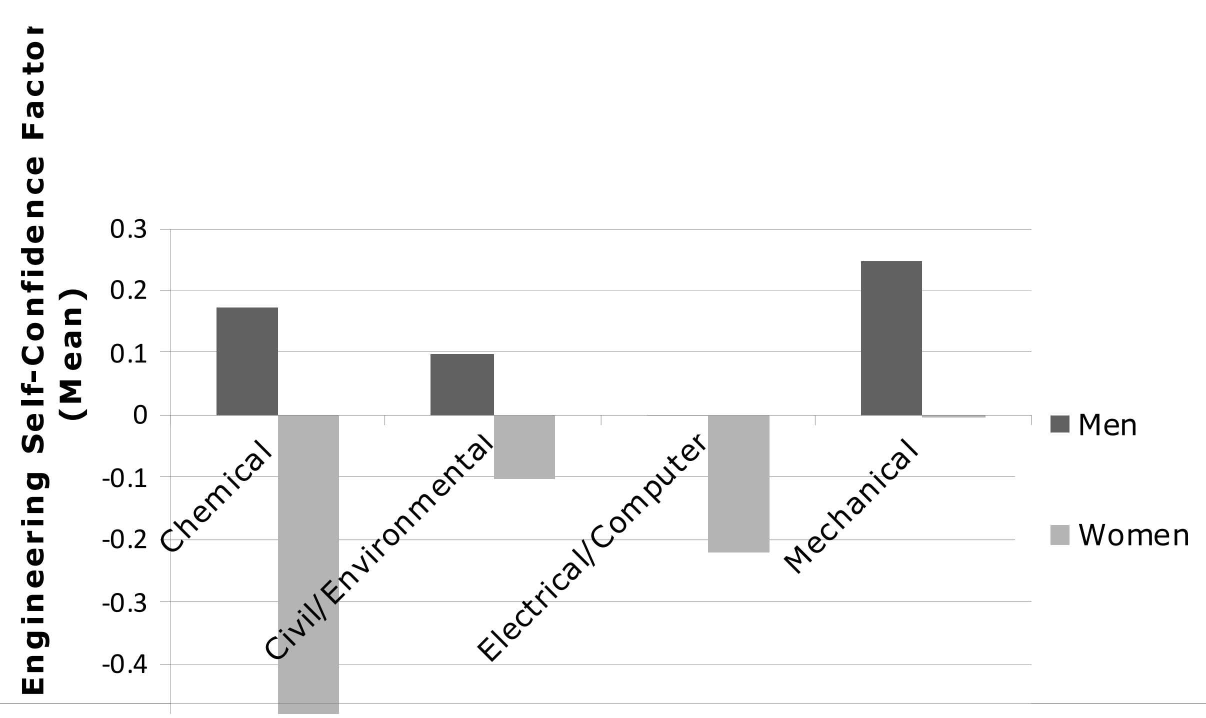
	Engineering Self-Confidence	**Core Course Satisfaction**	**Satisfaction with Peers**
Main effects			
Gender	38.89 (1)*	4.97 (1)*	0.07 (1)
Major	4.57 (3)*	2.56 (3)**	0.75 (3)
Year in Program	8.22 (3)*	6.80 (3)*	7.26 (3)*
Covariate			
Term of survey	1.53	21.12*	2.19
Engineering GPA	46.57*	0.34	5.37*
Two-way interactions			
Gender x Major	3.59(3)*	1.62 (3)	0.93 (3)
Gender x Year	1.39 (3)	0.11 (3)	0.23 (3)
Major x Year	1.48 (9)	2.28 (9)*	0.93 (9)

*p<.05; **p<.10.

While less important than these two factors, both major and year in the program also show significant variation in engineering self-confidence. Mechanical engineering students are the most confident, followed by civil/environmental engineering majors; electrical/computing engineering majors are next; while chemical engineering students have the weakest engineering self-confidence. After controlling for gender, year in the program, and cohort, mechanical and civil engineering majors remain the most confident, and electrical/computer and chemical engineering majors the least confident.

