38% of Women in Engineering! Why so many?

Results of a 1998 study conducted by the University of Puerto Rico at Mayagüez

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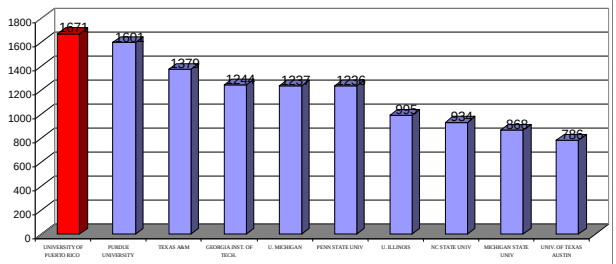
I. Introduction

The University of Puerto Rico at Mayagüez boasts an above-national-average enrollment of women in engineering. Intrigued as to why so many women at UPRM consider engineering as a career—and why so many of them actually stay and graduate—UPRM faculty researchers decided to conduct a study to find the answers. The University of Texas – El Paso collaborated. This paper summarizes the major findings of that 1998 study, which surveyed a statistical sample of 385 women.

II. National Statistics

Figure 1. Top 10 Colleges for Enrollment of Women in Engineering, Fall 1997



Source: Engineering Workforce Commission of ASEE, 1997

Nationally, only 13% of women state that they are going to pursue fields of natural science, math or engineering. Eighteen percent of those enrolled in undergraduate engineering programs are women, and 5% of those enrolled in science and engineering programs are Hispanics (NSF, 1996). UPRM has minority students who, in general, come from disadvantaged schools where access to advanced science and math courses may be less likely to occur (NSF, 1996). Yet, as illustrated in Figure 1, the 1997 ASEE Engineering Workforce Commission reported that UPRM, with 1,671 women in its College of Engineering, had the largest enrollment of women in engineering of any institution in the country. UPRM was followed by Purdue University, with 1,601 women in engineering, and Texas A&M, with 1,379. In that same year, among the universities rated the top ten for greatest number of women in engineering, an average of 24% of all engineering students were female. At UPRM, 38% of engineering students

were female, followed by Purdue University and the State University of Chicago-Ann Arbor, each of which had 28% female enrollment.

III. Attrition and Persistence

NSF statistics also show that attrition rates are the greatest among minority students. Overall, women and minority students are more likely to drop out of engineering programs than majority students (Mallory, 1998; NSF, 1996). Among the reasons cited for dropout are the following:

- While both men and women find engineering programs to be difficult (Mallory, 1998; NSF, 1996), women in particular perceive engineering as among the most difficult and demanding of college programs; only 30% of women surveyed felt they could successfully complete such a program (Betz and Hackett, 1981).
- Engineering programs are highly competitive (Mallory, 1998; Morgan, 1992). For example, in Morgan's study, 86.4% of participants cited the competitive atmosphere.
- While engineering faculty may not support any students well (Leslie and Oaxaca, 1995, cited in Mallory, 1998; NSF, 1996), college faculty's discriminatory attitude towards women may contribute to their under-representation in engineering fields (Morgan, 1992). A "chilly climate" often persists for women who choose non-traditional fields such as engineering (Hall and Sandler, 1992).
- Other reasons cited: male resentment of their female colleagues, difficulty of combining home and family responsibilities with demanding jobs; and discouragement by parents and others from studying engineering (Morgan, 1992).

Peers are often cited as playing a critical role in determining women's persistence in attaining an undergraduate education in engineering. In fact, those women who do not receive peer support seem to be much less likely to continue in engineering programs than those who do (Holland and Eisenhart, 1990). In a 1989 study, women in non-traditional career programs who did not have rigid sex role attitudes expected to encounter more difficulties than did women in traditional programs, but also had greater academic success (O'Connel, Betz and Kurtz, 1989).

IV. Profile of Women in Engineering

Having had "masculine" interests and activities during childhood distinguishes career women from homemakers (Lewis and Gerard, 1985, cited in Blaisdell, 1995). A study that looked at women in engineering and other technical fields found that they differed from women in more traditionally "feminine" fields in their subject choices in school, their taking advantage of curriculum opportunities in school, and their perceptions of their parents' attitudes towards their careers (Haworth, Povey and Clift, 1986, cited in Blaisdell, 1995). Similarly, other researchers have noted that women who choose engineering and other technical fields different not only from those who choose more traditional occupations, but also differ from the men who choose such fields (Ethington, 1988). For example, Ware, Steckler and Leserman (1985) found that the most important factors leading to a woman's choice of a science-based career were her having had highly educated parents, high SAT scores, a strong desire for prestige and control, and the desire for positive interaction with others. In contrast, for men, significant factors were

their own college freshman science grades and their choice of science as a major prior to entering college, while parents' education was not a major determinant.

