STRATEGIES OF WOMEN PURSUING DEGREES IN ENGINEERING & SCIENCE

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ABSTRACT

This paper discusses two studies of academic self-confidence of undergraduate students pursuing engineering or science degrees at the University of Washington. The first, a longitudinal study of female students, has consistently revealed that these women experience a noticeable drop in their academic self-confidence during their first year of college, from which they never completely recover. Nonetheless, many of these women are able to develop and rely on other resources in order to persist in completing their degrees. Drawing on what these women have told us themselves, as well as analyses which have produced factors correlated with persistence, we describe the changes in self-perception these students undergo as they interact with the engineering and science environments of the university. The second study, a more intensive short-term investigation comparing female and male students, concluded that, although both groups experience initial drops in self-confidence, the patterns of loss and recovery differed slightly.

INTRODUCTION

Over the past 15 years, there has been an increasing awareness of the lack of women in the fields of science, mathematics and engineering (SME), and a movement to encourage young women to enter traditionally male-dominated fields. Recruitment seemed at first effective (peaking in 1983 at 17% enrollment), but women continue to be underrepresented in SME fields.[1] Although women in the U.S. currently earn 51% of all bachelor degrees, they earn only 16% of degrees awarded in engineering, 11% of degrees awarded in physics, and 29% of degrees awarded in chemistry. Further, women make up 44% of the total workforce, yet they account for only 8.5% of the engineering professions, 9% of physicists, and 1% of chemists.[2]

Why is it that women do not pursue degrees in SME at the same rate as men? Initial attempts to investigate the reasons behind the lack of women in SME used biological evidence to support the conclusion that women are simply unable to meet the intellectual demands of these fields.[3] As most research eventually turned away from seeking explanations in biological differences, investigators began to focus on factors that create and perpetuate gender role stereotypes, and the influence these stereotypes have on academic self-confidence and achievement.[4]

Rosser[5] refers to this research as a deficit model of female achievement. In this model, women are seen as lacking the skills needed to succeed in a male-dominated culture and told they must adapt to fit in with the traditional male gender roles in order to be successful. This conflicting message often produces detrimental results for high-achieving young women, such as low academic self-confidence and fear of speaking up or seeking help in male-dominated environments.

From the beginning, lack of self-confidence and influence of gender role expectations are reinforced by a variety of factors, as demonstrated in studies of child development. There is evidence that children as young as five years old hold strong gender role stereotypes, and begin to model their behavior according to those traditionally viewed as male or female.[6] Parents and teachers transmit their expectations to their children by encouraging differences in play patterns, and differentially reinforcing expectations of sons and daughters about academic performance and social activities.[7] Fathers, who often have the most influence on their children's career choices,[8] tend to spend more time on achievement-related activities with sons than with daughters.[9] The media has had a powerful effect on parents' expectations of their children. Eccles[10] observed that mothers' beliefs about their daughters' mathematics abilities dropped significantly after a widely-publicized 1980 scientific journal publication claiming significant sex differences in mathematics ability.

Classroom interaction studies have also shown that teachers reinforce gender-role stereotyping. Studies of student-teacher interactions consistently show that teachers spend a greater amount of time with boys, ask them more challenging questions, reward their interruptions,[11,12] and generally have higher expectations of boys than girls.[13] One study found that although teachers judged boys' competence based on age and IQ, judgments of girls competence included their level of compliance with teachers.[14] Boys are encouraged to speak up in class, but girls are actually discouraged. This differentiation in expectations is furthered by school counselors who neglect to tell girls about non-traditional career opportunities.[15]

Students reinforce these stereotypes in their interactions with each other. Negative stereotypes associated with giftedness are stronger for girls than boys. The view that mathematics is a male domain is generally held more strongly by males than by females.[16] The exception to this finding is high-school girls enrolled in high-level mathematics courses, who share the opinion that mathematics is a male domain.[17] Sherman speculates that this apparent contradiction may be another manifestation of the deficit model, which gives conflicting messages about what it means to be "successful" and what it means to be "feminine."[18] Females tend to feel less satisfaction with their performance on tasks defined as masculine,[19] yet, tasks defined as feminine are less valued, and not usually equated with success in our culture. Thus, high-achieving girls may see themselves as different from the norm and, as a way to resolve the conflict of gender roles, see themselves as being personally able to handle male domain tasks.

