AC 2007-1410: GENDER ACROSS ENGINEERING MAJORS

Moshe Hartman, Retired

Moshe Hartman (B.A., Hebrew University of Jerusalem; M.A. and Ph.D., University of Michigan) is retired Professor of Sociology from Ben-Gurion University of the Negev, and was co-p.i. on the NSF grant on which this paper is based. His research has centered on demography, stratification, and Jewish studies. His articles have been published in Journal of Engineering Education, Journal of Women and Minorities in Science and Engineering, American Journal of Sociology, International Journal of Sociology and Social Policy, Population Research and Policy Review, Journal of Contemporary Religion, and others.He co-authored the paper winning Best Paper Award from WIED and Pic IV for ASEE, 2005.

Harriet Hartman, Rowan University

Harriet Hartman (B.A., UCLA; M.A., University of Michigan; Ph.D., Hebrew University of Jerusalem) is Professor of Sociology at Rowan University, and was principal investigator of the NSF grant on which this paper is based. Her articles have appeared in Journal of Engineering Education and the Journal of Women and Minorities in Science and Engineering, Journal of Marriage and Family, Compare, Sociology of Religion, and Social Identities among others. Her co-authored paper won the Best Paper Award from the ASEE WIED and Pic IV in 2005. Her research interests include gender roles, Jewish studies, family and immigration.

Jennifer Kadlowec, Rowan University

Jennifer Kadlowec is an Associate Professor of Mechanical Engineering at Rowan University. She received her BS in physics at Baldwin-Wallace College and her MS and PhD in mechanical engineering at the University of Michigan. She has been actively involved in ASEE, serving in officer roles in the Mechanics and ERM Divisions.

Gender Differences Across Engineering Majors

Abstract

Certain engineering majors attract more women than others, and this seems to be fairly universal. Bio-engineering, biomedical engineering, chemical engineering, civil/environmental engineering lead in the proportion of women enrolling and persisting, while mechanical and electrical and computer engineering have the lowest proportions. Engineering programs that have increased their proportion of women usually incorporate more of the former specializations, or have added in a new program of this kind. Little research has been done comparing differences between the women in these different kinds of majors. This paper contributes to filling this gap by addressing how the women in majors that are more commonly attracting women differ from women in majors with proportionately fewer women. The paper draws on data aggregated from surveys collected during the last six years from engineering students at Rowan University. It compares women in mechanical and electrical/computer engineering, to women in chemical and civil/environmental engineering, where the proportions of women are larger. Students are compared in terms of their academic and family backgrounds, whether they come in with different orientations to engineering (including engineering self-confidence and expectations from the engineering degree), and whether they exhibit different levels or types of satisfaction with the engineering major. Five hypotheses are offered; most of them are not supported by the data. Background differences, differences in general academic and math/science self-confidence, attributions of success, and expectations about the engineering degree do not result in the expected differences. Women do differ with respect to engineering self-confidence. Results are also compared to men in the respective majors.

Introduction

Women are not distributed equally across the various engineering disciplines. According to data collected by the American Society for Engineering Education,

> They 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[4]: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[2].

Students' choice of majors has been linked to early socialization experiences from parents, teachers, academic preparation and success, work experience, and play (summarized recently by

Margolis & Fisher[9], and Tillberg & Cohoon[14]). Self-efficacy in the skills and characteristics perceived as necessary to the major has also been noted as a motivator for choice of major[3]. 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[5,13]. The social benefits of science and technology seem to be much more important to women than to male students in similar fields[11]. As a result, providing meaningful contexts for problem solving and applications has been suggested as a means of attracting and retaining women in engineering[1].

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. An obvious example within engineering is the increasing proportion of women enrolled in bioengineering or biomedical specializations, for which the societal benefits are most clear: over 40% of the bachelor's degrees awarded in biomedical and environmental engineering went to women in 2004-5[4]. Women's enrollment in bioengineering/biomedical specializations has more than doubled in the last decade, while in most other engineering specializations (such as chemical engineering, civil engineering, electrical engineering, mechanical engineering) the increase of female enrollment has been much more modest (calculated from NSF[10]). While women are also attracted to chemical and environmental engineering (earning 37.2% and 42.9% of the bachelor's degrees in these fields, respectively, in 2004-5), women still earn less than 15% of the bachelor's degrees in mechanical, electrical and computing engineering[4].