V. Ethnicity

One study looking specifically at the effect of ethnicity on self-efficacy found that Mexican-American students were less confident of their occupational and academic skills. Those researchers also reported that faculty encouragement aided students in performing successfully. However, Anglo and Hispanic men reported having received significantly more faculty encouragement than did Anglo or Hispanics women (Hackett, Betz, Casas and Rocha-Singh, 1992). African-American, Native American and Hispanic women earned more degrees than did men from those ethnic groups. Nonetheless, a 1996 NSF report stated that, "So few minority women earned degrees, however, that they remained under-represented among students achieving baccalaureates in science and engineering combined" (NSF, 1996, p.41).

VI. Parents' Education and Income

In every racial and ethnic group studied in a 1996 NSF-sponsored research project, higher family incomes were generally associated with higher student scores on both verbal and mathematical sections of standardized tests, such as the SAT (NSF, 1996). Within every racial/ethnic group, higher levels of parental education were associated with higher student scores on the math portion of the SAT. For example, the difference between average SAT scores of students whose parents did not complete high school and those whose parents held a Master's degree ranged from 85 to 120 points (NSF, 1996). Parents of women engineers were more likely to have college degrees and to be employed in professional positions (Jagacinski, 1987). Fathers of students in non-traditional programs had significantly more education than did fathers of women in traditional career programs (O'Connell, Betz and Kurth, 1989). Father's education correlated with math achievement (Ethington and Wolfe, 1984). Among economically disadvantaged students aged 16-24, women had very low self-efficacy for engineering careers (Post-Kammer and Smith, 1986).

VII. Why Engineering?

According to a 1992 study, female students generally tend to place a more emphasis than do male students on people-related values, enjoyment of their work and self-efficacy (Lips, 1992). That researcher concluded that women are more likely than men to seek careers in which they are able to "combine career and family, to be helpful to others, and to work with people rather than things." (Lips, 1992, p.77). Greenfield, Holloway and Remus (1982) found similar results. However, another researcher postulated that women in non-traditional careers had higher self-efficacy for working with things rather than working with people (Whiston, 1993). Hacket (1985) reports that, in general, those more confident of their math skills were more likely to select science-based majors.

Parental expectations and family background play a strong role in women's participation in engineering (Ehrhart and Sandler, 1987; Farmer, Waldrop, Anderson and Risinger, 1995; Fitzpatrick and Silverman, 1989; Sherman, 1983). Pipeline into engineering careers begins at grade one and ends with a Ph.D. or other professional degree (Berryman, 1985). Availability of jobs, acceptable salaries and fringe benefits were important influences in choices of career (Fitzpatrick and Silverman, 1989; Stringer and Duncan, 1985).

VIII. UPRM

Table 1 provides a profile of UPRM and its student body. Table 2 profiles the UPRM College of Engineering.

Table 1. UPRM (1998)

• Founded in 1911 • Comprehensive university • Public bilingual commuter institution • Fall 1998 enrollment: 12,600 • Highly selective • 99.9% Hispanic • 51% female • Over 1800 degrees awarded in 1996-97 with close to 140 graduate degrees • Over 50% are first-generation university students

Table 2. UPRM College of Engineering (1998)

• All engineering programs are ABET-accredited • 7 bachelor's, 6 master's, and 1 doctoral degree (2 in the pipeline)[1] • 160 faculty members (19% female)

