The Need for Female Role Models in Engineering Education

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Abstract

The relative under-representation of women in engineering compared to their male counterparts might be related to women's lack of self-confidence in their abilities (Felder et al., 1995), serious "academic dissatisfaction" (Adelman, cited in Brainhard, Metz, & Gillmore, 1999, p. 61), feelings of isolation (Bergvall, Sorby, & Worthen, 1994), and the uncertainty of balancing an engineering career with family life (Hynes, 1992). Studies have confirmed that females have a lower level of self-efficacy than males (Besterfield-Sacre et al., 2001; Felder et al., 1995; Zohar & Bronshtein, 2005), and because of this lack of self-confidence, females benefit from increased encouragement and validation. Demonstrating that becoming an engineer is attainable by "someone like them" (Lockwood, 2006, p. 36) might build prospective female engineers' confidence. Determining the validity of this idea was the focus of this research study.

The researcher examined whether or not strong female engineering faculty members might be a strategy to increase the admission and persistence of female engineering students. An initial focus group (N = 6) at one institution was used to create a survey that was sent to eight post-secondary institutions. Usable survey responses came from female undergraduate engineering and technology students (N = between 382 and 508, depending on the question) in their third year of study or beyond. Survey questions fell into eight categories: demographics, role model characteristics, needs in an educational environment, needs fulfilled by other people, views on the engineering education environment, level of comfort in the engineering education environment, needs from an instructor, and views of how effective scenarios might be for helping a student feel more comfortable and confident being a female in engineering. Results of data analysis suggest that female students with greater numbers of female professors have higher levels of self-confidence and worry less about how others view them.

Introduction

For decades, women have been striving to succeed and increase their numbers in science and technology fields. Fields like biology and medicine have achieved nearly equal numbers of men and women for years now; however, the fields of engineering and engineering technology still struggle each year to attract and retain females. Only 11.1% of the U.S. engineering workforce is comprised of women, compared to 43.3% in Biology and Life Sciences (cited in Table H-7. Employed scientists, 2007). Possible explanations as to why women choose not to pursue and continue in these engineering fields include lack of self-confidence in their abilities (Felder et al., 1995), high levels of "academic dissatisfaction" (Adelman, cited in Brainard, Metz, & Gillmore, 1999, p. 61), feelings of isolation (Bergvall, Sorby, & Worthen, 1994), the uncertainty of balancing an engineering career and family life (Hynes, 1992), as well as various combinations of these and other reasons.

Many studies have confirmed that females have a lower level of self-efficacy than males (Besterfield-Sacre et al., 2001; Felder et al., 1995; Zohar & Bronshtein, 2005). Because of this lack of self-confidence, females benefit from increased encouragement and validation in reference to the work they do. One suggested way to increase self-confidence in female students is to show them that the goal of becoming an engineer is attainable by "someone like them" (Lockwood, 2006, p. 36). This research study assesses the need of undergraduate female engineering students for encouragement and validation, and will evaluate the idea that the most effective way to increase the low numbers of female engineers is to provide undergraduate female engineering students with the presence of strong role models in the form of female faculty members.

Literature Review

What is a Role Model?

Any person who has ever wished to achieve a goal can likely trace his or her aspiration back to another person, a role model. Researcher Penelope Lockwood (2006) defines role models as "individuals who provide an example of the kind of success that one may achieve, and often also provides a template of the behaviors that are needed to achieve such success" (p. 36). This definition highlights what I felt were the two very important functions of a role model—to act as an archetype of an attainable objective and to demonstrate a path that one may follow in order to attain this goal. Role models are typically older than those they inspire. Downing, Crosby, and Blake-Beard (2005) go further in their discussion of role models to specify that "a role model is someone with whom one identifies emotionally… An individual looks up to and admires the role model. The role model may or may not be aware of the admiration he or she invokes and may not be aware that he or she is a role model for others" (p. 422). The last part of this definition is important to note. Some role models also act as mentors, which is a relationship in which the more experienced person "provides both technical and psychosocial support to a less experienced person" (Chesler & Chesler, 2002, p. 50), but not all role models personally know the people they inspire (Chesler & Chesler, 2002; Downing, Crosby, & Blake-Beard, 2005; Lockwood, 2006).

Though role models do not necessarily have a relationship with the people they inspire, this study explores the importance of faculty members, specifically female faculty members, as role models, and because of this, when discussing role models throughout this research paper, it is assumed that these role models will have some interaction with those they inspire. These individuals are considered role models rather than mentors because the amount of interaction they provide will vary depending on the individual students and professors in the relationship.

The Impacts of Role Models

"College students' role models are important because role models may influence the students' motivation to choose and pursue a given career over the course of their studies" (Lockwood, 2006, p. 45). Aside from the inspiration to attain a goal, in this case, obtain a career in engineering, role models also provide several other very important benefits to the people who look up to them. Women are especially influenced by the attitudes, accomplishments, and attention of other people (Etzkowitz et al., 1994; Felder et al., 1995; Henes et al., 1995). Zeldin and Pajares found that "verbal persuasions (e.g., from mentors) and vicarious experiences (e.g., from role models) were critical sources of… women's sense of self-efficacy" (cited in Lips, 2004, p. 370). Increased self-confidence, along with a sense of support that can be found by seeing "someone like [them]"(Lockwood, 2006 , p. 36) succeed, can greatly increase the rate at which female engineering students continue to pursue careers in engineering. Lacking role models on whom to pattern their accomplishments or seeing the role models they follow be ignored or disrespected can greatly discourage students and may cause them to discontinue the engineering path (Etzkowitz et al., 1994; Lips, 2004). Because choosing and following a role model is a very personal thing, it is difficult to summarize the breadth of their importance on shaping the paths chosen by those who follow them.