Surprisingly little research has focused on the differences between women in these various engineering disciplines in order to better understand better why some women are attracted to one discipline more than another. The present research addresses this gap by comparing first-year women in different engineering disciplines on a variety of background characteristics as well as orientations to engineering. Our aim is to study whether the women attracted to the different disciplines differ in any noticeable ways.

We wondered whether different kinds of women might be more attracted to, or less deterred from, fields in which they were smaller minorities such as mechanical or electrical/computing engineering than fields in which a higher proportion of women are now enrolled, such as chemical or civil engineering. Did such women have higher levels of support from significant others for their pursuit of the non-traditional field? Did they have stronger backgrounds in some of the skills considered necessary for succeeding in these fields? Would such women have higher levels of engineering self-confidence and/or self-confidence in general? Were they looking for different things from an engineering degree than women in other engineering majors?

Data

Data were taken from an ongoing study of Rowan University's engineering students, and aggregated for the years 2000-2005.[i,7] Students were administered one survey at the beginning of their first fall semester and one at the end of the following spring semester. The data reported in this paper are taken from the fall surveys, which queried first-year students' academic and family backgrounds, attitudes toward engineering, self-confidence in engineering, and expectations from a degree in engineering, among other topics.

For the purposes of this analysis, all first-year students from 2000-2005 were combined (after verifying that there were no major differences between the respective cohorts). Aggregating the data is functional because of the larger sample for analysis, especially when focusing on groups of students who are a minority of the students (such as women).

The resulting sample included 83 women: 29 chemical ("chem") engineering majors; 21 civil/environmental ("civ/env") engineering majors; 11 electrical/computing ("ECE") engineering majors; and 22 mechanical ("mech") engineering majors. The latter two majors were combined for most of the analysis, as for most of the years they have admitted smaller proportions of women than in the other majors, and they each have an average of less than 12% women in their first-year cohorts. Civil/environmental engineering, in contrast, has 15.4% women and Chemical engineering, 17.9%. For some purposes they are compared with their male counterparts, which included a total of 545: 133 chemical engineering majors, 115 civil engineering majors, 130 electrical/computing, and 169 mechanical engineering majors.

The students are compared on the following indicators, with the following hypotheses:

(1) Background characteristics: (a) Academic Background (self-reported) high-school grades generally, and in math and science in particular; Verbal and math SAT scores; participation in extra-curricular science or math activities in high school; AP courses taken in math and science; (b) Role Models: having a sister or brother in engineering, math or science; having a female math or science teacher (role model for women); (c) Support of significant others for the student's choice of engineering as a major and/or career.

Hypothesis 1: Women who enter fields that have lower proportions of women will have stronger academic backgrounds, greater exposure to more role models, and stronger support from significant others for their choice of such a non-traditional major or career.

(2) Self-confidence: (a) General academic skills; (b) Math-science academic skills; and (c) Engineering-related skills and subjects. Students were asked in what percentile they would place themselves in comparison to other students in their high school class (highest 10%, above average, average, below average, lowest 10%) in terms of several general traits and skills (drive to achieve, speaking skills, writing skills, test-taking skills, problem-solving skills, library skills, study skills, critical thinking, overall academic ability) and in terms of more specific math/science traits and skills (mathematical ability, interest in science, computer skills); they were also asked how confident they felt (strongly confident, confident, neutral, not confident, strongly not confident) about the following skills and subjects (problem-solving skills, critical thinking skills, study skills, chemistry, physics, calculus, math, computer science, biology). Students also rated themselves in terms of their engineering strengths, by the extent to which they agreed (a 5-point scale from strongly agree to strongly disagree) with 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, whether they were confident that they would do well in the math/science/engineering course they had this year, and whether they felt competent in skills required for their major.

Hypothesis 2: Women who enter fields that have lower proportions of women will exude higher self-confidence, both generally and in terms of more specific math, science, and engineering skills and competencies.

