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Increasing retention of women engineering students

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AC 2007-1529: INCREASING RETENTION OF WOMEN ENGINEERING STUDENTS

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Increasing Retention of Women Engineering Students

Abstract

This paper reports the results of a study carried out over several years to determine the factors predicting success for women engineering students at Santa Clara University. We examined psychosocial factors, such as commitment to engineering and confidence in engineering abilities, as well as the effect of a specific intervention on the retention rate of young women engineering students.

Studies have shown that among students with adequate aptitude for STEM (Science, Technology, Engineering, and Mathematics), girls drop out more often than boys. Several programs have been developed to encourage girls to persevere in their interests in STEM fields. In the summer of 1999, SCU hosted a National Science Foundation workshop[1] gathering directors of such programs to share their experience and insights. Forty-four people representing over 30 STEM programs for girls in the United States and Canada met to share the successes and challenges they had witnessed in their programs. We applied the experience gained in the workshop discussions in developing a questionnaire to assess psychosocial factors that appeared to be related to the retention of women engineering undergraduates. Exploratory factor analyses and reliability analyses confirmed that our newly-developed measure reliably assessed nine factors that had been suggested as important for retention: commitment, confidence, the value of engineering, computer interest, beliefs that anyone can succeed in engineering, family support, social perceptions, and perceptions of bias in the field of engineering.

Equipped with this new measure, we then designed an intervention aimed at enhancing the students' view of themselves as "techies." Each young woman received a handheld computer, and agreed to complete surveys regarding her use of the computer and to meet with the other students to share experiences, evaluate the computer's capabilities, and imagine ways it could be improved.

We tracked the graduation rates and degrees earned by these students and compared them with women engineering majors who came before and after this cohort. Four-year and six-year graduation rates were higher for the intervention cohort (54% and 69%, respectively) than for comparison cohorts (48% and 57%, respectively)

The Problem

"Every time an engineering problem is approached with a pale, male design team, it may be difficult to find the best solution, understand the design options, or know how to evaluate the constraints."[9]

Dr. Wm. A. Wulf, as President of the National Academy of Engineering, often spoke of the problem of lack of diversity in engineering. He pointed to the need for a diversity of perspective and experience in order to avoid the opportunity loss of designs not considered, constraints not understood, processes not invented, and products not built. At the time Dr. Wulf wrote the quote above (1998), the percentages of women and minorities enrolled in engineering programs was increasing (very slowly, but the trends were in the right direction). Since that time, the trend has reversed; women's enrollment peaked in 1999 at 19.8% and has steadily decreased to just 17.2% in 2005. Table 1 charts the engineering enrollment by gender in 1995 through 2005.

Year	All enrolled		Full-time, first year	
	Female	Male	Female	Male
1995	18.5	81.5	19.9	80.1
1996	19.0	81.0	19.9	80.1
1997	19.4	80.6	19.7	80.3
1998	19.7	80.3	19.6	80.4
1999	19.8	80.2	19.2	80.8
2000	19.5	80.5	18.9	81.1
2001	19.2	80.8	18.3	81.7
2002	18.5	81.5	17.2	82.8
2003	18.0	82.0	16.4	83.6
2004	17.7	82.3	16.3	83.7
2005	17.2	82.8	16.2	83.8

Table 1. Undergraduate enrollment in engineering programs by gender percent: 1995-2005.[7]

Women are underrepresented in almost all STEM fields, but the problem is the worst in engineering and computing. Figure 1, below, charts the percentage of degrees earned by women in several STEM fields.[3] Computing and engineering lag behind the other sciences, which have made great strides in increasing the representation of women over the past twenty-five years.

