

PROFILES OF PERSISTENCE AMONG WOMEN IN ELECTRICAL AND COMPUTER ENGINEERING

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INTRODUCTION

As we enter the 21st century, women continue to be relatively underrepresented in engineering undergraduate and graduate programs. Likewise, women are severely underrepresented among engineering faculty in academia. These educational pipeline issues are still occurring in engineering programs all across the nation despite rigorous efforts over the past two decades directed at outreach, recruitment, and retention. Nowhere is this more evident than in the disciplines of electrical and computer engineering where low enrollments and graduation rates of women continue to be commonplace. Yet these two disciplines offer some of the most rewarding and financially lucrative career opportunities for professional engineers and academicians. It is imperative that program administrators, corporate partners, and engineering faculty continue to address this issue in the coming millennium. This paper discusses the results of a qualitative research study conducted in 1999 and based on a 1997 study, both designed to gain some insight into these pipeline problems. The earlier study examined the profiles of persistence among undergraduate women enrolled in engineering programs at a large, comprehensive research university in the southeastern United States.⁴ The latter study, also based on qualitative methodology, specifically examined the profiles of persistence of undergraduate women, women in graduate programs, and women faculty in electrical and computer engineering. Investigating and learning about the strengths and experiences of these women can influence the initiatives and programs that are developed and implemented in middle schools, high schools, and post-secondary institutions.

OVERVIEW OF THE 1997 STUDY

The purpose of this qualitative study was to develop profiles of persistence among undergraduate women in engineering. Through a developmental life-span and social learning theoretical approach, the study investigated women's choice of engineering as a major as well as their persistence in that choice. Previous research on persistence in engineering had been quantitative in nature and based on such academic measures as high school grade point average, class rank, math and science achievement, and SAT scores.

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This research base had also demonstrated the importance of family background variables such as parental education and occupational levels and individual factors such as academic background, self-efficacy, and personality. A growing body of knowledge had suggested the effect of environmental and social factors such as institutional fit, the climate and culture of engineering education, and social support networks for persistence. Many of these studies used a combined sample of women and men while others made comparisons between men and women on various variables. Studies have also considered differences in persistence rates among various racial and ethnic groups. For example, women and African American students, in particular, have been found to persist at lower rates than Caucasian men do. No prior studies had looked at the phenomenon of persistence from the perspectives of the participants; that is, those men, women, and students of color who persist or fail to persist in engineering. Since the literature had demonstrated lower persistence rates for women than for men, this study sought to understand why women persist at lower rates by incorporating the voices of both persisters and non-persisters. The study also considered differences in experiences among women of various racial groups as well as women from rural geographical areas. Guided by the tenets of feminist and inclusive research, the assumption was made that all women have strengths and personal viewpoints that are worthy of recognition whether they persist or not in engineering.

FINDINGS OF THE 1997 STUDY

Factors that seemed relevant to persistence and non-persistence in engineering were family background variables, individual variables, environmental factors in the culture of engineering education, and social factors; therefore, persistence is a complex phenomenon that involves the interaction of many variables. Persisters and non-persisters had no clear cut profiles but presented more complex profiles. One group of persisters made early decisions and stayed the course through academic preparation and hands-on experiences that provided exposure to engineering. A second group of persisters made later decisions based on encouragement and the structure of opportunity for women and students of color. The personalities of one group of non-persisters did not provide a good person-environment fit with the culture of engineering. A second group of persisters left engineering after experiencing personal problems; many later regretted the decision to leave engineering. Perceptions and experiences with the institution itself and the culture of engineering education varied depending on factors such as the career decision making process, academic level, group membership, and individual factors such as personality.