(3) Related to self-confidence, is the attribution of success to one's own efforts (such as study or preparation) or characteristics (such as ability) or external factors that may be transitory (such as luck) or more permanent (such as the ease or difficulty of the material). Women with higher confidence in themselves are more likely to attribute their success to their own characteristics rather than external factors[9]. Students were asked which of the following were least to most important (on a scale of 1, indicating the least important to 5, indicating the most important) in explaining their grades last year: their ability, their effort, luck, ease/difficulty of the material, the quality of teaching, and the amount of preparation.

Hypothesis 3: Women who enter fields that have lower proportions of women will attribute their grades to their own efforts rather than to external factors, while women who enter fields that have higher proportions of women will be more likely to attribute their grades to external factors.

(4) Students were also asked how satisfied they were with their major in engineering. They were asked the extent to which they agreed (a 5-point scale from strongly agree to strongly disagree) with statements about their personal satisfaction with the major, desire to change to another major, ability to think of more rewarding majors, confidence that engineering was the right major for them, the advantages of studying engineering outweighing the disadvantages, the future benefits of engineering being worth the effort.

Hypothesis 4: Women who enter fields that have higher proportions of women will be more satisfied with their fit in engineering.

(5) Students were asked what they expected from a degree in engineering. They were asked the extent to which they agreed (a 5-point scale from strongly agree to strongly disagree) with statements that a degree in engineering would enable them to: get a well-paying job, live in any geographic location they chose, get a job they liked doing, be respected by others, get a job where they could use their talents, get a secure job, get a challenging job, have time for outside interests, get a job where they could associate with interesting people, and be an important contributor to society.

Hypothesis 5: Women who enter civil/environmental and chemical majors will expect to contribute more to society through engineering, while women who enter mechanical or electrical/computing majors will be more concerned with the extrinsic benefits an engineering job will provide, like pay and personal freedom. Women will value engineering for being able to contribute to society and associating with interesting people more than men in the respective majors.

Background Characteristics

Background differences between the women who entered the various majors were minor. They were not significantly different in terms of whether they had taken AP math (calculus) or science (biology, chemistry, or physics) courses in high school. Their high school grades in math and science were not significantly different, nor were their SAT scores (verbal or math). Women tended to have similar or higher grades in math and science than their male counterparts. Most

striking, however, were the gender differences in high school math and science grades among civil/environmental majors, the women being significantly more likely to have had mostly A's in these subjects than the men (Table 1).

Table 1
Background Characteristics by Sex and Major

Sex:	Women			Men		
Major[a]:	Chem	Civil/ Env	Mech/ ECE	Chem	Civil/ Env	Mech/ ECE
Academic Background						
Math SAT (*mean score*)	643	621	622	657	644	647
Verbal SAT (*mean score*)	566*	580	597	597	576	589†
H.S.Math Grades (*% mainly A's*)	62.1	71.4*	45.5	53.4	41.7	49.8
H.S. Science Grades (*% mainly A's)*	51.7	61.9*	48.5	55.6	37.4	42.5†
AP Calculus *(% took)*	44.8	28.6	34.4	44.3	33.9	39.3
AP Chemistry (*% took*)	34.5	10.0	25.0	33.9	12.0	13.4†
AP Biology (*% took*)	17.9	25.0	3.4	15.7	10.9	6.7†
AP Physics (*% took)*	3.4	15.0	17.2	25.0	16.8	29.0†
H.S.math/science competitions (*% participated in)*	42.9	38.1	46.9	48.1	39.0	36.4
H.S.math/science clubs (*% participated in)*	39.3	38.1	41.9	39.5	32.1	34.9
H.S. math/science work experience (*% participated in)*	11.1	42.9*	20.0††	12.8	13.2	11.5
Role Models						
% brother in engineering/math/science	5.6	22.2	20.0	22.4	24.0	16.6
% sister in engineering/math/science	16.7	22.2	11.8	13.2	9.6	13.4
Support for Pursuit of Engineering (*% Strongly supportive)*						
Mother	82.8	85.0	78.8	87.9	93.0	85.8
Father	72.4	95.2*	90.6††	83.1	93.9	88.1†
Other relative or sibling[b]	57.1	80.0*	53.1	52.8	50.5	57.9
Best friend(s)	50.0	71.4	56.3	54.5	52.2	53.7
Boyfriend/girlfriend	56.0	72.2	64.3	56.3	58.9	52.1
Most influential high school teacher	72.4	71.4	81.3	75.6	71.9	73.3
High school guidance counselor	55.2	57.1	62.4	64.6	65.5	63.4
(n)	(29)	(21)	(33)	(133)	(112)	(298)