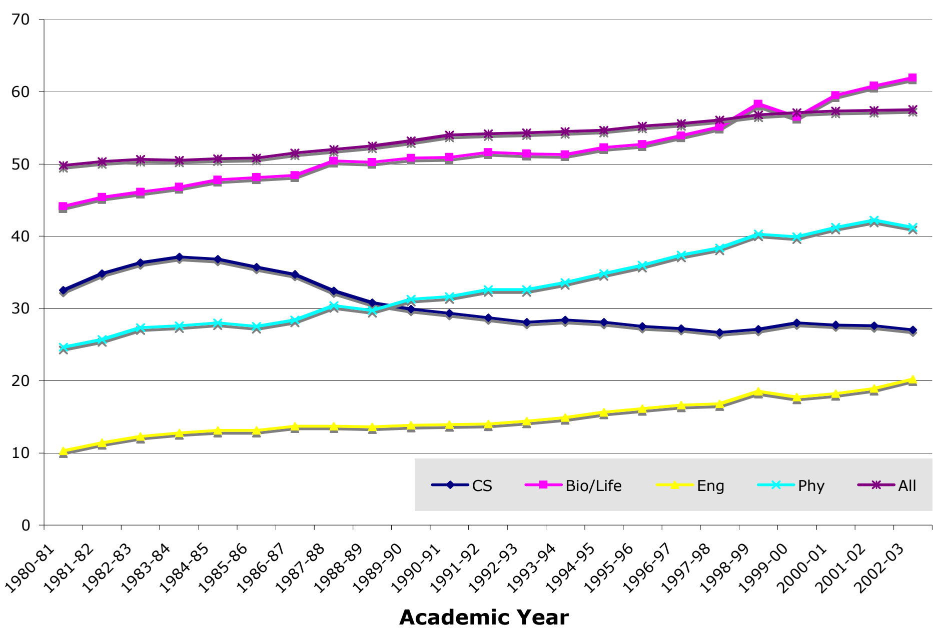


Figure 1. Percent of B.A./B.S. Degrees Awarded in Science and Engineering to Women, 1981-2003. Source: U.S. Department of Education

Certainly, an important part of the problem is recruitment. We have been unable to attract a sufficiently diverse population to engineering. However, another critical part of the problem, and the one on which we focus in this study, is retention of the women engineering students we do enroll. An emerging body of research indicates that the problems in retention are based on psychosocial factors rather than differences in abilities. In a report of a longitudinal study of chemical engineering students at North Carolina State University (1995),[4] the authors noted that, while the backgrounds and pre-engineering academic credentials of the women students indicated they would be more likely to succeed than the men, the percentage of women who dropped out of the major after the sophomore year was twice the percentage of men who dropped out. In spite of the fact that they were better prepared, the women entered engineering with greater anxiety and lower confidence in their preparation than did the men. The men consistently expressed higher self-assessments of their abilities, and this gender difference in self-assessed ability became more pronounced as students approached graduation. Women were more likely than men to attribute poor performance to their own lack of ability, while the men were more likely to blame a lack of hard work or being treated unfairly. On the other hand, men were more likely to attribute success to their abilities, while the women were more likely to attribute success to outside help.

Consistent with this finding, much of the recent research suggests that women's persistence in engineering is tied to their self-efficacy in the field. Self-efficacy "refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments."[2] This includes dimensions of confidence in one's abilities, commitment to a chosen path, and positive feedback with respect to accomplishments. It is based on an individual's perception, not always in agreement with an objective assessment, of one's performance. The website of the Assessing Women in Engineering Project provides a wealth of references in this area.[1]

Additional evidence for the importance of focusing on psychosocial factors appears in a study performed at the University of Southern California Viterbi School of Engineering. The researchers found that while the retention rate for women students in engineering was higher than that for men, the average GPA of women students leaving the field was higher than that of men students leaving. This suggested that rather than focus on academic assistance, retention efforts should concentrate "on activities which help women develop self-enhancing attitudes."[5]

Identifying the Psychosocial Factors that Impact Retention

At Santa Clara University, in August 1999, 44 people representing over 30 STEM programs for girls in the United States and Canada, came together to discuss the successes and challenges they had witnessed in their programs. Dr. Eleanor Willemsen, a psychologist at Santa Clara University, spoke about key concepts from developmental psychology that are relevant to girls' persistence in STEM careers.[10] She noted that persistence in the face of challenging circumstances is highest for goals that are valued in themselves (intrinsic motivation) rather than when striving for the goal as a means to another end (extrinsic motivation). Thus girls who enjoy the process of problem solving, using complex equipment and mathematical skills, and who are proud of being technically competent, are much more likely to succeed and persist than those who are acquiescing to parental pressure, following advice about better paying jobs, or trying to "prove" something.