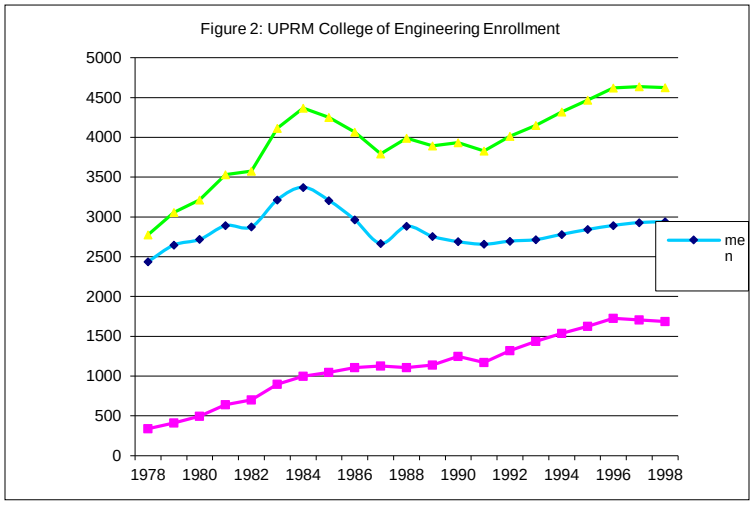
[1] As of 2001, there are 3 PhD programs in the College of Engineering

- 4620 undergraduates (38% female)
- 671 undergraduate degrees/year (36% female)
- Retention rate: 76% overall

As shown in Figure 2, over the 20-year period of 1978 to 1998, UPRM experienced a 20-fold growth of its female population. Currently, Chemical and Industrial Engineering at UPRM have over 50% women enrolled.

IX. The Study

During academic year 1998-99, UPRM developed a survey with 40 questions to query women studying engineering. The survey was designed after a focus group as conducted that posed a series of questions to participating female students and faculty. Basically, there survey was composed of three parts: information about the respondent, questions regarding the student's life before entering college/university and decisions made at that time, and finally, questions about their current academic environment and future plans. Various questions had write-in spaces to further explain answers in different sections. Once the instrument was developed, it was distributed to female engineering students. Due to the large population of women, it was distributed to a randomly selected sample of the population: 385, which corresponds to a 5% absolute error and 95% confidence. The sample covered all engineering departments and levels (undergraduate to graduate). Three hundred fifty seven (357) surveys were completed (which corresponds to a 5% absolute error and 94% confidence level).



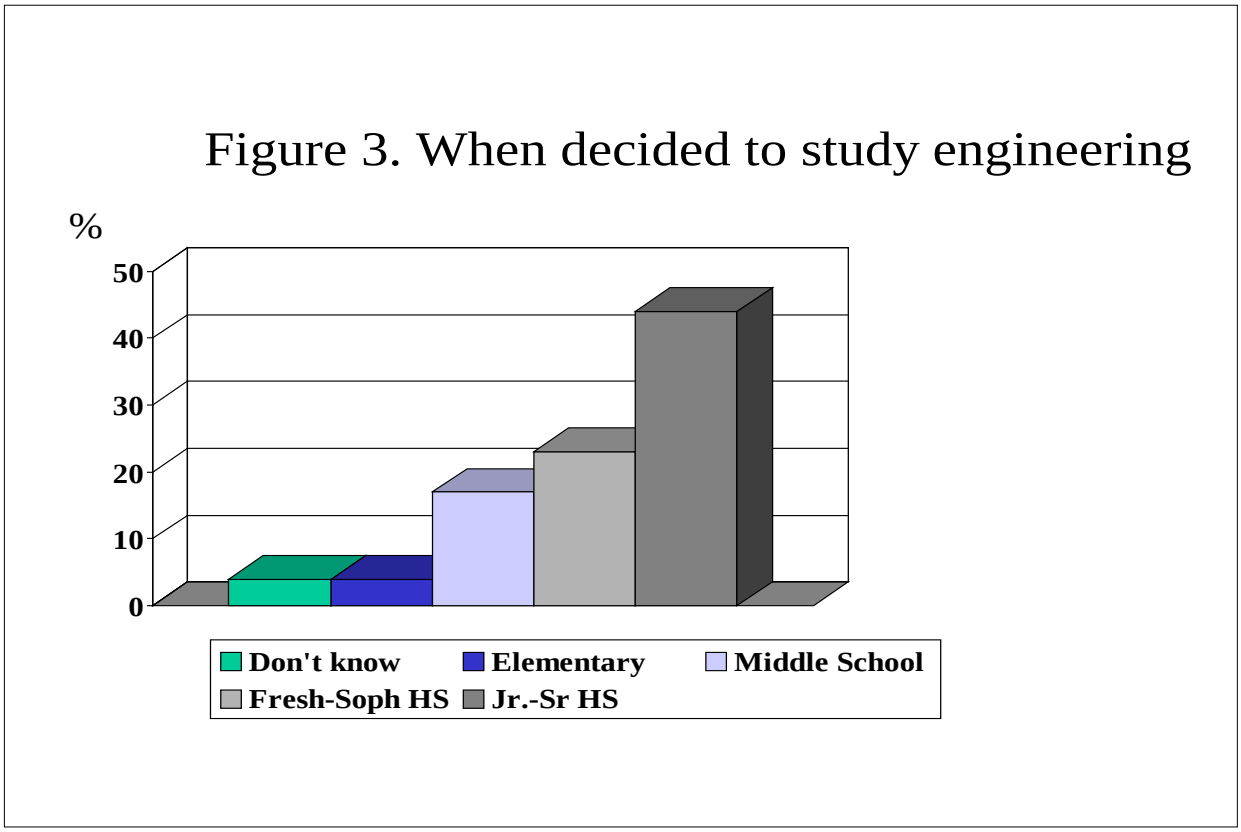
Dr. Sandra Lloyd – who collaborated in a similar study at the University of Texas at El Paso - analyzed the data.