There is, however, a significant interaction effect between major and gender. While both men and women mechanical engineering majors are the most confident in themselves as engineers (the mean for women in mechanical engineering approaches 0 and actually lays on the 0 line and hence can barely be seen in the graph), electrical engineering majors are the least confident among the men (again, with a mean approaching 0, so that their average score lays right on the 0 line and can barely be seen in the graph), but chemical engineering majors are the least confident among the women. Further, major makes more of a difference among women than among men. The gender gap in engineering self-confidence is especially large among chemical engineering majors (see Figure 1). It is narrowest among civil/environmental majors.

Figure 1
Engineering Self-Confidence by Gender and Major



As might be expected, students are increasingly confident in themselves as engineers as they progress through the undergraduate program, with first-year students' mean factor score being -.062 compared to seniors' .202. The pattern is much clearer for men than for women, however; among men, self-confidence varies from -.032 among first-year students to .301 among seniors, $p<.001$; among women, the variation over year is very small, ranging from -.278 to -.233, and not statistically significant. Partly this reflects non-linear fluctuation in women's engineering self-confidence: sophomore women's self-confidence is higher than first-year women's self-confidence, but women's self-confidence is lower among juniors and seniors than it is for sophomores.

The year of the survey, or the engineering cohort, is not significantly related to engineering self-confidence.

Core course satisfaction.

Women are more satisfied with the core engineering course than are men (Table 3), and the gender differences remain once the other variables have been controlled, the gap diminishing only slightly. Gender is not, however, the most important factor explaining variation in course satisfaction (Table 4), and there is no interaction between gender and major or year in the program in how much it explains satisfaction with the core course.

More important than gender is the year in the program, with upper division students being more satisfied than lower division students. There is little difference between junior and senior satisfaction, which is to be expected, as juniors and seniors usually participate in the core course together.

There is an interaction between major and year in the program in terms of satisfaction with the course: there is a greater variation between majors among seniors, with electrical/computer engineering seniors being least satisfied compared to the other majors; and less variation by major among first-year students. This may be related to the interdisciplinary nature of the first-year course, which intentionally mixes students from different majors. As the core courses in junior and senior years vary by discipline, the variation by major may reflect a difference in the way this discipline runs its upper division core course. Further, while junior and senior core courses may also be multi-disciplinary, the teams themselves are more homogeneous. The variation by discipline may reflect variation in the projects the students in more advanced years are working on or how they integrate with the other majors in the various years.

The year that the survey was taken makes a significant difference in satisfaction with the core course (Table 4). This may reflect changes that have been made to the core course between 2002-2008. Unfortunately, these changes may not sit well with students, as there is less satisfaction with the course in 2008 than there were in earlier years.

Satisfaction with Peers.

There is no significant gender difference in terms of satisfaction with peers, once major, year in the program, grades, and survey year are controlled (Table 4). Both men and women feel equally positive about their peers. More important for explaining the variation in peer satisfaction is year in the program: the longer a student (whether man or woman) is in the program, the more positively they feel about their fellow students. Since cohorts in each of the majors travel through the program with their peers, solidarity builds as they encounter similar classes and projects. Apparently this camaraderie is positive and contributes to a feeling of community with their peers. Also, students who have higher grades are more positive about their peers (or perhaps peer integration helps a student succeed academically).

Expectations from the Engineering Degree.
There is no gender difference in the expectation that engineering will enable a well-paying job or a job with interesting people, and there is no significant variation in major, year, or cohort either. Students with higher grades are more likely to expect a well-paying job, but that is the only significant source of variation between students in this respect (Tables 5 and 6).

There is a slight tendency for women more than men to expect to be important contributors to society with an engineering degree, in line with the expectations that women place more importance on this facet of a career. There is also a tendency for chemical and civil/environmental engineering majors to have higher expectations in this regard than do electrical/computer or mechanical engineers; while a higher proportion of women are in chemical and civil/environmental engineering (as we saw above), the effects of gender and major are independent (the interaction between them is not statistically significant with regard to expecting to make a contribution to society). Students with higher grades have higher expectations in this regard, as well, but controlling for grades does not eliminate the gender difference in this respect, either.