After sharing best practices and hearing what psychology can tell us about motivation, the group turned its attention to the problem of assessing motivational and identity constructs. Dr. Kieran Sullivan presented some background information on assessment and evaluation procedures, including construct and item development, reliability and validity.[8] Construct development was the main focus of one of the workshop sessions. Participants spent time identifying and developing psychosocial constructs such as commitment, confidence, motivation, identity, etc. It was hoped that these constructs would be useful in tracking changes following interventions designed to increase retention. Items were later developed for each of these constructs, based on workshop discussions.

Influencing Attitudes: The Jornada™ Intervention

The intervention reported here was designed to improve retention of the women students in engineering by increasing their self-identification as "techies" and by creating a cohort of women students who knew and regularly interacted with each other on technical issues. We knew that social factors were important in supporting a positive self-image as an engineer. Also, we believed that it was important to reinforce the expression of technical competence. We wanted the students to enjoy meeting and being with each other, and also wanted them to have a technical basis for their meetings. We set up regular meetings for the students to interact on a technical issue of importance to all of them – how best to make use of a device they had all been given.[2]

Purpose and Hypotheses

The purpose of the current study was twofold. First, we planned to develop and evaluate an instrument to measure the factors related to retention of women entering their first year of engineering. Utilizing this new instrument, we then planned to determine whether intervening with first-year women engineering students would positively influence their attitudes and increase their retention rates in engineering.

The following hypotheses were posed:

1. Psychosocial factors will be related to success in engineering programs (i.e., whether students graduate with an engineering degree and students' cumulative college grade point average).
2. Psychosocial factors will be enhanced by the intervention, such that women's scores on the Success in Engineering Measure (SEM) survey will improve following the intervention.
3. Women in the intervention group will have higher follow-up SEM scores compared to women who did not participate in the intervention.
4. Women in the intervention group will be more likely to graduate with an engineering major compared to women who did not receive the intervention.

Method

Participants

Sample 1. All freshman and sophomore female engineering students in the program in the fall quarter of 1999 were asked to participate in a study of attitudes and beliefs about being an engineer. The women who agreed to participate (65%) were each asked to complete the Success in Engineering Measure (SEM; See Table 2 in the appendix for the questions) and were subsequently given a handheld computer, a Hewlett-Packard Jornada™, either a model 420 (an early PDA) or a model 820 (a ¾ size laptop). The students participated in regular meetings to discuss their use of the computers, problems, and ideas for improvement. They also participated in a workshop to imagine the next generation cell phone. Two years after receiving the Jornadas, participants were asked to complete the SEM again. Twenty-one (21) of the original fifty-four (54) participants completed the follow-up questionnaire.

Samples 2 and 3. Two additional samples were collected in subsequent years. These samples were collected for two purposes. First, evaluating the SEM using data from three different academic cohorts allows us to be more confident about the external validity of our measure. Second, the women from these subsequent samples were used as comparison groups for the intervention sample. In the fall quarter of 2000, all freshman engineering students, men and women, were invited to fill out the SEM (Sample 2). Fifty-seven (57) students agreed to participate (49%), 17 of whom were women (30%). Two years later, these students were again asked to complete the SEM. Thirty-eight students (67%) completed the follow-up questionnaires, 10 of whom were women (26%). Finally, in the fall of 2002, all freshmen engineering students were again invited to complete the SEM (Sample 3). One hundred and fourteen (114) students (99%) participated, twenty-four (24) of whom were women (21%).

Questionnaires

Commitment. The level of students' commitment to engineering and to their current major was assessed using four items that asked how committed they were to each when they entered the university and how committed they are now. The commitment scale had adequate inter-item reliability, with a coefficient alpha of .76.

Confidence. Fourteen items were used to assess students' level of confidence in various areas judged to be important to engineering success: academic ability in engineering, math, and science, ability to use a calculator, to use a computer, to complete the math, chemistry, and physics requirements as well as their major requirements, the requirements for any engineering degree, and the ability to stay and excel in engineering for a year. The confidence scale also had excellent inter-item reliability, with a coefficient alpha of .93.