[a]In this and subsequent tables, Chem=chemical engineering major; Civil/Env = civil/environmental engineering major; Mech/ECE=mechanical/electrical/computing engineering major.
[b]The first year of the study students were asked about "other relatives"; in subsequent years they were asked about "siblings".
*χ^2 of differences between men and women in major significant at $p<.05$.
†χ^2 of differences between male majors significant at $p<.05$.
††χ^2 of differences between female majors significant at $p<.05$.

Participation in extra-curricular math/science activities in high school did not vary significantly for students entering the different engineering majors, for men or women, with one exception: women entering the civil/environmental major were unusually likely to have participated in paid or volunteer work experience related to math or science. While there was a tendency for women entering civil/environmental or mechanical/electrical/computing engineering to participate more in extra-curricular activities than their male counterparts did, the differences were statistically significant only in the case of the work experience for civil/environmental majors.

In terms of role models, less than 25% of male or female students had brothers or sisters in math, science or engineering, and the differences between women (or men) in different majors were not statistically significant. In all six years of the study, only one (male) student did *not* have a female math or science teacher, so there was no variation in exposure to this kind of role model.

Women majoring in Mech/ECE do not appear to have more support from significant others for their pursuit of their major. Generally women majoring in civil/environmental engineering appear to have more support for their pursuit of their major or career than do the other women, although the differences rarely reach statistical significance. There are few differences between men and women in the various majors, either (again, with the exception of two cases in which women in civil engineering have significantly stronger support from their fathers and siblings than do the men entering the major). Among both men and women, parents give the strongest support, high school teachers the next strongest support, and peers generally give the weakest support (though over half are still strongly supportive of the student's choice).

In summary, our hypotheses regarding background differences between the majors are not supported.

Self-Confidence

In terms of general academic self-confidence, women entering as Mech/ECE majors have higher self-confidence than the women entering as Chemical or Civil/Environmental majors in terms of drive to achieve, test-taking skill, speaking and writing skills. However, their differences from women in other majors are not large, and do not indicate a clear pattern. In fact, *all* of the women have greater self-confidence in terms of their drive to achieve, their overall academic ability, and their study skills than their male counterparts entering in the same majors, and many of the differences between the genders are significant. (Table 2) This suggests that their general academic self-confidence may not differentiate the women in the different majors from each other, but in comparison to their male counterparts it does seem to characterize women choosing engineering as a major, whatever the specific discipline.

In terms of more specific skills and traits related to math and science, women majoring in Mech/ECE tend to have stronger confidence in their computer skills and calculus proficiency than do women entering the other disciplines, but they have lower confidence in their overall math, biology and chemistry abilities than chemical engineering majors. The latter two are not so surprising, since biology and chemistry are expected to be used more by chemical engineering majors. In comparison, the male counterparts often show higher self-confidence when it comes to the skills and traits more closely aligned with math and science.

Table 2
Self-Confidence in General Academic Skills and Traits, Math and Science Skills and Traits, and Engineering Skills and Traits by Sex and Major