Commitment to the Engineering Profession.
Men are more likely than women to anticipate working as an engineer ten years after college; this gender gap persists even when year, major, grades, and cohort are controlled (Tables 5 and 6). The relationship between major and commitment to working as an engineer is different for men and women. Women majoring in civil/environmental engineering are the women most likely to expect to be working as an engineer ten years later; in fact they are the most likely of any of the engineering students to express this long-term commitment. Men in this major are the least likely to express this commitment; it is men majoring in electrical/computer engineering who are the most committed among the male engineering students (Figure 2), and in all of the other majors, men are more likely to be committed to the engineering career than are women.

Table 5: Analysis of Variance of Expectations after Engineering Degree and Long-term Commitment (F(df))

	Expectations of Good Pay	**Expectations of Interesting People to Associate With**	**Expectations of Making Contribution to Society**	**Expect to be Working as Engineer in Ten Years**
Main effects				
Gender	0.00 (1)	2.08 (1)	2.95 (1)**	3.96 (1)*
Major	1.64 (3)	0.75 (3)	1.80 (3)	0.90 (3)
Year in Program	1.78 (3)	1.99 (3)	2.58 (3)**	3.02 (3)*
Covariate				
Term of survey	0.08	1.99	0.14	68.23*
Engineering GPA	4.72*	3.72*	4.45*	4.16*
Two-way interactions				
Gender x Major	0.14 (3)	2.16 (3)**	1.91 (3)	2.54 (3)**
Gender x Year	0.47 (3)	0.17 (3)	0.82 (3)	0.60 (3)
Major x Year	1.06 (9)	0.97 (9)	1.05 (9)	2.05 (9)*

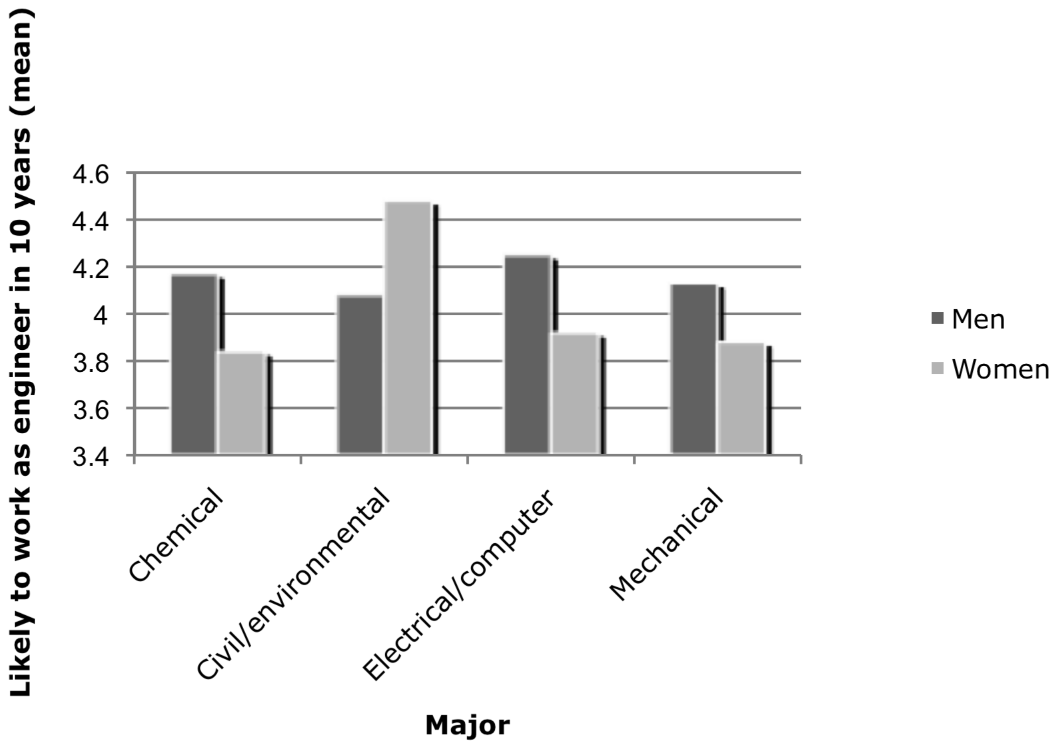
*p<.05; **p<.10.