Despite findings of equivalent male and female achievement in high-school math[20,21] an abundance of published research exists about why "girls can't do mathematics." The news media publicizes these studies, thus reinforcing the persisting deficit stereotype.[22] As a result, research showing that females exhibit equal achievement to males in mathematics must take a defensive stance in order to challenge the stereotype.[23,24]

Research is beginning to focus less directly on questions of female abilities as the primary reason women do not persist in math- and science- related fields, and more on issues of academic climate.[25] The *chilly climate* of high-school math and science classrooms[26] and in particular the SME classes in college,[27] are significant topics of research.

To date, few studies have examined the intersection of academic climate, self-confidence, and academic performance in science- and math-related classes at the college level. Two such studies examining academic self-confidence of students pursuing degrees in SME are currently ongoing at the University of Washington. The goal of the first longitudinal study is to identify barriers, examine self-confidence levels over time, and develop a profile of the characteristics of women who persist in SME. The other, a short-term in-depth study of academic self-confidence in the first quarter of college, examines self-confidence in a different manner, and provides a male control group.

STUDY 1

The Women in Engineering (WIE) Initiative at the University of Washington Undergraduate Retention Study, a 6-year longitudinal study, has been ongoing since 1991.[28] To date, five cohorts of SME students, totaling 554 women, are participating in this study. As first-year students, participants are contacted in Autumn and Spring for individual interviews. This personal contact can be a critical factor in retention since students are most at risk during their first year in college. Sophomores, juniors, and seniors are contacted by email throughout the year to notify them of various WIE programs, and in the Spring are sent an annual questionnaire. The interviews and questionnaires contain, among other things, questions designed to determine changes in academic self-confidence, persistence factors, and perceived barriers to obtaining a degree in engineering or science.

Results

Self-Confidence

Academic self-confidence in math is measured each year for each student on a self-rating 5-point scale of ability in math and science. Math self-confidence, analyzed by repeated measures ANOVA, decreases significantly ($p<.05$) between the Autumn quarter and Spring quarter of the first year in college (Figure 1). Self-confidence ratings begin a gradual increase in the sophomore year, and continue increasing through the senior year, but never return to the initial level. Self-confidence ratings for science show a similar pattern. In addition, when asked whether they thought their self-confidence level had changed during their time in college, 25% of 4th- and 5th-year students reported a decrease in math self-confidence, and 21% reported a decrease in science self-confidence.

