PREDICTORS OF WOMEN'S ENTRY INTO ENGINEERING: WHY ACADEMIC PREPARATION IS NOT SUFFICIENT

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INTRODUCTION

The U.S. Department of Education and The National Institute for Science Education recently published Women and Men of the Engineering Path (WMEP)[1]. The book reviews longitudinal data from the High School and Beyond, Sophomore Cohort Longitudinal Study in hopes of determining what attracts and keeps male and female students in the engineering pipeline. In determining which factors are responsible for students choosing engineering majors, the study considered monetary rewards, parental support, socio-economic standing, and high school preparation (courses taken, school ranking, mini-SAT score percentile). In sum, the study concluded that males who had originally decided to major in engineering, and then changed their minds between 12th grade and college were "curricularly challenged", however, this was not the case for women. The author goes on to state that "neither grades nor SES add anything to the explanatory power of the model", and that "for women, something else is at work that no regression equation will uncover" (p. 61).

The fact is, a regression equation including variables other than those considered by the above study CAN help to predict what factors influence the choice of engineering majors by male and female students. WMEP is a wonderful examination of a number of valuable factors, including how the culture of engineering affects women's choice to enter, or not enter, engineering majors. However, it comes short of integrating the more nebulous factors of culture into the model for statistical analysis. The present study attempts to do just that. Furthermore, the present study approaches the question from a particular perspective: Social Cognitive Theory. While the WMEP study touches on some aspects of Social Cognitive Theory, it does not make use of the rich body of research which has focused on the career development of women in traditionally male fields, gathered over the past two decades. The present study attempts to use Social Cognitive Theory as an anchor to explain why more women do not pursue engineering majors. Some of the findings parallel the WMEP study, but by using a theoretical approach, the present study is able to quantify attitudinal and other intrinsic factors in order to reach a more comprehensive conclusion about which factors best predict women's entry into engineering.

Social Cognitive Theory

Betz and Hackett[2] were the first to apply Bandura's's[3] Social Cognitive Theory to women's career decisions. The authors (Betz & Hackett) note that women and girls today are either not encouraged or are actively discouraged from engaging in a variety of activities that serve to increase and strengthen their expectations of personal efficacy. Women's continued underrepresentation in professions such as engineering are hypothesized to be at least partially due to low or weak self-efficacy expectation with regard to behaviors required for the successful pursuit and performance of those occupations. Thus, low self-efficacy expectations may be a major factor in the restriction of women's and minorities' career options, particularly in their failure to consider occupations traditionally viewed as more appropriate for Caucasian males.

A number of other studies have seized upon the application of self-efficacy to women's career development. Research has shown a number of factors explain women's low self-efficacy for engineering-related tasks, including a lack of science and math preparation[4,5,6,7,8], a lack of role models[9,10,11], and the perception of engineering as incompatible with women[12,13]. While little research has focused on the career development of minorities, existing findings suggest that many of these same factors are responsible for minority students' low self-efficacy for engineering-related tasks[14].

A handful of studies have examined specifically which factors interact to predict math or science-related college major choice[15,16,17,18,19]. Of these, only one (Farmer et al, 1995) is a longitudinal study, but while Farmer's model is basically congruent to Social Cognitive Theory, it is empirically, not theoretically, driven. None of the studies examining predictors of college major choice focus specifically on engineering.

The present study uses a Social Cognitive framework to determine what factors predict the intentions of male and female high school students to pursue engineering majors in college. The study is unique in its comprehensive measures, its large and diverse sample, and the statistical analysis used: Structural equation modeling.

METHOD

Participants

Five hundred and two high school students participating in two days of a fall, 1996 recruiting activity for the College of Engineering and Applied Sciences at Arizona State University participated in the study. Students attending the event were predominately juniors (34.7%) and seniors (46.7%) from public and private high schools throughout the state, representing inner-city, suburban and rural communities. Females made up 36.7% of the participants, while 35.7% were minorities (Hispanic, Mexican-American, Asian-American, Other, Black, American Indian, and Pacific, in that order), and 14.3% were both female and a minority. These students were mailed an additional survey in fall, 1997. The study will eventually include data collected through an additional survey to be mailed in fall, 1998.