X. Findings

a) Female population at UPRM. The general characteristics of UPRM women who chose engineering as a major are as follows:

- 100% from 18 to 24 years of age, inclusive
- 5% married; 4% with children
- 79% pursuing B.S.; 13% M.S.; 3% Ph.D.
- of those pursuing the B.S., 10% were freshman; 12% sophomore; 34% junior and 31% were seniors
- 29% lived with parents
- 16% employed
- 42% had GPA of 3.01 or above
- 63% received financial aid

We found that 40% of the women surveyed decided very early to go to college (in elementary or middle school), and that 67% decided on engineering during their high school years (Figure 3).



In relation to what encouraged the women to study engineering, the survey revealed the following statistics:

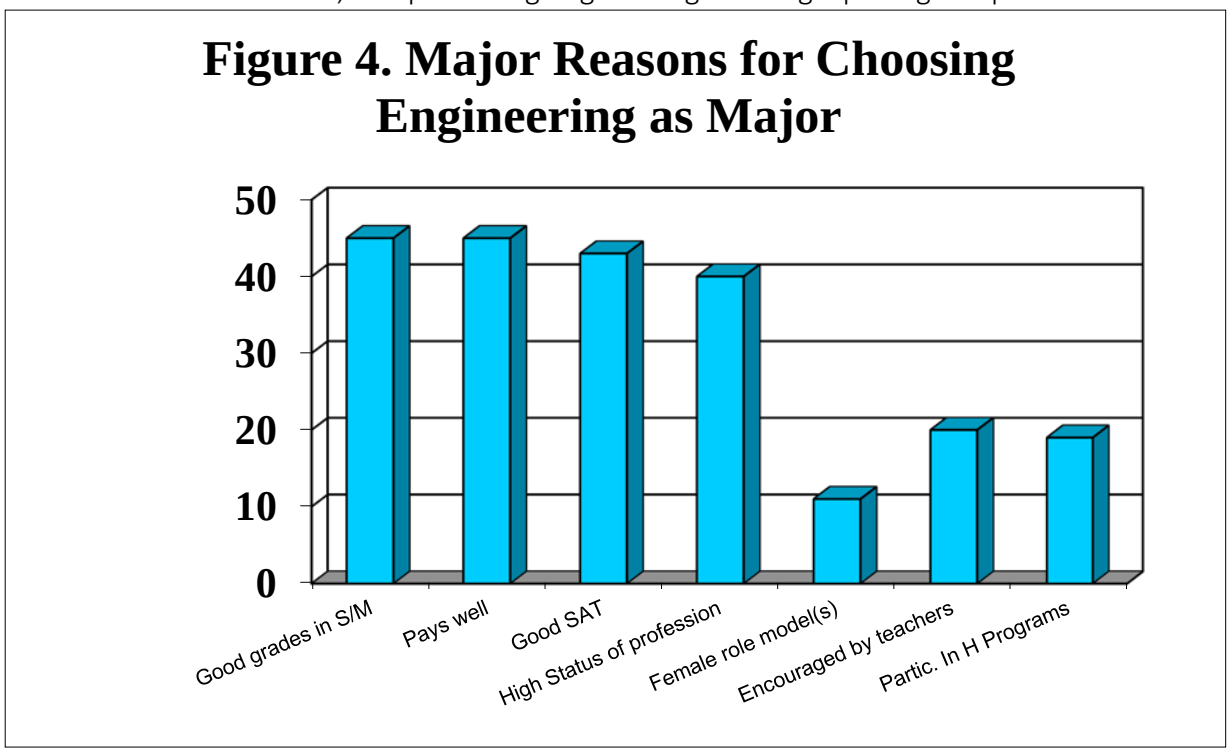
- 55% of UPRM's students had been involved in a non-traditional high school (HS) program.
- 27% of all students had been involved in career day activities in HS.
- 23% of the women had a family member that was an engineer
- 12% had a female friend who was an engineer.