Obstacles for Women Students in Engineering

Engineering students face many difficulties as they work their way through school. The female engineering students, however, are likely to be presented with even more obstacles than their male counterparts. The difficulty of facing these additional obstacles is compounded by the fact that female students "do not have access to a large number of faculty who have had similar experiences and whose very presence says 'you can do it', as male students do" (Henes et al., 1995, p. 4). With these hurdle to overcome, it is not surprising that few females enter engineering, with even fewer of those staying to graduate with a degree in engineering. Brainard, Metz, and Gillmore (1999) noted that the persistence rates of women in science, math, and engineering majors vary between 30 and 46 percent depending on the type of institution, while the persistence rates of men in the same majors and institutions vary between 39 and 61 percent. This difference is noticeable. A study completed by Felder et al. (1995), however, shows that this disparity should be cause for even greater concern. The women in their study "came into engineering with better predictors of success—high levels of parental education, higher SAT scores, better study skills and strategies, etc.—and the instruction in the experimental courses had been designed to reduce or eliminate some of the factors purported to work against women in engineering, e.g. by stressing cooperation over competition" (p. 155). However, the study found that though one would likely expect the women to outperform the men in the courses, the men actually did better, especially in later years. The results from this study indicate that the persistence rates of female students in engineering are not affected by a single factor, like classroom environment, alone, but are instead affected by a much more complex net of obstacles.

Women made up only 17.5% of students enrolled in undergraduate engineering programs in the United States in 2005 (Gibbons, 2006). Being a member of such an obvious minority, as women are in engineering classrooms, is often a very large obstacle to overcome in itself. A study at the University of Waterloo in Ontario, Canada, found that women and minorities tend to leave math and science majors because they feel singled out as one of so few in the classes (cited in Wolcott, 2001). Wadsworth also found that “female students transfer out of engineering due to feelings of isolation and incompetence” (cited in Demir, 2004, p. 2). Being a member of a minority can lead to the individuals feeling uncomfortable asking questions in class or approaching professors for fear of drawing more attention to themselves (Brainard, Metz, & Gillmore, 1999). Bergvall, Sorby, and Worthen (1994) found that problems encountered by women faculty in engineering from being a minority—only 11.3% of all engineering faculty are women (Gibbons, 2006)—include that “(a) a lone woman is highly visible, which means that she will face increased performance pressures; [and] (b) the male faculty members may be unsure of how to interact with a token female faculty member, which leads to isolation” (p. 327). These same problems are also faced by female students, and can be magnified when performing work in groups. Many female students feel that their ideas and input are often unheard during group work and that their contributions are undervalued (Felder et al., 1995). Male students’ uncertainty of how to relate to and interact with female students can sometimes lead to women taking less active or more stereotypically feminine roles in groups, sometimes of their own accord, other times not (Felder et al., 1995).

	Female	**Male**
Motivation	Encouragement	Challenge
Group Interaction	Integrated	Separated
Task Engagement	Collaborative	Competitive
Vision of Success	Group Affiliation	Individual Achievement

Figure 1. From Chesler and Chesler 2002.

Another major issue facing women is that since the field of engineering has been historically male-dominated, the methods by which teaching, advising, and mentoring take place are based upon what is beneficial for male students. For example, Chesler and Chesler (2002) point out that there is an emphasis on “technical conversations, relationships, and guidance [rather than] psychosocial issues” (p. 50). A female faculty member interviewed by Etzkowitz et al. (1994) commented that women are “just are not taught to be competitive” and worry that they cannot compete on such a “competitive, fierce playing field” (1994, p. 53). Figure 1, which was adapted by Chesler and Chesler (2002, p. 50) from work done by Carol Gilligan, shows the socialization aspects to which males and females respond to more positively. The characteristics listed for males are the types of ideals upon which teaching, advising, and mentoring in engineering have historically been based. In the past decade, switching to more collaborative methods of teaching and learning has been promoted. Despite this, the number of female students completing degrees in engineering fields has remained low, indicating that there are still more changes to be made.

Throughout the research done in preparation for this study, the reason most often noted and focused on as a major factor affecting the number of women persisting through school to earn engineering degrees was their level of self-efficacy. Research shows that women tend to have a lower level of self-confidence than men, especially when it comes to technical fields. Studies done by Besterfield-Sacre et al. (2001); Brainard, Metz, and Gillmore (1999); Felder et al. (1995); and Lips (2004), among others, show that female students have lower levels of confidence in their engineering, math, and physics skills than male students. A study by Rayman and Brett found that “women have lower self-confidence, perceived ability, and self-reliance than men, even though their grade point averages are equal to or higher than men” in engineering classes (cited in Brainard, Metz, and Gillmore, 1999, p. 63).

This discrepancy in self-efficacy levels is enough to hinder the success of female students on its own, but when combined with the previously-discussed factors, the obstacle it presents is magnified. Seymore and Hewitt indicate that by being an obvious minority while studying engineering, they are put at a psychological disadvantage that negatively affects their level of confidence (cited in Brainard, Metz, Gillmore, 1999). With regard to the fact that teaching styles in engineering are based around the characteristics that benefit male students, Felder et al. (1995) state that the traditional methods of instruction used in science and engineering program, which emphasize competition and individual work, enhance the negative thoughts many women have about their competence in technical areas of study. Female students tend to transfer out of engineering due to what Clifford Adelman calls “academic dissatisfaction” (cited in Brainard, Metz, & Gillmore, 1999, p. 61), which can be caused by any combination of the obstacles previously discussed. In order to change the low persistence rates of women in engineering, we must attempt to address all of the factors that contribute to it.