SUGGESTIONS FOR FURTHER RESEARCH

Like women in engineering all across the nation, women at this southeastern university continue to migrate to certain disciplines while enrollments of women in other disciplines remain relatively low. Results of the 1997 study indicated that those engineering disciplines that are viewed as more “people oriented” or more “applied” – those that typically appeal to women – are viewed as less valuable and prestigious among some of

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the engineering faculty and students. Those disciplines that appeared to be higher on the occupational prestige hierarchy were those with higher enrollments of men and higher enrollments in general, that is, mechanical, electrical, and computer. In these disciplines isolation and tokenism in the classroom and laboratory environment was sometimes even more pronounced. It was suggested that future research be conducted to learn more about the profiles of women in those disciplines and the “personalities” of the disciplines themselves. A more in-depth glance into the environments and cultures in those disciplines was needed to gain further insight into reasons for the low enrollments of women.

THE CURRENT STATUS OF WOMEN IN ENGINEERING

The climate of engineering programs nationwide and the enrollments of women in those programs are still issues today. “Women and men perceive the undergraduate experience differently, particularly in areas that relate to self-confidence.”¹ Nationwide 18 percent of all engineering bachelor’s degrees are awarded to women; however, the percentage of women in the engineering workforce is only about 7 percent.^{7,8} The workplace “culture poses challenges and struggles reminiscent of those faced by women first entering the workforce years ago.”⁸ The “small number of women in academic positions means that there are few female role models for women undergraduate and graduate students to demonstrate that an academic career is possible.”⁷ The percentage of engineering Ph.D.’s awarded to women ranges between 8-12 percent.^{7,8} While some disciplines have made great strides at all points along the educational pipeline, others are still floundering. The most popular engineering disciplines among women in 1999, as determined by the number of bachelors degrees awarded, were chemical at 36 percent and industrial at 33 percent.³ Relatively fewer degrees in electrical, computer, and mechanical engineering are being awarded to women, leaving women out of the pipeline for some of the most financially lucrative and rewarding engineering jobs. Employment opportunities for all electrical engineers are expected to increase faster than the average for all occupations.² Computer scientists, computer engineers, and systems analysts are predicted to be the top three occupations with the fastest employment growth in the decade from 1996-2006.² However, only 17 percent of the high school students who took the Advanced Placement Computer Science test in 1997 were females – the lowest percentage of all tests given, including Physics.⁶ Employment opportunities for all electrical engineers are expected to increase faster than the average for all occupations.² The issue of women in science, engineering, and technology continues to merit serious attention as evidenced by a bill passed into law by President Clinton in 1998. U. S. Representative Connie Morella (R-Md.) proposed the creation of a “commission that aims to advance the presence of women and minorities in science, engineering, and technology.”⁵ The commission “aims to strengthen and expand the high-tech workforce by ensuring that women, minorities, and people with disabilities have the skills they need to compete.”⁵

PURPOSE OF THE 1999 STUDY

The purpose of this study, conducted at the same research university, was to gain a more thorough understanding of women's status along the educational pipeline in the disciplines of electrical and computer engineering. Graham identified environmental and cultural barriers encountered by undergraduate women in engineering.⁴ The more recent WEPAN Pilot Climate Survey demonstrated lower confidence levels and less satisfaction with the engineering experience among undergraduate women.¹ Literature related to the status of women in graduate school and academia demonstrates some similar and some unique barriers. The next section provides some background information on the status of these women. Research at all levels demonstrates some themes that appear to be constant: feelings of powerlessness, isolation, and invisibility, an impact on self-esteem, and exclusionary practices.⁷

BACKGROUND INFORMATION

As mentioned above, Graham provides a thorough literature review of the factors that contribute to a non-traditional major choice among undergraduate women including relevant family and academic variables, and the psychological, sociological, and environmental factors related to persistence in those non-traditional majors.⁴ Readers may refer to that document. Among other authors, Levenson discusses the key points along the educational pipeline, including graduate study and entrance into academia.⁷ The first big drop in the pipeline occurs with the choice of undergraduate majors in college.