When asked what was the most influential factor in their decision to study engineering 26% indicated that it was due to having been involved in a non-traditional traditional HS program (Table 3).

Table 3. Most influential factors in deciding to study engineering.

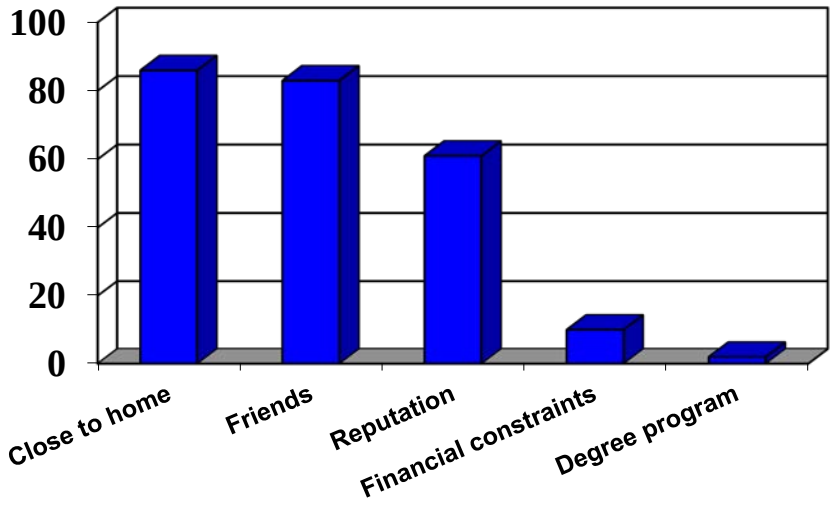
Factor influencing decision	%
HS program, non-traditional	26%
Attended career day activity	21%
HS program, engineering	14%
Family member was engineer	8%
Encouraged by parent	5%
Family friend engineer	5%
Other	5%
Thought field interesting	4%
Female friend engineer	1%
Male friend engineer	1%

As shown in Figure 4, the major reasons for choosing engineering as a major included having good grades in science and math, perceiving engineering as being a well-paid profession, scoring well on standardized tests, and perceiving engineering as being a prestigious profession.



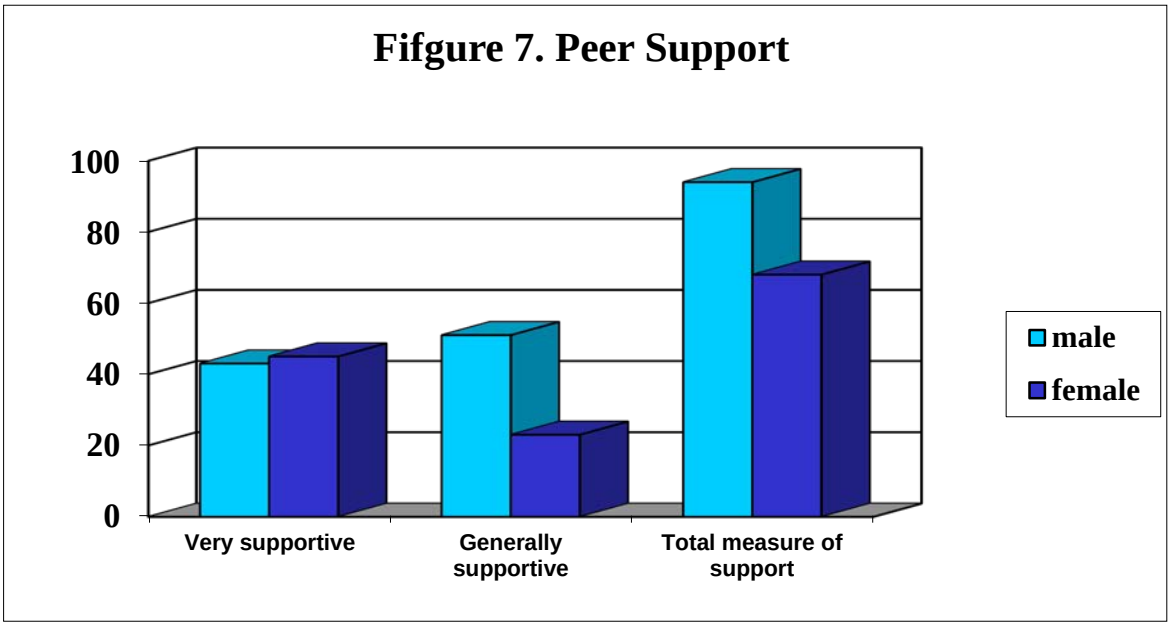
Notably, only 10% of those women surveyed indicated that one or more female role models influenced their decision.