Proposed Solutions

As explored earlier, the presence of role models can increase students’ levels of self-efficacy, can lessen feelings of isolation, and can increase a student’s sense of support and encouragement. Many of the sources reviewed suggested increasing the number of female faculty within engineering (Bergvall, Sorby, & Worthen, 1994; Chesler & Chesler, 2002; Seymore & Hewitt, cited in Chesler & Chesler, 2002; Daniels, 1992; Etzkowitz et al., 1994; Felder et al., 1995) as the most effective way to increase the number of female engineering students. As stated earlier, only 11.3% of all engineering faculty are women. Of the full professors in engineering fields, women make up only 6.3% (Gibbons, 2006). In 2003, only 11.1% of the over 1.5 million people in the United States’ engineering workforce were women. Of these women, 32% reported their highest degree earned as a master’s degree, and 5.0%—only 8,600 women—had earned a doctorate (cited in Table H-7. Employed scientists, 2007). Because of the low numbers of women in the engineering profession, and the even lower numbers of women with advanced degrees, not all of which are in engineering, finding women to be engineering professors often proves to be difficult. The low numbers of females qualified to be professors will delay achieving a substantial number of female engineering faculty. Until this ideal solution can be fully accomplished, the sources suggest several other factors that need to be addressed to aid women students.

1. Encourage involvement in groups for women engineers. Encourage participation in groups and programs designed to help women in engineering students (Daniels, 1992; Felder et al., 1995; Hartman & Hartman, 2003), such as the Society of Women Engineers (SWE), Women in Engineering Programs put together by the school, and engineering sororities such as Phi Sigma Rho and Alpha Omega Epsilon. Not only should students be encouraged to join these groups, but the groups should also be shown support by the schools and departments they enhance (Felder et al., 1995).
2. Educate faculty members. Zohar and Bronshtein (2005) noted that even though "teachers may have good intentions, they lack specific knowledge about how to teach [girls] effectively according to these intentions" (p. 69). With or without these intentions, many faculty members do not realize or refuse to admit that there are added struggles being a woman in engineering (Etzkowitz et al., 1994; Zohar & Bronshtein, 2005). To combat this, engineering faculty need to be educated so that they are better able to understand the obstacles female engineering students face (Besterfield-Sacre et al., 2001; Chesler & Chesler, 2002; Daniels, 1992), as well as what resources are available to help female students face these difficulties with success (Felder et al., 1995). Faculty education should also include, teaching styles that benefit both men and women (Besterfield-Sacre et al., 2001; Rosati, 1999), how to better relate to and communicate with female students, and how to aid in the interaction between female students and their male counterparts during class and group work (Bergvall, Sorby, & Worthen, 1994; Felder et al., 1995).
3. Change the learning environment. The main goal of the two previous proposed solutions, especially the latter one, is to change and enhance the educational environment. Professors play a very large role in setting the tone of the classroom learning environment. Harsh criticism, mockery, and lack of support can damage students' (especially the female students') levels of self-confidence (Haddock, 1993). Supportive environments are needed where professors are approachable, play active roles in teaching, and are open to learning from the students (Chesler & Chesler, 2002; Daniels, 1992; Kramarae & Treichler, cited in Bergvall, Sorby, & Worthen, 1994).
4. Mentors. Aside from role models, mentors are also needed, both from within the school and from outside, in the work force. There are several online networking groups available through schools that offer mentoring for women and other minorities in engineering and technical fields, including SYSTERS and MentorNet (Wolcott, 2001). Alumni and other engineers in the community are also valuable resources that should be utilized (Bergvall, Sorby, & Worthen, 1994; Daniels, 1992). Perhaps the most important resources, however, are right within the school. Faculty members have the potential to make extremely good mentors as they are known by the students, seen often, and usually accessible for students. Not all faculty are suited for mentoring, they must be supportive, caring and understanding, as Taft Broome, Jr. mentioned, "faculty who make the best mentors… buttress their female students against the 'slings and arrows' of outrageous treatment" (cited in Chesler & Chesler, 2002, p. 53). Female faculty to serve as mentors

> (as well as role models) would be ideal for female students (Bergvall, Sorby, & Worthen, 1994), but a couple sources also noted that male mentors are often also very helpful for women engineering students (Bergvall, Sorby, & Worthen, 1994; Downing, Crosby, & Blake-Beard, 2005). Like the groups and programs mentioned in the first solution, in order for faculty to be effective mentors, schools and departments must begin to see the value in mentoring and reward and support professors who are willing to take the time and effort to support their students (Daniels, 1992).

Adding female faculty members will increase the numbers of available role models and mentors, enhancing the support systems available to female engineering students. As Nancy Betz stated, “an increase in the number of women in the profession is likely to have a resounding effect” (cited in Henes et al., 1995, p. 1).

Methods

There were two main studies for this research, a beginning focus group to aid in the development of a survey and the survey, itself. All study participants were female undergraduate engineering or engineering technology students in their third year of study or beyond. The Internal Review Board (IRB) or Research Compliance Committee at each institution was contacted and sent all necessary materials to approve the research on human subjects.

Beginning Focus Group

The first focus group was held only at the University of Dayton. A group of 24 potential participants were selected to reflect a variety of engineering majors, year in school (again, third year or beyond in their undergraduate study), and GPA. A recruitment email sent to the potential participants explaining the focus group, and the first twelve students to respond as available to attend the focus group were welcomed as participants. Only six of the potential participants were available, and all six attended the event.

The primary investigator, also a student, acted as the focus group’s facilitator. All students were given a consent form to sign and were asked to fill out a brief demographic sheet. All of these forms were kept in a secure location for the remainder of the research, as required by Research Compliance standards for participant privacy. The semi-structured discussion was based around ten pre-determined questions, with allowances for slight topic-related digression as arose naturally from the conversations. The questions were based both on information gathered during literary research and personal experiences of the researcher. The discussion was voice-recorded, and the primary investigator also took notes to emphasize important points made by the subjects. The findings from this focus group were used as a basis upon which to develop questions for the survey distributed to multiple post-secondary institutions across the U.S.