Sex:	Women			Men		
Major:	Chem	Civil	Mech/ECE	Chem	Civil	Mech/ECE
General Academic Self-confidence (*top 10% or "strongly confident"*)						
Drive to Achieve	44.8*	38.1*	48.5*	25.0	19.3	22.0
Overall Academic Ability	34.5	42.9	37.5	29.0	24.6	25.8
Problem-solving skill	32.0	23.1	21.4	38.2	33.7	34.4
Critical thinking	24.0	7.7	14.3	23.0	19.2	17.8
Study skills	24.0*	15.4	7.1	9.8	6.7	3.1†
Test-taking skill	8.0	23.1	28.6	23.6	12.5	19.3
Speaking skill	13.8	4.8	15.2	14.4	14.0	9.1
Writing skill	6.9	9.5	12.1	9.8	11.4	10.4
Math-science Self-Confidence (*top 10% or "strongly confident"*)						
Interest in science	58.6	20.0	36.4†	51.9	21.9	28.3†
Computer skill	4.0*	7.7	28.6†	25.2	20.2	35.9†
Math ability	37.9	38.1	24.2	46.6	27.2	38.0†
Confidence in math	56.0	38.5	42.9	60.2	35.0	48.3†
Confidence in biology	16.0	7.7	7.1	8.9	2.9	6.2
Confidence in calculus	27.6	23.8	36.4	45.1	18.6	28.5†
Confidence in chem. ability	31.0	9.5	18.2*	40.6	5.3	7.4†
Confidence in physics	13.8	14.3	15.2	27.1	11.5	27.2†
Engineering Fit (*% strongly agreeing*)						
Mechanically inclined	13.8	14.3	27.3	26.5	23.9	33.2
Technically inclined	6.9*	14.3	30.3††	28.0	19.5	35.6†
Good at designing things	13.8	9.5	28.1	26.5	25.7	34.6
Competent in skills required for major	20.7	14.3	24.2	33.3	15.0	27.9†
Well-suited for college major	27.6	20.0	36.4	35.6	23.0	33.9
Well-suited for chosen career	31.0	38.1*	39.4	32.6	18.8	29.5†
(n)	(29)	(21)	(33)	(133)	(115)	(299)

*χ^2 of differences between men and women in major significant at p<.05.
†χ^2 of differences between male majors significant at p<.05.
††χ^2 of differences between female majors significant at p<.05.

When it comes to skills and traits more specifically related to engineering, women entering as Mech/ECE majors consistently have stronger self-confidence than the women entering as Chemical or Civil/Environmental engineering majors. The women entering as Mech/ECE majors are much more likely to strongly agree that they are mechanically inclined, technically inclined, good at designing things (skills usually perceived as necessary at least for mechanical engineering), and well-suited for their college major than women in the other majors. They are also the most likely to strongly agree that they are competent in skills required for their major, and are well-suited for their chosen career, but the differences between the women are smaller on these indicators. Compared to their male counterparts in terms of engineering fit, men in each of

the disciplines are more likely to see themselves as mechanically inclined, technically inclined, good at designing things, and competent in the skills required for their major. However, the differences between men and women in Mech/ECE are much smaller than the differences between men and women in Chemical or Civil/Environmental engineering. In terms of being well suited for their chosen career, women in Mech/ECE or Civil/Environmental are more likely to strongly agree than are the men.

Attribution

Most of the engineering students (women or men) credit their grades to internal factors, either permanent (ability) or temporary (effort and preparation) (Table 3). Among the women, those majoring in Mech/ECE are different in that they attribute their grades first and foremost to the quality of teaching they experienced (an external factor), and only secondarily to their effort and then their ability. Their male counterparts do not value teaching above their own input, nor do the women or men in the other majors. Few of the students attribute their grades to luck or even to the ease or difficulty of the material, relying more on their ability and effort to surmount challenges.

Table 3
Attribution of Reasons for Last Year's Grades by Sex and Major
% answering "most important" on scale of (1) least important to (5) most important

Sex:	Women			Men		
Major:	Chem	Civil	Mech/ECE	Chem	Civil	Mech/ECE
My ability	58.6	52.4	48.5	47.0	43.0	36.2
Quality of teaching	55.2	42.9	66.7*	44.4	37.7	35.2
How much effort I put in	51.7	71.4*	57.6*	39.8	28.1	37.4
Amount of preparation	16.0	38.5*	35.7*	22.8	13.5	18.1
Ease/difficulty of material	13.8	9.5	21.2	8.3	14.0	11.8
Luck	3.4	0	6.1	2.3	1.8	2.4

*χ^2 of differences between men and women in major significant at $p<.05$.

Interestingly the women are more likely to attribute their grades to their own ability, effort, and preparation (the latter two internal factors under their control) than are their male counterparts, reinforcing the idea that the women who have selected engineering are quite confident in themselves, even compared to the men in engineering.