Instruments

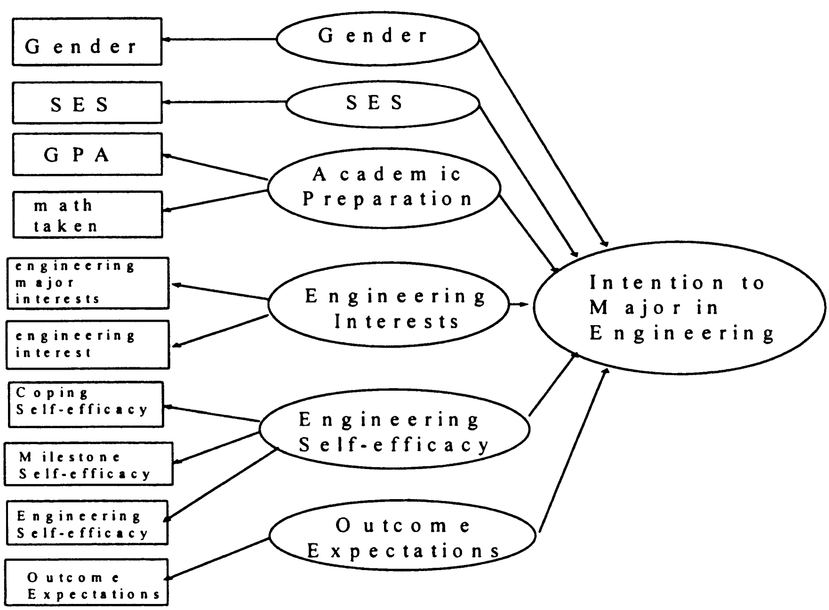
Participants completed a Career Expectations Questionnaire, including: 1) Demographic information [gender, ethnicity (collapsed into two categories: minority or non-minority), and SES as measured by the higher-level parent's occupation rating (according to Stevens and Cho, 1985)]; 2) Major and career plans [ranked according to Golman & Hewitt's (1976) science-non-science continuum with a separate category for engineering 3) Academic achievement (math and science courses taken, grade point average and SAT/ACT scores); 4) Quality of high school math education based on schools' Iowa Tests of Basic Skills and Test of Achievement and Proficiency percentile rank scores for mathematics; 5) Perceived support for pursuing an engineering degree by parents, family members, friends and boyfriend/girlfriend as well as a question as to whether the participant had ever been encouraged to consider an engineering career; 6) Self-efficacy for completing an engineering major (as measured by the Mathematics Self-Efficacy - College Courses Scale[20],); 7) Self-efficacy for coping with various obstacles in the pursuit of an engineering degree [measured by the Academic Milestones Self-Efficacy Scale[21] and the Coping Self-Efficacy Scale (based on Hackett, Betz, Casas and Rocha-Singh's 1992 coping inventory[22]); 8) Engineering interest (measured by Betz and Hackett's Career Interest Scale[23] and the Math/Science Interests Scale[24], and 9) What outcomes are expected as a result of completing an engineering degree [measured by Hackett, Betz, Casas and Rocha-Singh's Outcomes Expectations Scale[25].

The questionnaire was piloted with a group of 84 female high school students participating in a summer engineering program. Based on the pilot group's responses, all of the instruments included had acceptable reliabilities, with alphas ranging from .8429 for the Coping Self-efficacy scale to .9758 for the College Major Self-efficacy scale.

RESULTS

The reported model and results should be considered preliminary only. This project is a three-year study, however, the final data will not be available until October, 1998. In the final analysis the model will use intention to major in engineering as an additional predictor for which students will actually pursue engineering. In this model, intention to major in engineering is the variable being predicted. The data were analyzed using structural equation modeling. The model in Figure 1 was analyzed.

FIGURE 1



In keeping with standard practice, a number of variables were dropped in an effort to achieve the best fit for the overall model. First, due to a large amount of missing data for ACT/SAT scores and quality of high school math education rankings, these data were not used. Second, a number of variables, including level of science taken, and support for choice of major/career were not included due to the lack of fit within the model. In other words, these indicators did not help to predict intention to major in engineering. Surprisingly, minority status was dropped for the same reason. This will be discussed further in the Discussion section.

Maximum Likelihood Estimation techniques were used to establish parameters. Squared multiple correlations (R^2s) for the endogenous variables range from .17 for cope-self-efficacy to .86 for interest in engineering major-engineering interest. The regression equation (unstandardized) for the overall model is as follows:

Intention to Major in Engineering =

0.18*Engineering self-efficacy	- 0.22*Outcome Expectations	+ .32*Engineering Interest
(0.14)	(0.087)	(0.12)
1.32	-2.48	2.75

- 0.010*Academic Preparation	+ 0.0093*SES	– 0.11*Gender,	Error Variance = 0.88,
(0.084)	(0.051)	(0.056)	(0.067)
-0.12	1.18	-2.01	13.13

$R^2 = 0.12$

The chi-square for the model is 124.76, P = 0.0. The Critical N is 151.94. This indicates a lack of fit within the model, which will be adjusted for in future iterations. It is difficult to predict how the final data will affect the overall model, but it may be that coping self-efficacy will need to be dropped, due to its relative lack of contribution to the model.