Success in Engineering. This questionnaire was developed to assess a variety of factors that were believed by workshop participants to be important to girls' success in completing math and engineering programs. Seven factors were identified:

1. enjoyment of and interest in computers;
2. perceptions of the social value of engineering;
3. beliefs that anyone can succeed in engineering;

4. enjoyment of engineering;
5. math/engineering persistence;
6. family support; and
7. the perceived value of math and engineering.

An exploratory factor analysis[6] was run using principal axis factoring with oblique rotation to allow for correlations between the factors (N = 225). Ten factors with eigenvalues over one were yielded by this analysis. The ten factors accounted for 63% of the variance. The scree plot, however, indicated a seven factor solution. Thus, a second analysis was run, again using principal axis factoring with oblique rotation, with the number of factors constrained to seven. This analysis yielded a solution that was remarkably consistent with the proposed factors and that accounted for 53% of the variance.

Two substantial modifications were made to the factor structure based on these results. First, the items assessing enjoyment of engineering and the items assessing the perceived value of engineering loaded on the same factor, now called Value of Engineering. Second, the items assessing beliefs that anyone can succeed in engineering loaded on two separate factors. Items with gender or racial content loaded together, this factor is now called Gender and Racial Bias in Engineering. The remaining items now make up the Anyone Can Succeed factor. The revised factors and their coefficient alphas, along with the factor loadings, can be seen in Table 2 (in appendix). Several items, from multiple factors, loaded with almost equal weight on the Family Support factor. This seems to indicate that the attitudes assessed by these items (e.g., "Knowing engineering will help me earn a living") may have their roots in the family environment. Item 22, "I enjoy the challenge of engineering problems I can't understand immediately" also loaded on two factors (Value of Engineering and Persistence). Items that loaded equally on two factors were retained as part of each factor.

Gender Differences

Before evaluating the hypotheses, several one-way analysis of variance (ANOVA)[9] tests were run to determine whether there were gender differences in initial ability (as measured by SAT scores and high school grade point average) or in initial SEM scores. These analyses were conducted to determine whether data in the current study are consistent with previous findings; that is, that men and women enter programs with similar ability levels but with different attitudes and beliefs about success in engineering.

SAT scores and grades. Preliminary analyses indicated that there were differences in average SAT scores and average high school grade-point average among the three freshman samples, so gender differences in these indicators were analyzed separately in Sample 2 and Sample 3 (Sample 1 is women only). Results from one-way ANOVAs indicated that there were no significant gender differences in math SAT scores or in high school grade-point average in either sample or in verbal SAT scores in Sample 2. However, verbal SAT scores were significantly different in Sample 3, with men ($M = 580$) scoring significantly higher than women ($M = 541$), $F = 4.31$, $p < .05$.

Success in Engineering Measure (SEM). Preliminary analyses indicated that there were no significant differences in SEM scores the samples, therefore the three cohorts were combined for the following analyses. A one-way ANOVA was computed to determine whether there were any gender differences on the SEM factors (see Table 3). No significant differences were found between men and women on the commitment, confidence, computer interest, anyone succeed, family support, or value of engineering scales. However, women scored significantly higher on the remaining scales, indicating that women perceive more gender and racial bias in engineering, more social value to the field of engineering, and report higher levels of persistence on math and engineering problems compared to men.

Results

Hypothesis 1: College students' attitudes about self and engineering will be related to their outcomes: Regression analyses[12] were used to determine whether the SEM scales predicted successful engineering outcomes. These analyses were run separately for women and men. Stepwise logistic regression analyses were used to determine if the SEM scales predicted whether students graduated with a major in engineering. For women, the results indicated that two scales, committed and confidence, predicted graduation with an engineering major (see Table 4). Women with higher commitment and confidence were significantly more likely to graduate with a major in engineering. For men, commitment was the only factor that predicted graduation with an engineering major. Men with higher commitment were significantly more likely to graduate as an engineer.