Survey

Students from eight colleges and universities across the United States participated in the survey portion of the study. The post-secondary institutions were chosen because of their renowned, ABET-accredited undergraduate engineering programs. Several other institutions were considered for survey participation, but eliminated due to the severe complexity of their

Research Compliance procedures or unwillingness of staff members to assist in the survey distribution.

After gaining approval from the IRB or Research Compliance committee, a member of each school's Women in Engineering Program, Dean's Office, or engineering staff was contacted. Contact was initiated via an email that explained the research and its approval for distribution at the institution. Once willingness to distribute the survey had been confirmed, the contact was asked to forward another email to all female undergraduate engineering students in their third year of study and beyond. This email explained the research and provided a link to the on-line survey. Participation was completely voluntary. The survey questions were developed based on three things: the literature review, the responses from the beginning focus group, and personal experiences of the primary investigator as an undergraduate female engineering student. The questions fell into eight overall categories:

- Demographics
- Characteristics of role models
- Participant's needs in an educational environment in order to promote success
- Participant's needs that can be fulfilled by other people to promote success
- Participant's view on the environment in engineering education
- Participant's level of comfort in the engineering education environment
- Participant's needs from an instructor
- Participant's view of how effective certain scenarios might be for helping a student feel more comfortable and confident being a female in engineering

The items consisted primarily of multiple-choice responses (79 questions), but also included four free-response sections and had four optional areas for any comments from the participant.

The online survey was constructed and distributed using the online service SurveyMonkey, and included a consent page before the questions and a page at the end thanking the participant and giving her instructions on how to enter herself into a gift card drawing. Students were allowed two weeks from the initial survey distribution date to complete the survey. Approximately three days before the end of this period a reminder email again containing the link was sent to the students through the institutional contact. The number of students who received the link was noted and used to calculate the response rate.

Responses were analyzed using the statistical analysis program SPSS version 15.0. Frequency distributions were generated on all items. The demographics variables and the proposed solutions variables were analyzed as a full body of responses, while the remaining items were sorted into three separate analyses. The first group included the responses from all participants who reported that they had not been taught by any female professors in a technical class containing primarily engineering students. The second group included participants who reported having one, two, or three female professors for such classes. The last group consisted of the participants who responded as having four through six female professors for these types of classes. Less than two percent of the respondents answered as having seven or more female professors, and they were considered to be outliers in the study, and thus not included within the female professor range analyses for this study. Data from these three groups were disaggregated to study the differences among participants having no female professors, a few female professors, and what would hopefully be a substantial number of female professors. When delineating the groups, it was questionable whether participants who had three female professors should be included with those who had one to two or those who had four to six. After comparing the frequencies of the respondents who had three female professors with these two groups, it was determined that their responses more similarly resembled those of the one to two female professors group, and they were included there.

Several items that were deemed most applicable by the researcher for answering the research question were then used as the dependent variable to create cross-tabulations with the three female professor ranges as the independent variable. Most of the responses for these questions were recoded so that answers with similar levels of importance, validity, etc. were grouped together. For example, answers of “completely true” and “more true than untrue” were recoded to “true,” and answers of “more untrue than true” and “completely untrue” were recoded to “untrue.” This was done to allow the trends present within the data to be seen more easily. Chi square analyses were performed on the cross tabulations, and though most of the values were not identified as statistically significant, there are still strong trends that were observed.

Results

Beginning Focus Group

There were six participants in the beginning focus group. Two were in their third year of study, three in their fourth, and one in her fifth. They were evenly divided between chemical, mechanical, and civil engineering majors. All six reported having a female professor for at least one of their technical classes. During the focus group, it came to light that two of the six participants had attended all-female high schools. Many of the responses and ideas brought up during the focus group were incorporated into the survey part of the research, including the following:

- A role model should have success in the workplace as well as in the rest of his or her life
- It is important for some people that role models share same gender, ethnicity, geographic area growing up, or obstacles such as being the first in the family to attend college; having these similarities aids in the “I can do it, too” inspiration the person gets from the role model
- It would be helpful for professors to allow for digressions during class and be more relaxed, by telling an entertaining story or joke, for example, but not ones that are degrading to women (i.e.- women supposedly worse drivers than men) or exclude women (i.e.- too many car or sports stories)
- It would be helpful for professors to share a little bit about other parts of their lives outside of school and show their human sides
- Some female students feel uncomfortable approaching male faculty members outside of class, even during set office hours
- Most female students do not want to stand out or be put in the limelight during class; they already feel singled out enough by being one of a few females

- It seems that women are often more apt to accept support roles or roles no one else wants in group work, though this does not seem true in majors where the ratio of men to women is closer (i.e.- chemical engineering)
- Girls worry about how the boys in the class see them as peers—for example, that girls have to work harder for the same grades, that if a girl does well she has no social life, or that if the girl makes a mistake it's "because she is a girl" and doesn't know any better
- Girls worry about the negative stereotypes that become associated with them as female engineering students when "that girl" constantly asks questions that are not thought out, not intelligent, or are "sucking up" to the professor—basically, questions that are interruptive and not beneficial to the learning environment
- Girls worry about the negative stereotypes that become associated with them as female engineering students when "that girl" constantly has to answer all questions posed to the class
- There is a good possibility that males would also benefit from having female professors through varied teaching styles, exposure to diversity, and learning to show respect for females in the profession
- It is not enough just to add female professors, the professors need to be strong and good role models—they should be approachable and accommodating but not "pushovers"; the should be professors and advisors in class, not "mothers" to the students; they should be intelligent and command respect through their actions and knowledge
- There are things that male professors can do to improve the atmosphere in engineering education: talking about daughters and wives in a positive light to show that they are understanding of females and also of the student age-group; show that they are well-rounded and have a life outside of academia; have interaction with students outside of the classroom (for example, at a departmental picnic), so that students and faculty can learn to better understand on another

Survey

Over 1200 undergraduate female engineering students in their third year of undergraduate study at various institutions were invited to participate in the survey. The total number of students who started the survey was 508, and 382 of those respondents completed the entire survey. Seventy-eight percent of those who began the survey completed over half of it.