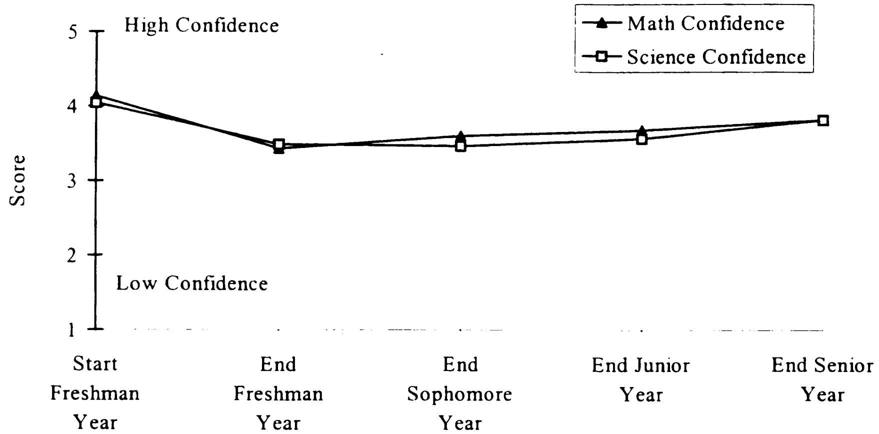

Figure 1. Mean levels of self-confidence by year

Barriers

As anticipated, the most frequently reported perceived barriers for first-year students and sophomores are lack of self-confidence and concern about not being accepted into their department when they apply at the end of their sophomore year (Table 1). Approximately one-fourth of the first-year students, sophomores, and juniors report that they feel no barriers to completing their degrees. Surprisingly, by the time they are seniors, all of the remaining women in our study, many of whom had earlier reported no barriers to their academic progress, report at least one barrier. The percentage who report low self-confidence as a barrier has almost doubled since their first year.

Table 1. Most Frequently Reported Perceived Barriers

Barrier	First-Year	Sophomore	Junior	Senior	Average
Not being accepted into department	29.4%	29.4%	3.0%	N/A	20.6%
Lack of self-confidence	32.1%	21.8%	18.2%	57.1%	32.3%
Lack of interest	15.7%	21.8%	18.2%	68.6%	31.1%
Financial problems	17.4%	19.9%	21.2%	42.9%	25.4%
Poor advising	8.4%	12.7%	15.2%	51.4%	21.9%
Intimidation/competition	17.6%	20.4%	12.1%	34.3%	21.1%
None	28.9%	24.6%	30.3%	0	21.0%

Persistence Factors

There are a number of common factors which bear a strong relationship to a student's decision whether or not to persist in SME, whether to switch to another major, or to drop out of school altogether. Table 2 summarizes factors, by cohort, which have shown, based on chi-square analyses for independence, a correlation ($p<.10$) with persistence in SME. Factors in the first two years center on academic achievement and concerns about acceptance into a department. In the junior and senior years, persistence factors turn more to interest in coursework and support from faculty and family (particularly mother).

Table 2. Persistence Factors for Women in SME

First-Year Students	Juniors
Enjoyment of math and science	Interest in coursework
No problem adjusting to difficulty of college courses	Positive influence of WIE
No problem adjusting to lack of one-to-one help	Positive influence of advisor
Competition seen as a motivator	Positive influence of mother
Sophomores	Seniors
Registered pre-science or pre-engineering	Positive influence of WIE
Influence of math and science classes	Positive influence of mother
Acceptance into a department	Positive influence of advisor

STUDY 2

As shown in Study 1, the initially high level of academic self-confidence of women pursuing an SME degree drops precipitously during their first year in college. In order to further investigate this finding, and to compare it with a male control group, a second study focused on the experiences of these students during their first quarter in college.

Participants in this study were 130 high-achieving students (mean high-school GPA of 3.8) who were self-identified as pursuing an SME degree. All of the students were enrolled in the same courses (calculus, chemistry, and English or a social science), which enabled an analysis of performance across a variety of academic areas. Each student completed a questionnaire which included family description, educational background, initial self-confidence, educational interests and goals, and performance expectations. Students completed a series of questionnaires throughout the quarter which asked them to estimate their academic performance at that point in time. Each student then participated in an in-depth individual interview focused on perceptions of academic ability. Finally, at the end of the quarter, all students' grades were obtained from the registrar's office to determine if there was a relationship between judgments of academic ability and actual performance.

Results

Academic self-confidence was measured in the calculus and chemistry classes before and after mid-term exams and before and after final exams. Similar measures were taken for English or social science class at the time that mid-term and final papers were due. A repeated measures ANOVA revealed a significant decrease ($p<.05$) in self-confidence in all three classes for both males and females. Although there was no significant difference in self-confidence between males and females at any measurement point, there was a consistent pattern evident in the mean self-confidence scores of males and females. Across all three courses, males reported a higher initial self-confidence which would drop significantly, and then begin to return toward the initial level. Females would report a more conservative initial self-confidence which would then drop slightly and continue at the lower level.