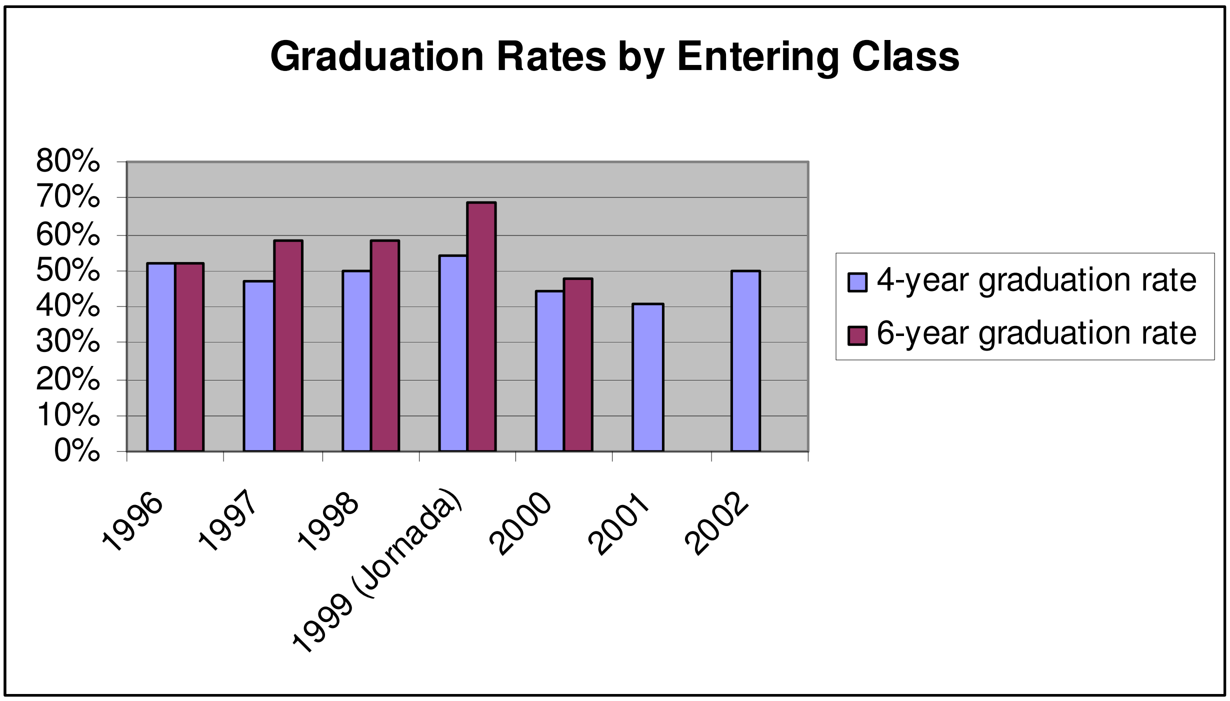
Linear regression analyses were run to determine whether college grade-point average was predicted by the SEM scales. For women, none of the SEM scales was a significant predictor of college grade-point average. For men one variable, persistence, predicted college gpa. Men who reported being more persistent on math and engineering problems had significantly higher grade-point averages compared to those who reported being less persistent, $B = .27$, $p < .01$.

Hypothesis 2: Women in the intervention group will have more positive attitudes after the intervention compared to their pre-intervention attitudes. Differences between SEM scales assessed before the intervention and after the intervention were analyzed using paired-samples *t*-tests. Only the women who completed the second assessment were included in these analyses (N = 21). Using the Bonferroni correction to control for the number of tests conducted, none of the factors changed significantly from pre- to post-intervention.

Hypothesis 3: Women in the intervention group will have more positive attitudes compared to women who did not receive the intervention. Differences between the intervention group and Sample 2 on the follow-up SEM assessment (conducted when each group was in their junior year) were analyzed using paired-samples *t*-tests. Using the Bonferroni correction to control for the number of tests conducted, none of the factors were significantly different between the two groups.

Hypothesis 4: Women in the intervention group will be more likely to graduate with an engineering major compared to women who did not receive the intervention. Two approaches were used to ascertain whether there was an increase in graduation rates for the women who participated in the intervention. First, graduation date and graduation major for the women in the intervention group and the women in Sample 2 were identified via University records. Any student who graduated with a degree in engineering within 6 years of commencing the engineering program was considered successful in completing an engineering major (thus Sample 3 was not included in these analyses as only 4 years have passed since these students began their engineering programs). Using these data, the intervention group graduation rate was 75.9% and the comparison group's graduation rate was 52.9%.