Table 6: *Means (Observed and Adjusted)[a] of Expectations after Engineering Degree and Long-term Commitment for Gender, Major, and Year in Program Observed Means (Adjusted Means)[a]*

	Expectations of Good Pay	**Expectations of Interesting People to Associate With**	**Expectations of Making Contribution to Society**	**Expect to be Working as Engineer in Ten Years**
Main effects				
Gender				
Men	4.45 (4.45)	3.87 (3.87)	4.09 (4.10)	4.16 (4.17)
Women	4.48 (4.45)	3.95 (3.95)	4.22 (4.19)	4.02 (3.99)
Major				
Chemical	4.52 (4.50)	3.86 (3.84)	4.17 (4.16)	4.08 (4.11)
Civil/environmental	4.52 (4.50)	3.91 (3.91)	4.16 (4.17)	4.15 (4.20)
Electrical/computer	4.39 (4.39)	3.90 (3.91)	4.08 (4.09)	4.23 (4.19)
Mechanical	4.40 (4.41)	3.85 (3.85)	4.07 (4.06)	4.10 (4.08)
Year in Program				
First-year	4.53 (4.52)	3.86 (3.86)	4.05 (4.04)	4.11 (4.08)
Sophomore	4.50 (4.51)	3.93 (3.94)	4.17 (4.19)	4.07 (4.09)
Junior	4.39 (4.40)	3.86 (3.87)	4.18 (4.19)	4.31 (4.32)
Senior	4.38 (4.37)	3.86 (3.85)	4.13 (4.12)	4.08 (4.08)

[a]Adjusted in analysis of variance for other main effects and covariates (term of survey, GPA).

Figure 2
Long-term Commitment to Engineering by Gender and Major



DISCUSSION

With regard to our first research question, gender clearly matters with respect to engineering grades; self-confidence; satisfaction with the core course; and, commitment to the engineering career, even when major, year, and cohort (and grades, for all of the other dependent variables) are controlled. This reinforces previous findings in the literature, which have not controlled for major and year in the program. Of particular concern are the lower self-confidence and commitment of women, despite their higher grades on average; their satisfaction with the core course; and, perceived integration with their peers. Despite gains made in terms of retention and academic success in this particular program (Hartman and Hartman, 2006) and more generally nationwide, women continue to doubt their abilities as engineers and identify as engineering career professionals.

That women are more satisfied with the program than their male counterparts may simply reflect their assimilation to the engineering culture, which in turn may actually reinforce the dominant masculine engineering culture, rather than challenge it (Powell et. al, 2007). The underlying masculinity of engineering cultures across disciplines may well be the culprit, as Bagilhole (2002) suggests.

In line with this way of thinking, Bastalich et. al. (2007) suggest, 'there is a need to find a new kind of engineering image, one in which professional values, ethics and sensitivity to the effects of engineering outcomes in the world at large are emphasized' (p.397), and one in which one's feminine identity is not challenged by one's engineering identity.

Furthermore, women's self-confidence may actually be undermined by their anticipation of the workplace. Some of our earlier analysis shows that the gender gap among undergraduates in this particular engineering college narrows from first through third year, but in the senior year widens once again, mainly because graduating women do not increase their engineering self-confidence at the same rate that graduating men do (Hartman and Hartman, 2001). As Gill et al (2008) suggest, there is a need to incorporate into undergraduate engineering education 'more understanding of the politics of the workplace and the development of strategies in order to position themselves more effectively and comfortably as colleagues' (p.400). While this need is reflected by both men and women in Gill et al's study, it is particularly important for women, whose downfall is less their actual ability and more their positioning of themselves vis-à-vis colleagues and supervisors (Evetts, 1998; McIlwee & Robinson, 1992).