Figure 6. Reasons for Choosing UPRM



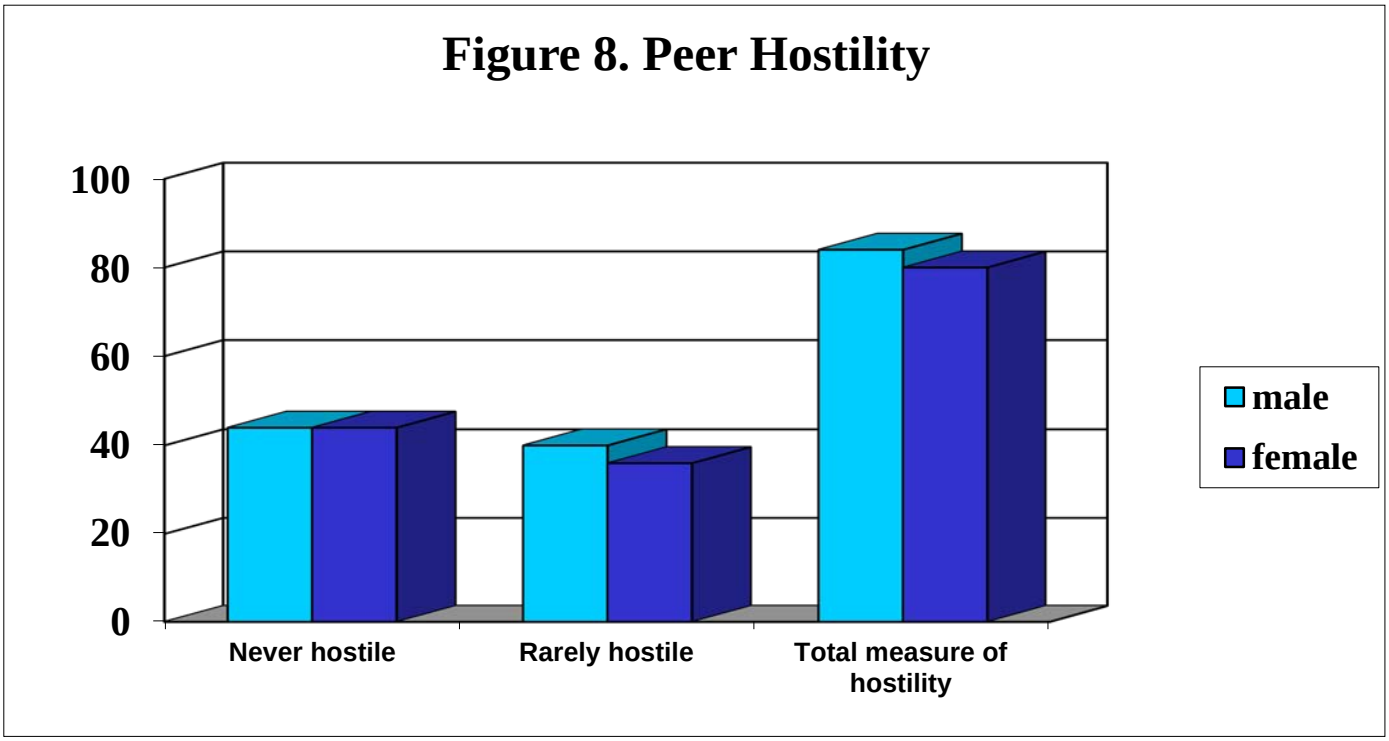
We also found no connection between college enrollment/GPA and family income and between college enrollment/GPA and family education. Family incomes of the sample surveyed ranged from below $10K to over $50K. Interestingly, with regard to the family's education, the study showed that 65% of the students' mothers had achieved a college level education, compared to 55% percent of their fathers. Twenty four percent (24%) of the respondents were the first in their families to attend college (the average at UPRM is 50%).