Satisfaction with Engineering

Women entering as Mech/ECE majors are among the most satisfied with their major compared to the other women in engineering. They are more likely to strongly agree that they are satisfied with their college major, that engineering is the right major for them, and that they have no desire to change their major. They are close to the chemical engineering majors in agreeing that the advantages of studying engineering outweigh the disadvantages (Table 4). However, there is not a large difference between them and women in one or both of the other majors.

All of the women seem to be more satisfied with their choice of major than their male counterparts in each major, and several of these differences are statistically significant.

Table 4
Satisfaction with Engineering as a Major
% Strongly Agreeing (SA) or Strongly Disagreeing (SD)

Sex:	Women			Men		
Major:	Chem	Civil	Mech/ECE	Chem	Civil	Mech/ECE
Satisfied with college major (*%SA*)	44.8	52.4	54.5*	38.9	35.4	37.9
Advantages of studying engineering outweigh disadvantages (*%SA*)	48.3**	33.3	45.5	31.6	30.1	33.6
Engineering right major for me (*%SA*)	37.9	23.8	39.4	30.1	21.2	32.6
No desire to change major (*%SA*)	41.4	38.1	51.5*	35.3	25.7	32.2
Can think of more rewarding majors (*% SD*)	28.0	30.8	28.6	22.8	18.6	29.3

*χ^2 of differences between men and women in major significant at $p<.05$.
**χ^2 of differences between men and women in major significant at $p<.10$.

Expectations from the Engineering Degree

Women in the various engineering majors do not vary from each other in any significant pattern (Table 5). The occasional differences are not statistically significant. They have highest expectations about getting a well-paying job after they complete the engineering degree. but they also expect to have a challenging job, and to be able to use their talents in a job they like doing. Additionally, they think they will gain the respect of others because of their occupation. Women majoring in civil/environmental and mech/ECE engineering are more likely to think they will have a job with security. About a third of the women think the engineering degree will enable them to be an important contributor to society, and somewhat less think they will be able to associate with interesting people. Fewer think they will have a flexible job: they are less likely to think they will have a choice to live in any geographic location, and the fewest women think their job will give them time to devote to interests outside their job.

It is in the latter respect that women most significantly differ from their male counterparts in the respective majors, but less than 18% of the men think a degree in engineering will give them the flexibility to devote much time to outside interests. Women are also significantly more likely than men to think that they will have a challenging job; they are more likely than men to think others will respect them (especially large are the differences between male and female chemical engineering majors). Like women, men are most likely to have high expectations about a well-paying job. Surprisingly, they are almost as likely as women to think they will be able to make an important contribution to society with their engineering degree.

Therefore, our expectations regarding Hypothesis 5 are not supported by the data.

Table 5
Expectations from the Engineering Degree
% Strongly Agreeing in Result from Degree in Engineering

Sex:	Women			Men		
Major:	Chem	Civil	Mech/ECE	Chem	Civil	Mech/ECE
Well-paying job	69.0	57.1	60.6	66.9	57.1	57.5
Challenging job	62.1*	33.3	54.5*	30.1	29.7	36.2
Respect by others	53.6*	38.1	36.4	30.1	26.8	31.2
Use of talents	44.8	47.6	51.5	34.1	32.1	44.1
Job I like doing	37.9	38.1	42.4	33.8	32.1	39.8
Important contribution to society	34.5	33.3	36.4	30.1	26.8	31.2†
Secure job	27.6	42.9	42.2	40.6	39.3	33.9
Association with interesting people	24.1	28.6	33.3	20.3	12.5	19.1
Choice of living in any geographic location	17.2	33.3	15.2	17.5	21.4	17.1
Time for outside interests	3.4*	9.5	3.0*	18.0	17.0	17.8
(n)	(29)	(21)	(33)	(133)	(112)	(298)

*χ^2 of differences between men and women in major significant at $p<.05$.
†χ^2 of differences between male majors significant at $p<.05$.

Summary and Conclusions

We began our inquiry into differences between women entering chemical, civil/environmental, and mechanical/electrical/computing engineering, with five hypotheses: that the women would differ in terms of (1) background characteristics; (2) academic, math/science, and engineering self-confidence and (3) attribution of grades to their own competency; (4) how well they thought they fit to engineering as a major and a career; and (5) their expectations from a degree in engineering. The hypotheses were only partially supported.