Women enter graduate school in the technical areas in proportion to their completion of bachelor's degrees. A combination of attrition and stopping at the Master's degree level creates the second major drop for the women students in the pipeline.⁷ Studies conducted at Stanford University in 1984 and at the Massachusetts Institute of Technology in 1986 and 1987 found that "women were indistinguishable from men in objective measures of preparation for graduate school, career aspirations, and performance."⁷ (Their grade point averages were slightly higher in both their undergraduate and graduate programs.) The women differed significantly, however, in financial support, self-confidence, the pressures and roadblocks they encountered, and the strategies they developed for coping with these pressures. Leveson found that many more women reported serious consideration of dropping out of graduate programs. In fact, the attrition rate for women was double the rate for men.⁷

A larger percentage of women than men are to some extent self-supporting during graduate school. Women are less likely to get financial support of any kind, and when they do, it is more likely to be a teaching assistantship. A smaller percentage of women graduate students than men in all fields of science are supported on research assistantships.⁷

Women appear to experience feelings of difference from the majority, including feelings of powerlessness and invisibility and increased pressure and isolation. Women may be (unintentionally) excluded from informal social interactions between faculty and graduate students; therefore, they tend to be less integrated into the informal networks where information is shared between faculty and students and between students. Women often report that their interactions with faculty are unhelpful as far as feedback on their research projects. Women often do not feel comfortable in disagreeing with their advisors, and they tend to believe that their ideas are neither well received nor respected. Women graduate students have reported fewer opportunities to publish, especially fewer opportunities to be first author on publications. These and other differences influence women to need and want advice about the political aspects of graduate and academic life, that is, how to “play the game”.⁷

The social and academic isolation of women is not unique to graduate students, but continues and perhaps even gets worse when women attempt to take their place in academia and industry.⁷ The “engineering culture may be more of a reality for female engineers working in academia than for those in industry.”⁸ “Even when they are quite successful, many women faculty members generally feel that they have a precarious toehold in academic.”⁷

Women faculty often find it difficult to make inroads into funding agencies. If they are assertive, they may be considered to be “pushy” and may feel uncomfortable about displaying the type of aggressive behavior required to accomplish this. Documents with women’s names attached receive lower evaluations from both men and women evaluators compared to the same documents with male names attached.⁷

There is also evidence of differential treatment in terms of the amount and kind of service. Women are appointed to a disproportionate number of committees where what they have to say or contribute is often dismissed. They also serve as advisors to students a larger proportion of the time. “Nearly 30 percent said they frequently or very frequently experience discrimination as a woman in engineering academia although the discrimination is usually subtle, making it impossible to prove.”⁸

Balancing work and family poses difficulties for many female academics who seem to have less spousal support than their male counterparts. “Thirty-six (36) percent said that family responsibilities have negatively affected their career advancement, and well over a third say they are putting off – or have already put off – having a family to advance their career. A large 62 percent of women in academia have considered leaving academia; some have resigned positions to take appointments at teaching colleges where they felt they would be better accepted.”⁸

METHODOLOGY

The 1999 study utilized both individual face-to-face interviews and questionnaire survey methodology via electronic mail. Including interviews of undergraduate women,

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graduate women, alumni, and faculty in both disciplines expanded the study. In all cases, questions were open-ended, thus giving participants the opportunity to provide detailed, personal answers. The questions were similar to those used in the first study; however, additional questions were added for the population of alumni, graduate students, and faculty. These groups were asked about workplace discrimination, compensation and other fringe benefits, opportunities for advancement, financial support in graduate study, research funding, informal and formal networks, the research advisor relationship, the tenure process, and balancing family and work. Including interviews of undergraduate women, graduate women, alumni, and faculty in both disciplines expanded the study.