DISCUSSION

It is necessary to begin this discussion with a caveat that this is a work in progress. Missing data necessarily modified the ideal model. That data will be compiled over time so that this model can be analyzed. Furthermore, the current model does not meet the criterion for a good fit. Finally, given that the predicted variable is dichotomous, it is appropriate to use the Prelis method for polychor and associated asymptotic covariance matrices. However, all other variables, except gender, are continuous, and utilizing that method resulted in a poorer fit. Alternative models need to be tested once the final data is available. Having said this, however, some interesting results do emerge from this model, and they are well worth examining.

In the regression equation, it can be seen that Outcome Expectations, Engineering Interest and Gender are significant predictors ($T > 1.96$) of Intention to Major in Engineering. However, Outcome Expectations was actually a negative predictor of Intention to Major in Engineering. In other words, the more rewards a student believed a career in engineering would bring them, the less likely they were to indicate an intention to major in engineering. At first blush this appears very odd indeed, however, it may be that students who feel engineering would be a highly rewarding career also feel that it is an unattainable one. Students intending on majoring in engineering may have had more exposure to engineering role models and ascertained that the career has pluses and minuses and that it is within their reach.

As one would predict, the more interest in engineering a student indicated, the more likely the student was to report their intention to major in engineering. Surprisingly, engineering self-efficacy was not significant (T=1.32) in this model, although it had been in previous iterations. One might suspect that when compared by gender, self-efficacy would emerge as a stronger predictor for women than men. However, group differences analysis did not reveal significant differences for men and women in this model (gender as a variable was removed), until the error variances were considered. The fact that women and men had significantly different error variances indicates that they are differentially affected in their intentions to major in engineering by variables outside the model. Revisiting the non-significance of self-efficacy, it may be that self-efficacy does not significantly affect the *intention* to major in engineering, but does significantly impact actual choice of engineering as a major. This is be determined upon the final data analysis.

The present analysis does indicate that women are significantly less likely to indicate an intention to major in engineering than men. This is despite the fact that the women students in this sample had higher GPAs and were more likely to be in higher level math and science courses than the men. In fact, academic preparation (GPA and highest level math taken) is a **negative** predictor of intention to enter engineering! Could it be that higher level math and sciences courses are such turn-offs that students who are academically prepared to major in fields such as engineering don't?

Perhaps most notable about the present model are the variables that are not present. Minority status was removed from the model after many different iterations. In fact, neither minority status nor gender fit into the model as predicted. The literature indicates that these variables should have an affect on at least the endogenous variables Engineering Self-Efficacy, Outcome Expectations and Interest. However, this was not the case with this sample. As far as the minority variable not fitting into the model at all, perhaps the minority students attending the engineering recruiting event from which this sample was drawn had already overcome many of the barriers to their participation in engineering. Or , perhaps minority status will become a significant predictor of entry into an engineering major versus *intention* to major in engineering.

CONCLUSIONS

This preliminary study used structural equation modeling to test a Social Cognitive theoretical model as to which high school students intend to pursue engineering- or science-related college majors and careers. The analysis supports previous evidence, such as the WMEP, that gender is a predominate factor in predicting which high school students plan to pursue engineering and science-related majors and careers.

Despite higher GPAs and a greater likelihood of enrolling in higher-level math and science courses, females were less likely to intend to major in engineering. In fact, the better academically prepared a student was to enter engineering, the less likely they were to intend to do so. Students who perceived engineering to be a rewarding career were also less likely to intend to major in it. Surprisingly, minority status did not have a significant affect on the intention to major in engineering. However, the model overall did not meet the criteria for a good fit and additional models need to be tested.

These preliminary data indicate that in order to increase the likelihood of a high school student planning on an engineering career, efforts should be focused on the student gaining QUALITY mathematical and science experiences, exposure to engineering role models to which they can relate and get an accurate picture of the career and its rewards, and a special emphasis must be made with respect to recruiting women into engineering. Details about how recruiting efforts can be particularly effective with women students have alluded this particular analysis, but will hopefully emerge in the final study.

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