With regard to background differences, there were no appreciable differences between the women in terms of the AP math/science courses they took in high school, their extra-curricular activities related to math or science, their high school grades in math or science, or their SAT scores. They did not differ in terms of role models, as indicated by exposure to siblings in math/science/engineering fields nor to their exposure to female math/science teachers (though conceivably the role models they were exposed to might have been in different engineering fields, which our data did not detail). Nor did they differ in terms of the approval they received from significant others for their choice of engineering major or career. It seems that the women enter their respective fields with comparable qualifications and background support for their aspirations. Accordingly, they do not differ significantly in terms of their self-confidence in their general academic capabilities.

With regard to more specific math/science/engineering skills and competencies, however, there are some differences between the women. Women entering chemical engineering are more self-confident in their chemical, biological and overall math abilities; women entering mechanical/ECE majors are more confident in their computer skills and calculus proficiency, and

also are more likely to perceive themselves as mechanically inclined, technically inclined and good at designing things. This suggests that the women's choice of majors is related to their perceived strengths.

That perceptions do not always mirror reality has been a major lesson of attribution theory, which has shown that equal academic results do not always result in similar perceptions of ability or capability. Some students credit their internal capabilities, while others credit a transitory effort, while still others credit external factors like the teacher or the ease/difficulty of the material. Women majoring in Mech/ECE were more likely to credit last year's grades with an external factor (quality of teaching), and only secondarily their own effort and ability. Women entering Chemical or Civil/Environmental engineering were more likely to credit their own ability or effort, which suggests somewhat greater confidence in themselves. Our third hypothesis was therefore not supported.

While women entering Mech/ECE tended to be somewhat more satisfied with their choice of major and career, reinforcing their perception of their fit with engineering, differences between them and the other women were small, lending partial support to the fourth hypothesis. Expectations regarding the results of their engineering degree did not vary much between the women in different majors. Most expected a job with good pay, a challenging job that made use of their talents, and the respect of others. Their major did not seem related to how much they expected to make a contribution to society, nor how interesting the people with whom they would associate were expected to be. Therefore, our fifth hypothesis was not supported.

The main difference between the women, therefore, appears to be in their perceived strengths as related to specific directions in engineering. The next step should be to determine how these perceived strengths are fashioned, and how well they reflect actual differences. If they are accurate, they do not seem to be dependent on high school academic background; how far back, and to what socialization experiences can they be traced? In her insightful work on *Lost Talent* [6] (women who do not choose the sciences), Hanson showed that the influence of background characteristics on attitudes toward, access to, and achievement in the sciences may be related to quite nuanced interactions within the home or with significant others; perhaps choice of engineering discipline follows similar subtle influences. If choice of discipline is influenced by characteristics of particular role models, will reaching out to high school students with math/science potential be effective in recruiting women to some of the less common engineering disciplines? Scott and Boles[12] demonstrate that it can.

Another direction for further research is the extent to which the women in the various majors persist in their respective majors, and what the contributing factors to this are. Does their early self-selection portend the kind of field they will continue in as undergraduates, graduate students and/or employees? Do their early differences in engineering self-confidence affect their later experiences, or are they simply important buffers for the women in positions of smaller minorities? Are reasons for switching out of (or into) the various majors similar or different? The unequal distribution of women across the majors underscores the necessity of understanding these variations better, especially regarding those engineering disciplines that are fastest growing.

Breaking the students down into their respective engineering disciplines also enabled us to re-examine gender differences among engineering students which may be confounded by the different composition of majors among male and female students. Comparison between the female and male counterparts in the various majors also provided some interesting insights, both in terms of differences and similarities. There were not significant differences between the genders in academic or family background, for example. However, in comparison to their male counterparts, the women in all of the engineering disciplines professed stronger self-confidence with regard to their academic abilities, and were more likely to attribute last year's grades to their own efforts and abilities. These findings reinforce the more general conclusion reached by Huang et al[8] that while women are less likely than men to *enter* science and engineering fields (analysis not confined to engineering), those that do tend to have strong family support, high expectations, healthy self-confidence and solid academic preparation