Finally, the study indicated that high school ranking, rather than GPA, was the best predictor for college success among women in engineering.



b) Basis of choice of institution. Why did the women surveyed choose UPRM over other institutions on the island or mainland? Eighty-four percent (84%) chose the institution because it was close to home, while 83% indicated that one factor in their decision was the fact that their peers and friends chose to attend UPRM. Sixty one percent (61%) indicated they chose the institution for its reputation, and only 10% said the decision was due to financial constraints. (See Figure 6.)

This study also revealed that women in engineering tend to feel more supported by their male



peers than by their female peers, and that they perceive their academic environment to be a non-hostile one. (See Figures 7 and 8.)

c) Female students' plans for the future. The study indicated that women had a clear picture of their future and had high expectations. The study found that 47% of the women in engineering at UPRM were considering a job in industry or government upon graduation, and 39% of UPRM female engineering students were considering pursuing a master's, Ph.D. or other professional degree in the future. (Table 4)

Table 4. Future plans

Job in industry or government	47%
MS degree	27%
Not sure yet	10%
Other professional degree	8%
PhD degree	4%
Other (join armed forces, mission, etc.)	3%
Own consulting firm	3%
Teach SM @ college level	1%

Teach SM @ middle/high school level	0%
Teach SM @ elementary level	0%

a. Perceptions for unusually high enrollment of women in engineering at UPRM.

Strong summer programs that encourage women, encouragement by high school teachers and counselors, and greater career opportunities for women were identified as the reasons that female engineering students at UPRM believe there are so many women in engineering at that institution (Table 5).

Table 5. Reasons for high enrollment of women in engineering.

Greater professional opportunities for women	48%
Encouragement by HS teachers	27%
Discouraged from leaving town/island	27%
Encouragement by HS counselors	24%
Don't know	24%
Strong summer programs encourage women	18%

Comments by respondents included:

- *Women finally know they're as good as men*
- *College is affordable*
- *Women are better students*
- *I don't want to be the same as a man; I want to affirm the difference.*
- *I always wanted to be a success and I knew engineering would do it.*

XI. Conclusions

From the data we have collected in this study, we can conclude that young women with interest in science and math choose early in their lives to go to college, but wait until middle and/or high school to choose engineering as their major in college. Evidence shows that attitudes of parents, teachers and counselors, as well as career and science/math activities, have an effect on these women's choices. They perceive themselves to be different from other female students, and are proud of that. They appear to be mature and tend to have high expectations in life. With respect to the challenges they face in pursuing an engineering college degree in college, these women feel supported by both men and women and many have future plans that involve graduate school.

Based on the survey findings, including the write-in comments on those surveys, as well as focus group data, female engineering students could be characterized as follows:

- *Searcher (more mature and sets high standards).* They typically see themselves as more mature than many of their female peers. They are more "future-oriented," and see themselves as holding themselves and others to higher standards of behavior and performance than others do. They are not inclined to "settle."

- *Warrior (revels in the prospect of success in a man's world).* They consciously think about prestigious/high income generating careers. Moreover, they have taken particular pleasure in selecting a field that is still dominated by men; the thought of succeeding in that kind of environment is particularly appealing.

- *Outcast ("different is good").* These students believe that "different is good". They take pleasure in knowing they are not viewed in a way that might describe them as "typically female," as defined by conventional and local culture. They enjoy knowing they are smart and that their intelligence makes them stand out; they enjoy knowing their tastes in things are generally different from their female peers; and indeed, some of them feel glorified by the "outcast" label.

- *Other.* Some respondents' comments were associated with the previous category, but were stronger. We observed a direct link to many of these women's likes and dislikes, which can be characterized as "male" in orientation. For example, these women indicated that in school (pre-university), they enjoyed subjects typically characterized as difficult and, therefore, "male." They enjoyed taking things apart and putting them back together again. And they enjoyed the company of boys with whom they shared interests and whom they found to be intellectually stimulating.