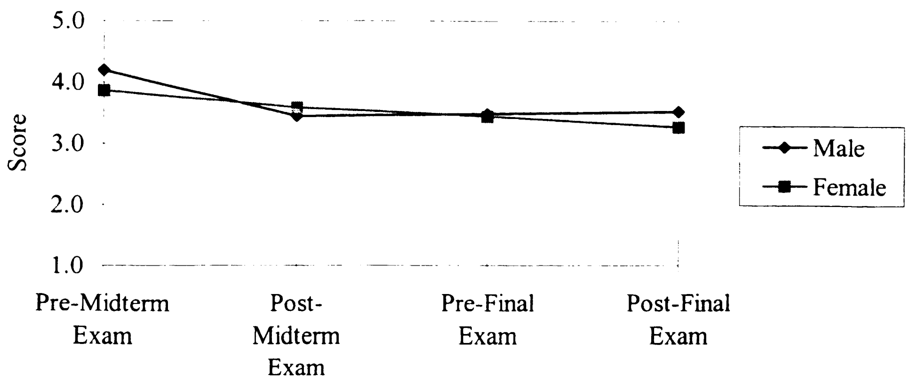

Figure 2. Self-Confidence Scores in Calculus

DISCUSSION

Because of the rigorous nature of SME curricula, we would expect academic self-confidence to be a mainstay of anyone completing an SME undergraduate degree program. However, this is not the case for the women in our study. Our data consistently show that the high level of self-confidence these women have in their math and science abilities upon entering college drops precipitously during their first year in college. Although self-confidence levels begin to rise again throughout the remainder of their education, they never return to initial levels. A comparison of self-confidence levels, grade point average (GPA), and persistence in SME shows no significant relationship; i.e. the decision to switch out of SME is independent of GPA and academic self-confidence. Further, the women who do persist, although maintaining an average GPA of 3.2 suffer from a decrease in academic self-confidence.

When examining this issue of self-confidence from two perspectives, we come up with some similar findings and some differences. The findings of Study 2 suggest that both male and female high-achieving students experience a significant decrease in their academic self-confidence during their first quarter in college. The surprising result was that males begin and end with a higher estimate of their abilities. Females tend to report more conservative estimates, which take an initial drop and remain low throughout the quarter. These patterns of reported self-confidence were consistent across calculus, chemistry and English (or social science) courses, despite the fact that there were no sex differences in final grades in any of the classes or in the overall average first-quarter GPA of 3.0.

This finding leads to an interesting question: how much are these students' responses influenced by the "social acceptability" of their beliefs about their academic ability? As one female math major put it, *"I would rate myself a 4 or even a 4 1/2 (on a 5-point scale), but rating myself a 5 would be bragging."*

Admittedly, the level of discrimination of our measurement instruments was not fine enough to answer this question. The questionnaires were simply measuring what they say, not necessarily what they think about their abilities. This finding suggests a need for an instrument that could measure what *students actually think* about their self-confidence in order to further explore the issue of self-confidence.

In addition to these finer measures of self-confidence, good measures of climate are needed in order to examine the relationship between climate and self-confidence for both males and females. As developmental studies have shown, it is the climate of the classroom that shapes a child's perception of her/his abilities. The academic climate in SME is decreasing, rather than increasing, students' self-confidence. Although the long-term implications are unknown, our findings show that this decrease in self-confidence is more of a barrier to women than men in their first year in SME. Possibly this outcome is due in part to the isolation women feel already when pursuing a still male-dominated area of study. Until there are enough women in SME to reach *critical mass*, the term being used for equity in numbers in education as well as the workplace, and the source of this decrease in self-confidence is determined and rectified, retention programs for women that focus on persistence factors play a crucial role in assisting women to complete their SME degrees.

Finally, it is important to continue tracking the relationship between climate, self-confidence and performance as women move into their careers and examine what happens to self-confidence and its relationship to corporate climate and performance.

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