Demographic information

Of the students who participated in the survey, 40.4% were in their third year of study, 44.5% were in their fourth year of study, and the remaining students were in their fifth year or above. Participants ranged in age between 18 and 32 years, with over approximately 91% aged 20 through 22 years. Figures 2 and 3 show the frequencies represented by the survey population of number of female professors the participant had for technical classes containing primarily engineering students and the participant's major, respectively. Survey responses were then grouped into three Female Professor Ranges (zero, one through three, and four through six) for analysis, as explained in the Methods section. From here, the results will be discussed by the categories included in the survey.

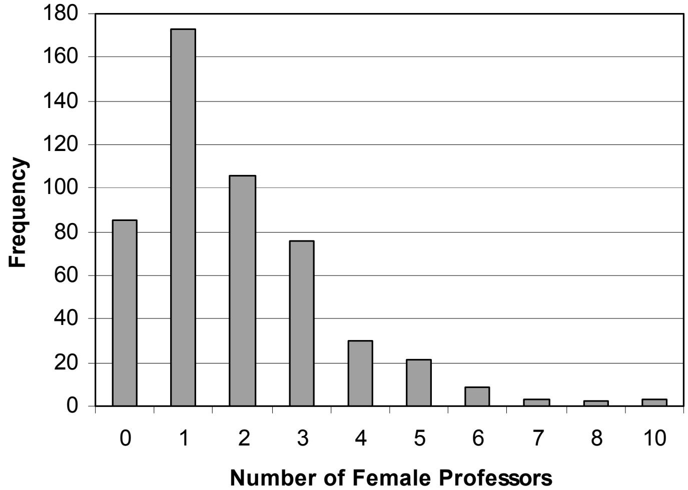

Figure 2. Number of female professors who taught each participant in a technical engineering class

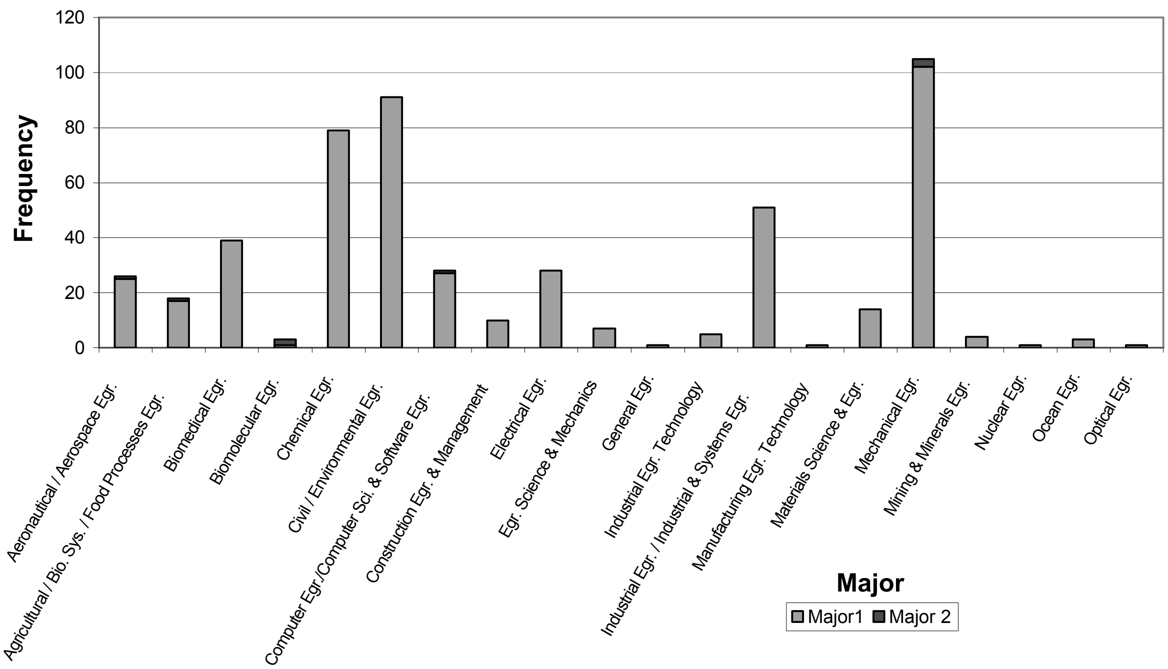

Figure 3. Frequency of majors represented by the survey data

Characteristics of role models

Participants were asked fourteen questions relating to role models. Prior to the first question, the following definition for role models was shown: “individuals who provide an example of the kind of success that one may achieve, and often also provides a template of the behaviors that are needed to achieve such success” (Lockwood, 2006, p. 36). Participants were then asked how they would define a role model. Several recurrent characteristics included having integrity and being ethical; being hardworking, driven and motivated; being intelligent or knowledgeable, but still being able to relate to people and communicate well; being happy with his or her life and career; being a leader; being passionate or enthusiastic; being confident but humble in their abilities; and having a successful life with a balance between career and personal aspects. Many respondents also mentioned the importance of a role model having something in common with them, most of these responses simply noted that there needed to be *a* similarity but that it could be anything, some examples were gender, career, and obstacles or struggles faced. Two other common themes were compassion or kindness and the want to volunteer, help others or make changes in the lives of others. Participants also frequently mentioned that it was important to have a relationship with the role model, making the role model also a mentor. A number of respondents also discussed role models as “she” or specifically mentioned that their ideal role model would be a woman.