In contrast to the persistence of gender differences even when major, year and cohort have been controlled, gender differences with regard to peer integration are insignificant; and there are few remaining gender differences with regard to expectations from an engineering degree. That women and men espouse similar perceptions of solidarity and integration with their peers is encouraging; certainly, it would seem preferable to women's alienation. However, the findings may reflect a double-edged sword. Tonso (1999) and Franzway, et. al. (2009) and others caution against taking these findings at face value, since they may rather reflect women's efforts to 'undo' gender and blend in as 'one of the boys' (Powell, Bagilhole, & Dainty, 2009).

More important, perhaps, is our answer to our second research question, regarding the interaction between gender and major that is evident with regard to engineering self-confidence and long-term commitment to the career. Both of these variables are critical in terms of retaining women in the profession of engineering. The interaction does not follow the commonly expected lines of where women are more or less of a minority. Rather, the gender gap in self-confidence is widest among chemical engineering majors (which overall have nearly a third of their students women). Women's self-confidence is highest among mechanical engineering majors, which has on average only 11.5% women. Civil/environmental engineering, with an average of 19.0% women, shows the highest proportion of women committed to working as an engineer in the long-term (at least ten years). It is possible that there is a self-selection into these fields of the women already committed to a non-traditional field, which persists throughout their undergraduate career. These findings reinforce the more general conclusion reached by Huang et al (2000) that while women are less likely than men to enter science and engineering fields, those that do tend to have strong family support, high expectations, healthy self-confidence and solid academic preparation. A similar distinction may be able to be made between women who enter the least traditional engineering fields for women, as compared to women who enter fields in which there is a critical mass of women. However, the findings also recall McIlwee & Robinson's (1992) work on engineering professionals, which found that mechanical engineers showed greater gender equality than their counterparts in electrical or high-tech engineering. McIlwee & Robinson suggested that the more bureaucratic and stable the field, the greater the chances for women to excel, as criteria for success were impersonal and related to achievement. In the more changeable and innovative fields, individual self-promotion and bending of rules resulted in greater success, and the culture was dominated by masculine values of aggressive self-promotion. Perhaps these differences seep into the undergraduate culture as well.

It may also be that the disciplines themselves employ somewhat different models of learning that have differential effects in terms of empowering women and garnering their long-term commitment to disciplines. The next important step would be to compare disciplines across undergraduate settings to determine whether the gender dynamics and other differences that we found are common to the discipline in all settings, or are particular to this particular program and setting. While our findings are reliable for this particular undergraduate setting (because of the years that are spanned), this is a relatively new engineering program, which specializes in interdisciplinarity and integrates hands-on team projects throughout the undergraduate career. In fact, the curricular and pedagogical practices across engineering disciplines reflect inclusive, and female-friendly, 'best practices' in undergraduate engineering education (Hartman and Hartman, 2003). If the findings are unique to this setting, they signal where to focus further study to better understand the gendered results. If the findings are generalizable across settings, a better understanding of why the disciplines vary as they do should be addressed. Either conclusion would lead to clear implications as to where it is most beneficial to work on empowering women and diminishing gender differences; and provide models of best inclusive institutional practices in engineering education that have long-term implications for retaining women in the profession.

More generally, it is clear that studying all engineering students as a whole misses some important points about the undergraduate experience. Engineering students recognize differences between the disciplines (Shivy and Sullivan, 2003; Trytten et. al., 2005); and researchers have recognized differences between employment in the various disciplines (McIlwee & Robinson, 1992). It is time that researchers recognize the importance of this source of variation in undergraduate education, and its influence on gender differences in long-term commitment to the field, also.

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