What is happening UPRM that fosters an environment adequate for women to consider engineering as a career and to stay in the field of study despite the various difficulties it presents? In addition to the conclusions derived from this study, we believe it may be due to the following:

1. The island of Puerto Rico environment. Women are becoming important players in the workforce in Puerto Rico. Women are relating to more female role models than ever before. UPRM elected its first woman dean of engineering, who eventually became the first female chancellor of the campus and of the UPR system. On November 7, 2000, the Island elected its first woman governor in 500 years of history. Thirty percent of all Hewlett-Packard engineers in Puerto Rico are women (including one of the operations managers of its Puerto Rico plant). According to the *San Juan Star* of October 11, 2000,

> *For years now, Puerto Rico's universities have been forerunners of a significant change settling into the island's general society. Signs of that change-to-come were there to read in annual numbers that showed females were replacing males as the majority on university graduation lists around Puerto Rico . . . . It seemed only a matter of time before*

the same change began to show up in the workforce . . . . The two top managers at Hewlett-Packard Puerto Rico are Lucy Crespo . . . and Iris Santos . . . . It is happening all over Puerto Rico as women become players in all fields.

2. The University of Puerto Rico at Mayagüez environment. UPRM focuses on a cooperative learning environment and pedagogy. Entering and mentoring programs, such as NSF Minority Institutions of Excellence and Alliance for Minority Participation, offer numerous experiences for both students and faculty that enhance the learning/teaching experience through collaborative learning and affinity groups, which, in turn, are changing the educational culture. UPRM highly regards its collaboration and interaction with industry and strongly emphasizes a curriculum of "learning by doing," as demonstrated by award programs such as the NSF-sponsored "Learning Factory" [Lamancusa, 1997] and NASA's Partnership for Spatial and Computational Research, an interdisciplinary option for SMET students that integrates undergraduate research as part of curricular requirements [Morell, 2000].

3. Outreach programs. UPRM has middle and high school outreach programs (for all students, not only women) that not only present science, math and engineering in an attractive way, but also involve students in projects (e.g., science fair, summer programs), and faculty in professional development. Examples of these programs at UPRM are:
    - NSF's Pre-engineering program
        - 3 summer sessions
        - 2 weeks; 30 high school students (50% female)
    - NASA GLOBE Program: "Science on Wheels"
        - Reaching more than 18,000 MS/HS students in 5 years
    - NSF's Future Scientists of America
        - MS teachers summer workshop
    - IBM's Science Summer Camp for Girls (IE)
    - ECE Department High School orientation and recruitment

XII. Some thoughts on future research

As with many studies, this study raised questions beyond those it answered. The conclusions reached in this study may very well characterize all women pursuing non-traditional careers, be they technical, vocational or professional. In all likelihood, this is what young women pursuing engineering careers look like, at least at the entry and exit points. Future research may explore whether there are any differences in perspective/attitudes between women graduating from institutions that are less "female-friendly" and those graduating from institutions that are friendlier toward female engineering students. Will there be differences? Or will the simple common factor of being in pursuit of a Bachelor's degree in engineering be shown to impose certain defining characteristics for all women studying in and graduating from that field? And if there are differences, what advantages and/or disadvantages might those differences result in for the female engineer functioning as a professional?

What role does the friendly-environment factor play in encouraging women to graduate from programs in engineering? Do those women have the opportunity to participate in research activities as undergraduates? If undergraduate research experiences increase the possibility for pursuing graduate study, does the fact that women have few of those undergraduate opportunities inhibit their pursuit of graduate study? What factors, historic and current, have predicted graduate study generally and for women specifically?

Are there particular disciplines in engineering that women tend to gravitate towards, as, for example, women in medicine have been known to gravitate towards pediatrics and obstetrics/gynecology?

What percentage of female engineering undergraduates go directly into industry jobs after graduation? Are there certain industry cultures that they gravitate towards and prefer to work in? Are they paid as well as their male counterparts? What are their rates of promotion as compared to those of men? What differences may their undergraduate culture have made with regard to these various issues, and what can we inside the university do to enhance the undergraduate culture for female engineering students and facilitate their achievement of an education and a career that is personally, professionally and financially rewarding?

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