The total enrollment figures, including both undergraduate and graduate enrollments, for Electrical and Computer Engineering at this university are 765 and 584 respectively. The student population in Computer Engineering includes the following percentages of women: 6 percent at the undergraduate level, 18 percent at the master's level, and 0 percent at the Ph.D. level. The large percentage of women at the graduate level is inflated by a sizeable number of women in the off-campus program, most of who are employed in industry and taking evening classes. The student population in Electrical Engineering includes the following percentages of women: 11 percent at the undergraduate level, 14 percent at the graduate level, and 10 percent at the Ph.D. level. Many of the graduate women in Electrical Engineering are international students who plan to return to their home countries upon completion of their graduate degrees. Among the 70 faculty members in the department, two are women. A total of twenty women were interviewed or responded to questionnaires: 8 undergraduates, 4 Master's students, 2 Ph.D. students, 2 faculty, and 4 alumni. Limiting data collection to one university and utilization of small sample sizes obviously restricts generalizability; however, that was not the intent of the study. Again, the intent and purpose was to gain some insight into their profiles of persistence.

It is noteworthy that the two women faculty members have electrical engineering backgrounds. One reality being faced by Computer Engineering departments across the nation is the lack of women at the graduate level and therefore the lack of potential women faculty. Opportunities in the high-tech computer industry are more lucrative financially for men and women; therefore, there is a shortage of computer engineering faculty in general.

FINDINGS

The personality profiles of all the participants are very similar to those of the women who participated in the 1997 study. These women are independent, competitive, organized, and, perhaps most importantly, determined. Independence is an especially important characteristic in academia where women are often left out of the faculty network. One of the faculty members, emphasizing a strong sense of self and the ability to say no, commented, "I just don't care what people think about me." In general, the women also have a strong work ethic and, especially in the case of the graduate students and faculty, a desire to learn more. They are not daunted by being the "only one" – in fact, they have

come to appreciate being different. Incidents of discrimination and discouragement have challenged them and motivated them to succeed. For example, one of the undergraduate women remarked, "I didn't accept the boys' advantage with computers. It inspired me to learn how to use them."

It is not surprising that many of these women have engineering relatives, most often a father or an uncle. In many cases, mothers, fathers, or influential teachers encouraged them to pursue engineering majors. Parents, in particular, were strong educators and/or stressed the importance of education. In a few cases, women faculty at the high school or community college level inspired these women to pursue their degrees in engineering. Interestingly, two of the undergraduate women were encouraged to pursue degrees in Electrical and Computer Engineering by their first year mentor, a young woman who recently graduated with an Electrical Engineering degree. The Electrical Engineering undergraduate student is now on co-op assignment with the same company in Oregon where her former mentor is employed.

The participants emphasized and demonstrated the importance of hands-on experiences and related coursework. Many of the younger women have essentially grown up with computers in their homes. They were encouraged to learn to use the family computers, rather than being warned about "breaking" them. Hands-on experience with electronics and circuitry through the military and science fair projects were mentioned in a significant number of cases. For example, one participant recalled designing a noise cancellation device for a hair dryer as a science fair project. Some of the participants fixed and programmed electronic devices in their homes. Most of the women in Computer Engineering had taken a programming course in high school, thus increasing their self-efficacy for programming at the college level. A strong mathematics and physics background as well as strong interests in those subjects was also common. Cooperative education and internship experiences at the college level had reinforced decisions to major in Electrical and Computer Engineering. Again, the desire to learn more motivated many of the graduate students and faculty to pursue advanced degrees. For example, one of the faculty members, who has a Bachelor's degree in Industrial Engineering, decided to pursue graduate study in Electrical Engineering after gaining several years of experience in industry and discovering her real interests.

Many of the participants talked about the culture and environment they have encountered in Engineering and Computer Science programs and the engineering workplace. The Computer Engineering undergraduate women mentioned bias against Computer Engineering majors among some faculty and teaching assistants in Computer Science. For example, one of the students went to see her teaching assistant for help with a particular concept. He remarked, "oh, you're a CpE, aren't you? That explains it." With a few exceptions, most of the women had encountered encouraging and helpful instructors and good instruction at all academic levels. Despite good instruction in her home department, one of the Computer Engineering undergraduate students mentioned that she often feels marginalized in her department. Although she is a scholarship student and ranked number one in her class, many of her male peers are unwilling to include her

in their networks. One of her “survival mechanisms” has been to develop relationships with faculty in the Mathematics and Philosophy Departments. Both she and one of the graduate students are on a full scholarship. Interestingly, they both mentioned that their scholarship status is a “study in itself.” While they both agreed that they experience pressure to maintain a minimum 3.5 grade point average, they also feel motivated to succeed. One of the women remarked, “the scholarship inspires me to do well because the department has faith that I can do this.”