Due to the low percentage of women who participated in the comparison sample (18% of the women in the entering class), comparative data from the university's office of Institutional Research was also obtained. The following figure includes 4- and 6-year graduation rates for women for the two years preceding and the three years following the classes that participated in the Jornada intervention.



The 4-year graduation rates in non-intervention years ranged from 41% to 52%, with a mean 4-year graduation rate of 48%. The 4-year graduation rate for the class that included most of the intervention group was 54%. The 6-year graduation rates in available non-intervention years ranged from 48% - 58%, with a mean 6-year graduation rate of 57%. The 6-year graduation rate for the class with most of the intervention group was 69%.

Discussion

The men and women in this study began their engineering programs at about the same level of ability (five of the six indicators showed no significant gender differences). This finding is consistent with previous research. The students also began with similar beliefs and attitudes about engineering, which is contrary to previous findings that indicated that women may have less positive beliefs and attitudes about engineering compared to men. Interestingly, the few differences that did emerge indicate that women tended to have *more* positive attitudes then men, specifically they reported higher levels of persistence on math and engineering problems and perceived more social value to engineering compared to men. This is interesting and may reflect strengths necessary for women to pursue STEM careers into college. The fact that they also perceived higher levels of bias in engineering (against women and minorities) is consistent with this supposition.

Regarding whether attitudes and beliefs about engineering predict retention, the majority of the factors measured did not predict graduation with an engineering degree in the current study. However, the finding that commitment to engineering and confidence in engineering abilities did significantly predict graduation in women replicates previous research findings. Thus, these two factors appear to be critical for the retention of women engineering students. The importance of confidence for women engineers is further highlighted by the fact that it is not related to graduation rates for men. While commitment is important to the success of women and men, increasing confidence levels in women may be one of the most important ways we might improve retention of women engineering students.

The results of our intervention were mixed. Pre and post scores in psychosocial factors were not significantly different. While the intervention did not appear to improve scores, it did appear to prevent the typical declines in scores reported by previous studies. The comparison data do not support this view, as Juniors in the intervention group had similar scores to the Junior comparison group, but we had a very small sample for these analyses. It seems possible, if not likely, that we simply did not have the statistical power to detect any differences. In addition, it could be that those women whose confidence levels had dropped were no longer in the program. Thus we believe it is premature to conclude that the intervention does not affect women's attitudes and beliefs about engineering.

Our intervention did appear to impact graduation rates, however. The group of young women who participated in the study graduated with engineering degrees at a significantly higher rate than the women in the cohorts entering prior to or after this cohort, as well as compared to those women in the same year who did not participate. In addition to the possible protective effects of the intervention on the groups' attitudes and beliefs, it seems likely that the support participants received in meeting with their peers and establishing friendships within engineering contributed to their retention in the field.

It is difficult to gather survey data from students leaving engineering; however, we feel that this is the next step in our attempt to understand the changes in attitudes that affect retention. We hope to devise sufficient incentives for these students to participate in future study.

End Notes

[1] This work was supported by National Science Foundation grant HRD-9877037.

[2] The intervention reported here was supported by Hewlett Packard, the Anita Borg Institute for Women and Technology, the SCU Center for Science, Technology and Society, and the SCU School of Engineering.

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Table 2. Factor structure of the Success in Engineering Measure (SEM)