The next question asked if the participants had an educational/career role model. Responses are displayed in Table 1 ($?^2(2) = 1.083$, $p > 0.05$) and show that as the number of female engineering professors female students have increases, the number of those students who report having an educational role model increases. After being asked if they had an educational/career role model, participants were asked to list any qualities a person serving in this role needs to have above and beyond the characteristics of a general role model. Responses to this question were very similar to those describing the traits of a general role model, but there was more frequent mention of the importance for this person to engage in continual learning.

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Table 1. Response rates by range of female professors to the question “Do you have an education/career role model?”

Needs in an educational environment in order to promote success

Ten questions relating to the participant’s needs in an educational environment were asked. Half of the questions showed little difference between students who had been taught by female professors and those who had not. However, participants from the four to six female professors range were at least 10% more likely to say it was important for them to compete against classmates and stand out from the class than those in the no female professors range.

Needs that can be fulfilled by other people in order to promote success

Eight questions were asked about the needs participants’ have that can be fulfilled by other people. The vast majority, between 90% and 100%, of all the participants, regardless of what professor range they were in, responded that having someone to fulfill each of the niches described was helpful. These areas included someone to look up to, someone to bounce ideas off of, someone to talk with about career options, and someone to encourage them.

Educational environment in engineering

Participants were asked to rank the validity of fifteen statements in order to develop a picture of what the environment in engineering education is like through the eyes of the student participants. Tables 2 through 5 present the responses to four of the items that were especially interesting: “male students view their female peers as less capable academically” (Table 2: $?^2(4) = 3.799$, $p > 0.05$) , “female students do not want to stand out” (Table 3: $?^2(4) = 5.353$, $p > 0.05$), “female students are more likely to take a leadership position in group work” (Table 4: $?^2(4) = 2.146$, $p > 0.05$), and “female students are more likely to take a support position in group work” (Table 5: $?^2(4) = 11.223$, $p < 0.05$). Table 2 shows that as the number of female engineering professors female students have increases, the number of those students who report feeling that males view them as less capable academically decreases. Table 3 demonstrates that with an increase in the number of female engineering professors female student have, the students are less likely to be discouraged by the idea of standing out. Table 4, which displays the only highlighted item that proved to be statistically significant, shows that female engineering students with increased numbers of female engineering professors are more likely to report that they and other female students are apt to take a leadership position in group work than students with fewer or no female engineering professors. Table 5 shows that as the number of female engineering professors a female student has increases, the less they are more apt to take a support position during group work.

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Table 2. Response rates by range of female professors to the statement “Male students view their female peers as less capable academically”

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Table 3. Response rates by range of female professors to the statement “Female students do not want to stand out”

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Table 4. Response rates by range of female professors to the statement “Female students are more likely to take a leadership position in group work”

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Table 5. Response rates by range of female professors to the statement “Female students are more likely to take a support position in group work”

Comfort in the engineering education environment

Respondents were then asked to rank the validity of seven statements about their comfort level in the engineering education environment. The ratings for two of these statements—”I worry about being criticized by my peers” and “I have no problem asking questions in class”—are shown in Tables 6 and 7, respectively. Table 6 ($?^2(4) = 3.619$, $p > 0.05$) demonstrates a negative relationship between validity and professor range, whereas Table 7 ($?^2(4) = 6.704$, $p > 0.05$) exhibits a positive relationship.

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Table 6. Response rates by range of female professors to the statement “I worry about being criticized by my peers”

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Table 7. Response rates by range of female professors to the statement “I have no problem asking questions in class”

Needs from an instructor

Participants then assigned a level of importance to eleven statements about characteristics and actions a professor may demonstrate. There was little difference among the responses of students in the three professor ranges for the majority of this section.

Effectiveness of proposed solutions

Thirteen scenarios were then proposed to respondents, and they were asked to rank the effectiveness these possible solutions might have in helping a student feel more comfortable and confident being a female in engineering. The responses were analyzed by the professor ranges and also as a single unit of all female engineering students. When comparing the results between the three female professor ranges, those respondents who had no female professors were more likely to rate the proposed scenarios as helpful than those who had female professors in technical classes. This trend was present in the proposed solution of “having more female professors to act as mentors and role models,” shown in Table 8 ($?^2(6) = 4.178$, $p > 0.05$). When examining the proposed solutions when all responses were grouped together, the two highest ranked scenarios were “having contact with female engineers currently in the workplace who can serve as advisors, role models, or mentors (through the school or through groups like SYSTERS or MentorNet)” and “having professors be more encouraging of students and their efforts” ranked the highest, with 85.9% of respondents answering that these would be somewhat or very helpful. The next two highly ranked solutions were “having occasional meetings or programs for women in engineering students to foster bonds and help them address issues that concern them” and “having male professors be more aware of the obstacles (emotional, academic, psycho-social) faced by their female students.”

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Table 8. Response rates by range of female professors to the statement that having more female professors to act as mentors and role models will help a student feel more comfortable/confident being a female in engineering

Discussion and Conclusions

The results of this study relate closely with the themes discussed in the literature review. The overall response rate to the survey was 40.9%, which is good for a lengthy survey distributed online to a targeted audience. The strong response rate may indicate that this is a topic of significance to many undergraduate women in engineering—whether they are strongly in agreement or strongly in disagreement. Though very few of the chi-square tests confirmed significant relationships, there were still interesting trends that presented themselves that I feel are very important when exploring this subject. The following sections, which refer to themes within both the literature review and the survey sections, will discuss the implications of the survey results.