Two undergraduate women had transferred internally from one engineering discipline to another, one from Mechanical to Electrical and one from Computer to Electrical. The student, who transferred from Mechanical to Electrical performed well in Mechanical, but had difficulty understanding the constant references to motors and engines by Mechanical Engineering faculty. The student who transferred from Computer to Electrical was extremely frustrated by the instruction in her Computer Science classes and the attitudes among some of the Computer Science faculty.

The alumni and faculty almost unanimously agreed that they became aware of discrimination for the first time in the workplace. For example, two participants mentioned that they were passed up for a promotion and/or pay increase despite performance equal to or better than their male co-workers. The status of women engineers in the workplace merits more attention.

The graduate students and faculty confirmed some of the same barriers and sacrifices discussed in Leveson and Thompson.^{7,8} When one of the women entered graduate school, her marriage failed due to the unwillingness of her former husband, who had earned a Master’s degree in Electrical Engineering himself, to support her own desire for an advanced degree. As graduate students and former graduate students, the women commented on “knocking on doors” to market themselves for research assistantships and other forms of funding. One of the faculty members, who attended a prestigious university in the Northeast, “fought tooth and nail” for a research assistantship despite prior extensive service through teaching assistantships. She saw some of her female peers leave when they failed to gain support for their research endeavors. Many of these graduate students and faculty have observed that many male faculty members appear to be uncomfortable chairing the committees of female graduate students, and graduate and faculty men more often exclude their female peers and colleagues from their networks. Formal mentoring relationships between tenured male faculty and untenured female faculty sometimes flounder as well. Again, an independent personality and strong sense of self as well as networks with other women graduate students and faculty are important for survival. Finally, other survival mechanisms are “learning to play the game,” “not making waves,” and “doing your own thing.”

CONCLUSIONS

Former and current research has identified profiles of persistence among women at all levels of the educational pipeline utilizing a model based on strengths versus a deficit model. The voices of the women who participated in these studies have provided some

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additional insight and sound direction for the future. This type of study does not dismiss the fact that continuing attitudinal and structural change in the culture of engineering is needed to level the playing field for women at all levels. For example, support for women must be evident from the top down. Employers and faculty who discriminate against women engineers must be reprimanded and warned about their discriminatory behaviors. Sexual harassment policies and effective teaching and advising practices are essential. Feminist pedagogies that emphasize collaborative and cooperative learning, classroom discussion, and gender-fair group and laboratory work promote opportunities for relationships with other people. Other suggestions include interaction with faculty and graduate students outside the classroom, hands-on learning opportunities, undergraduate research opportunities, internships and cooperative education, and instruction in formal mentoring for undergraduate women, graduate women, employers and new employees, and tenured and new faculty.

While the playing field is relatively level in a few engineering disciplines, more progress needs to be made in others. Degrees in Computer Science and Electrical and Computer Engineering are among the pathways to the top, and we must find ways to encourage young women to pursue those paths. As simple as it may seem, changes in course-taking patterns and some encouragement from faculty can make a difference. For example, an undergraduate student in Mechanical Engineering at Stanford University recently took a programming class taught by a female faculty member in Computer Science. The instructor's simple comment, "you're a very elegant programmer," is leading this young woman to pursue a major in Computer Engineering. "Scientific and technological progress will reach it's fullest potential only when those with the most ability, regardless of gender or race, have an equal opportunity to participate and contribute."

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