Our findings suggest that differences between the majors follow a similar pattern: men tend to express stronger math, science and engineering self-confidence than do their female counterparts in each major. However, in the majors with the smallest proportions of women, mechanical and electrical/computing, there are smaller gender differences in these respects than in chemical or civil/environmental engineering. Thus, while women are less likely to *enter* mechanical or electrical/computing engineering, those that do tend to express stronger engineering self-confidence than women who go into more "common" engineering venues for women. Perhaps they need stronger self-confidence to meet the challenge of being such a small minority, and only enter the fields if they are convinced they belong. If so, work needs to be done on raising the self-confidence of other qualified women, so that they too will consider the most non-traditional engineering disciplines.

Similar proportions of male and female engineering students expect good pay after they complete their engineering degree. Unlike Tillberg and Cohoon's[14] findings of women in computer science, there is no evidence in our findings that some of the women (or men) reject money as a motivation for getting an engineering degree (over 90% agreed or strongly agreed that a degree in engineering would enable them to get a well-paying job). Women were more likely than their male counterparts in each major to stress that they would be able to get a challenging job, making use of their talents, which would gain them the respect of others.

About a third of the students, men and women alike, thought that an engineering degree would enable them to be an important contributor to society, which questions the notion that this is of interest primarily to women. Slightly higher proportions of women were looking forward to associating with interesting people as a result of their degree, reinforcing the notion that women find interpersonal characteristics of more interest than men. The differences are, however, not large.

While less than 20% of the students thought they would be able to get a job that allowed them time for interests outside of their job, significantly fewer women than men thought so, reinforcing the well-documented (e.g., Margolis and Fisher[9]) constraints that women often perceive regarding career and a life outside the career. This too should be of interest to those wishing to motivate more women into engineering.

References

1. Davis, Cinda-Sue and Sue Rosser 1996. "Program and Curricular Interventions." Ch. 7 in Cinda-Sue Davis, Angela B. Ginorio, Carol S. Hollinshead, Barbara B. Lazarus, Paula M. Rayman & associates, *The Equity Equation*. San Francisco: Jossey-Bass Publishers.

2. Engineering Workforce Commission (EWC), 2001. Data for Enrollments. http://www.ewc-online.org/data/enrollments_data.asp. Retrieved 1/5/07.

3. 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* 2: 355-381.

4. Gibbons, Michael T. 2006. The Year in Numbers. http://www.asee.org/publications/profiles/index.cfm#The_Profiles_and_Data_Book. Retrieved 1/9/06.

5. 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 (WECE) Group*. Cambridge, MA: Goodman Research Group, Inc.

6. Hanson, Sandra L. 1996. *Lost Talent: Women in the Sciences*. Philadelphia: Temple University Press.

7. Hartman, Harriet and Moshe Hartman. *Final Report to NSF: A Gender Lens on Rowan University's College of Engineering*.http://users.rowan.edu/~hartman/research.

8. Huang, Gary, Nebiyu Taddese, Elizabeth Walter, Samuel S. Peng, 2000. *Entry and Persistence of Women and Minorities in College Science and Engineering Education.* Washington, D.C.: National Center for Education Statistics, NCES 2000-601.

9. Margolis, Jane and Allan Fisher. 2001. *Unlocking the Clubhouse.* Cambridge, MA: MIT Press.

10. NSF (National Science Foundation), 2006. Division of Science Resources Statistics, Survey of Earned Doctorates, Table 2. www.nsf.gov/statistics/nsf06308/tables/tab2.xls. Retrieved 5/28/06.

11. 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.

12. Scott, Wesley and Walter Boles. 1996. Emerging High-Tech Areas of Civil Engineering Attract Women. *Journal of Professional Issues in Engineering Education and Practice* (January): 42-43.

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

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

EndNotes

[i] The authors wish to acknowledge the support of the National Science Foundation, through Grant #HRD-0074857; Rowan University's Colleges of Engineering and Liberal Arts and Sciences; and the Department of Sociology. We are especially grateful to the engineering faculty's cooperation in allowing the surveys to be administered during class time. Needless to say, all responsibility for the contents of the paper and the conclusions from the research remains solely with the authors. For more information on the larger study, see Hartman & Hartman[7].