Role Model Definition, Characteristics, and Impact

Reoccurring themes in the open-ended responses defining a "role model" reflected Lockwood's (2006) definition. These themes indicate that role models, indeed, show the achievements one can accomplish (i.e.- happy with life, successful career and personal life) and indicate the characteristics one needs to have in order to do so (i.e.- integrity, self-motivation, good communication, humility). The definitions also show that inspired persons do need to identify with the role model on some level, which is additionally indicated by the high percentage of "somewhat" and "very important" responses in the survey results for questions regarding role models having characteristics in common with the participants. Despite recurrent themes, each definition has unique aspects, showing that choosing a role model is greatly dependent on the inspired individual.

In the free response question for defining the term "role model," many participants mentioned the need for a role model to have some characteristic in common with the inspired person. Noting that this mention was prior to being asked the importance of various specific similarities, one can conclude that people are inspired more by role models they can identify with. Respondents who had four to six female professors were more likely to report having an educational or career role model (Table 1; 55.8%) compared to those who had only one to three female professors (50.7%) or no female professors (46.0%). When looking at this and reflecting on the fact that several of the free response role model definitions given specifically noted that their ideal role model was female, the data seems to indicate that female students can identify more with female professors, and also appears to confirm that female students do look up to female professors as role models—when there are female professors present.

There was a strong percentage of respondents—between 90% and 100%—who noted that having someone to aid in fulfilling certain needs was helpful. Participants also frequently mentioned in their role model definitions that it was important to have a relationship with the role model. Similar to the findings in other studies, these trends indicate that female students have a strong need for people, and are also a sign that the students are more influenced by the scrutiny and responses of others.

The Obstacles and Overcoming Them

From the questions highlighted in the "Educational Environment in Engineering" and "Comfort in the Engineering Education Environment" sub-sections of the results, one can see that female students are less confident in themselves (comfort asking questions in class, Table 7), and frequently worry about what others think of them (criticism from peers, Table 6; males see females as less capable, Table 2). Similar trends also exist in other questions from those sections, further reinforcing this conclusion. These questions also show that those students who had more female professors were less likely to worry about what others thought and more likely to believe in themselves. This conclusion is consistent with findings in the reviewed literature (Etzkowitz et al., 1994; Felder et al., 1995; Henes et al., 1995; Zeldin & Pajares, cited in Lips, 2004).

Also in the "Comfort in the Engineering Education Environment" sub-section were the statements: "Female students are more likely to take a leadership position in group work" (Table 4) and "Female students are more likely to take a support position in group work" (Table 5). The details of the trends displayed when participants ranked the validity of these statements were interesting. Though many participants noted that females are more likely to take a leadership position in group work, those with four to six female professors were more likely to say this. Taking a leadership position requires a person to have confidence in herself, and these results seem to indicate that having more female professors increases the self-confidence of female students. That part of the trends was not unexpected when considering the information from the literature review. What was especially interesting when comparing the response percentages for these two statements was that since one statement is the converse of the other, the percentage of "true" responses for the two questions should add up to approximately 100%. For the participants who had four to six female professors, the responses did add up to just over 100%. The sum of these two values for the participants who had no female professors, however, adds up to over 120%. This seems to indicate that though female students would *like* to take more leadership roles, they often do not or are unable to.

In the literature review, several sources noted that female students are discouraged by situations of strong competition (Etzkowitz et al., 1994; Felder et al., 1995; Gilligan, cited in Chesler and Chesler; 2002). Questions from the "Needs in an Educational Environment in Order to Promote Success" sub-section of the results, however, indicated that participants who had four to six female professors were more likely to want to compete against classmates, and had little problem with the idea of standing out from the class when compared with those participants who had no female professors. Overall, the results support the idea that increasing the number of strong female professors in engineering fields might aid in increasing the self-efficacy of female students, which will aid them in looking beyond the other obstacles talked about in the literature review.

What is the Solution?

I feel the ultimate solution is to add more, *strong* female faculty members to post-secondary institution engineering staffs. Although highly speculative at this point, with only one set of data to study, one tentative conclusion might be that exposure to four female professors in technical classes composed primarily of engineering students is the minimum needed for a noteworthy increase in the self-efficacy of female engineering students. Female students can more easily relate to individuals who have certain characteristics in common with them, and gender is one of the most basic characteristics individuals can share. Feeling that one shares a trait with another, more experienced person lends to the idea that "someone like [her] can be successful" (Lockwood, 2006, p. 36), which is the primary function of a role model. Over half of the respondents answered that "having more female professors to act as mentors and role models" would be somewhat to very helpful. Though this was not the highest-ranked solution of the 13 included in the survey—rather, it fell towards the middle—its high importance percentages combined with facts from the literature research and other indicators within the survey—such as the trends previously discussed—reinforce my conclusion.

Unfortunately, reaching higher numbers of female professors will take some time, given the low numbers of female engineers in the US who have earned a masters or doctorate degree. This is the main reason more solutions were suggested by the researcher during the survey, so that the environment in engineering education could begin to lend more support to its female students until the ultimate solution could be reached. The fact that those respondents who had no female professors were more likely to rate the proposed scenarios as helpful than those who did have female professors in technical classes, seems to indicate that these students can tell something in the environment needs to change. The two solutions that tied as top-ranked—"having contact with female engineers currently in the workplace who can serve as advisors, role models, or mentors (through the school or through groups like SYSTERS or MentorNet)" and "having professors be more encouraging of students and their efforts"—again reinforce the importance for female students to have access to female role models in their field and also show that female students need to have validation and support in order to persist and succeed. The second- and third-ranked solutions—"having occasional meetings or programs for women in engineering students to foster bonds and help them address issues that concern them" and "having male professors be more aware of the obstacles (emotional, academic, psycho-social) faced by their female students"—also emphasize these same ideas.