	Factor Loadings						
Item content	1	2	3	4	5	6	7
1. Computer Interest							
Doing work on a computer or calculator is stimulating and enjoyable to me	.89	.01	.03	-.02	.06	-.17	.00
I find computers unappealing[a]	.64	.00	.01	.07	-.05	-.05	-.02
I enjoy playing with (exploring the capabilities of) new electronic gadgets (computers/calculators/vcrs/...)	.51	-.24	-.05	.00	-.01	.10	.07
2. Social Value of Engineering							
If I had good grades in engineering, I would try to hide it from my friends[a]	.02	.62	-.16	.08	-.12	-.05	-.10
It would make people like me less if I were really good at engineering[a]	-.12	.55	-.26	.14	.06	.17	-.01
Being regarded as smart in engineering would be a great thing	-.11	.59	.35	-.19	.14	-.02	.09
It would make me happy to be recognized as an excellent student in engineering	.10	.48	.31	-.19	.22	-.05	.09
Winning a prize in an engineering competition would make me feel unpleasantly conspicuous[a]	.04	.54	.02	-.03	-.09	.08	.11
3. Anyone Succeed/Try Hard Enough							
Anyone who works hard enough can have a degree in engineering	-.07	-.08	.65	.09	.02	.03	-.05
Generally my professors think that anyone can succeed in engineering if they try hard enough	.09	.01	.42	.22	-.03	.01	-.08
4. Perceived Bias in Engineering							
My professors generally think that some ethnic groups are more talented in engineering than others	.04	.10	.10	.62	-.14	.09	-.02
My professors generally think that men are more talented in engineering than women	-.07	.01	.20	.75	-.14	.10	-.12
I think that some ethnic groups are more talented in engineering than others	.11	-.01	.01	.64	.09	.04	.02
I think that men are more talented in engineering than women	.00	-.05	-.01	.74	.07	-.03	.12
5. Value of Engineering							
Engineering is enjoying and stimulating to me	.32	.06	.02	-.02	.52	.21	-.14
I enjoy the challenge of engineering problems I can't understand immediately	.15	-.06	-.04	.05	.48	.45	-.18
I study engineering because I know how useful it is.	.18	-.02	.17	.00	.51	.16	.05

6. Persistence							
I enjoy the challenge of engineering problems I can't understand immediately	.15	-.06	-.04	.05	.48	.45	-.18
If I can't solve a math problem quickly, I quit trying[a]	-.03	.02	-.09	.12	.01	.62	-.05
I find that I can do hard math problems if I just hang in there.	-.04	-.03	.07	-.12	-.06	.60	.06
I would rather have someone give me the solution to a difficult problem than to have to figure it out for myself[a]	-.02	.10	-.10	.09	.07	.52	-.01
When a questions is left unanswered in a math or engineering class, I continue to think about it afterward.	.01	-.04	.14	.01	.09	.49	.07
7. Family support							
My family wouldn't encourage me to plan a career that involves engineering[a]	.04	.14	-.08	-.05	-.09	-.03	.47
My family thinks I'm the kind of person who could do well in engineering.	.10	-.03	.02	-.12	.01	.29	.51
No one in my family is very interested in math or engineering[a]	.10	-.03	-.04	.13	-.27	.09	.48
Women are certainly logical enough to do engineering	-.10	-.03	-.02	.17	.12	-.02	.67
Knowing engineering will help me earn a living.	.07	.01	.17	-.15	.35	-.05	.44
Coefficient alpha	.76	.80	.70	.82	.66	.70	.67
Percentage of variance accounted for	4.16	7.05	4.38	8.30	17.60	6.00	5.18

a. Reverse-scored item

Table 3. One-way analysis of variance comparing gender on the SEM Scales

Factor		Mean	SD	F	
Commitment				.54	
	Women	22.2	3.7		
	Men	21.8	4.3		
Confidence				.24	
	Women	73.1	11.6		
	Men	72.4	11.8		
Computer Interest				.01	
	Women	17.6	2.7		
	Men	17.5	3.4		
Social Value of Engineering				11.90	***
	Women	30.6	4.0		
	Men	28.7	4.3		
Anyone Succeed/Try Hard Enough				.76	
	Women	9.8	2.6		
	Men	9.5	2.3		
Perceived Bias in Engineering				4.25	**
	Women	21.2	4.9		
	Men	19.8	5.4		
Value of Engineering				1.60	
	Women	16.3	2.8		
	Men	15.9	2.8		
Persistence				3.52	*
	Women	27.3	3.7		
	Men	26.3	4.2		
Family Support				1.21	
	Women	30.5	5.1		
	Men	29.9	3.2		

Note: *$p < .10$; **$p < .05$; ***$p < .01$

Table 4. Predicting graduation with an engineering major by SEM scales using logistic regression

Variables in the Equation	Women B		Women Exp(B)	Men B		Men Exp(B)
Commitment	0.20	*	1.22	0.16	**	1.18
Confidence	0.10	**	1.11			
Constant	-10.56	***	0.00	-2.78	**	0.06

Note: *$p < .05$; **$p < .01$; ***$p < .001$