Limitations

The methods by which both the focus group and the survey for this study were conducted do lead to several limitations regarding sampling method. As explained earlier, a group of possible participants for the beginning focus group were identified in an attempt to achieve a variety of majors, year in school, and GPAs. The final participants for the focus group included a convenience sample of students who were interested and available on the date of the focus group. Potential survey participants were first narrowed down by the post-secondary institution they attended at the time of the study. These institutions were chosen because of their well-reputed undergraduate engineering programs. All undergraduate female students at these institutions in their third year of study or beyond were then invited to participate. Limiting the participants' year of study ensured that the students were well into their engineering coursework, had enough exposure to the engineering environment to be able to comment about it, and had been in an engineering program long enough to encounter multiple faculty members. Neither of these two approaches results in a random sampling, which is considered to be ideal for generalizing the results of the study to the population.

Despite the fact that the sampling is non-random, the findings of this study can still be considered applicable on a large scale. According to data compiled by Michael Gibbons (2006), engineering enrollment for the graduating class of 2006 dropped by nearly 18% between the students' freshman and sophomore year, compared to approximately 2% between sophomore and junior year. This suggests that by junior year, almost all of the students enrolled in engineering will remain so. No doubt a good number of the students who leave engineering between the freshman and sophomore year do so because they feel their calling lies in a different field; however, it is also very likely that many of these students do not feel they can handle the environment present in engineering fields. The students who remain into their junior year are likely those who have found a way to "tough it out," and thus the results may indicate a lower level of importance and need for more females in engineering education than actually exists.

Summary

This paper presents a look into the obstacles faced by female engineering students, and attempts to quantitatively show the effects of these obstacles on female engineering students' self-efficacy. The study also evaluates the idea that increasing the number of female faculty members in engineering is the solution that will ultimately create an environment that will better support women engineering students. By improving the environment, it is likely that retention rates and entrance rates of females studying in the engineering field will increase. Retention rates is principally important because until the women currently entering engineering schools can be encouraged to stay, recruiting increased numbers of female students to pursue engineering will be in vain.

Through literature research, focus groups, and surveys, this comprehensive study found that women have a lower sense of self-confidence than men. However, when they had access to higher numbers of female faculty members in engineering, this sample female students exhibited higher levels of self-confidence and worried less about what others might think about them, they were more ready and willing to compete, and were seemingly less affected by the obstacles discussed. It is important to note that adding women to engineering faculty simply for the sake of adding women is not a sufficient resolution, and often has a negative effect on students, not to mention the faculty member herself (Bergvall, Sorby, & Worthen, 1994). Female faculty members, as any group of professors, should be knowledgeable, intelligent, good-communicators, and, perhaps most importantly, strong role models.

It is often easier for female students to relate to a female role model because they share a very basic and obvious trait in common. Having role models and mentors is important for every college student, but for women, as a minority in engineering, it is even more important that they are able to discuss their problems and worries about the future, so that they can see "someone like [them]" (Lockwood, 2006, p. 36) has succeeded in the field the way they want to.

Though it will likely take a while to significantly increase the pool from which to draw female faculty, there are other, shorter-term solutions that can be implemented to offer support for female engineering students. These solutions include increasing students' exposure to engineers (especially women) who are already in the workforce, whether through a program organized by the school to connect current students with alumni, as done at Purdue University (Daniels, 1992), or through online groups like SYSTERS or MentorNet. Increasing the time female students spend together can also be helpful so that they can create emotional and academic support networks, and voice and address issues that concern them. Increasing the awareness of all faculty members to obstacles female engineering students face and increasing their positive involvement with students is also important. Students benefit from encouragement given by the professors that teach them. It is also critical for professors, particularly the male professors, to be more aware of the emotional and psycho-social difficulties faced by their female students. Workshops for faculty that not only explain these obstacles, but also suggest how the professors themselves might address them, and what resources are available at the schools, would be particularly helpful. Increasing outside-of-classroom encounters between students and faculty of both academic and social nature also increases each party's understanding of the other's needs and traits. Asking more of professors' time for workshops or additional time spent with students also means that colleges and universities have to recognize the incredible value of both the programs and the time vested by the professors in the success of all, not just female, students.

Future Work

There are many, many more studies that could, and *should*, be done with reference to female engineering students. The survey administered for this research, alone, could produce numerous further studies. Examining more in-depth each of the question sections might help produce a better picture of the environment in engineering education, the self-efficacy levels of female engineering student, and the needs of female engineering students. Evaluating the data in a fashion similar to what was done with this particular study, but using ranges of female students present in the participant's major as the independent variable rather than number of female professors the participant had been taught by, would also produce more valuable results regarding female engineering students' self-efficacy rates within the disciplines. Asking many of the same Environment or Comfort Level questions to male students at the same colleges and universities to compare to the responses from the female students will help more concretely define the differences in self-efficacy levels and determining if male students are aware of the struggles their female peers face. During the focus group, one participant suggested having focus groups (or other types of studies) for professors that could attempt to determine any of the following:

- Professors' views of students—do they perceive a difference in male and female students?
- Professors' awareness of and reaction to studies like this one—do they feel there is a problem or do they feel it is imaginary?
- Professors' awareness of how their actions affect students (both male and female) motivation levels, persistence rates, and self-efficacy.

Overall, it is clear there is much to be explored in the engineering education system, especially in reference to female engineering students. Not only would these explorations prove to be interesting, but they would also serve to accomplish what engineering programs across the country have been striving to achieve for years—increasing the retention rates and entrance rates of women students.

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