

AC 2007-2377: WOMEN: SUPPORT FACTORS AND PERSISTENCE IN ENGINEERING

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Women: Support Factors and Persistence in Engineering

Abstract

Limited information is available regarding the factors that promote persistence by women in engineering programs. Stated simply, the problem is that the number of women engineers continues to fall short in comparison to the gender ratio of women to men in the population in the U.S.¹ and worldwide². More women engineers are needed in general and in proportion to male engineers. This study addressed two questions. (1) What are the factors that support women in engineering? and (2) What are the factors that attract women to and help them to persist in a career in engineering? The methods consisted of a search of related research to identify probably factors followed by qualitative interviews with program persisters and switchers. The most frequently cited factors were selected for inclusion in the interview protocol for the qualitative portion of this study. They were: (a) faculty support, (b) class environment, (c) department environment, (d) attraction to another discipline, (e) parental encouragement, and (f) self-confidence. The result was an evaluation of the relative merits of the factors for persisters and switchers. Additionally a new metaphor relating to force field analysis is proposed. This metaphor was supported by the findings of the study whereby persisters reported fewer restraining forces while switchers reported fewer driving forces. The two driving forces that are common among persisters and switchers are formal support programs and peer support programs. Strengthening these two programs would increase the driving forces for all students. These findings will assist faculty, advisers, and program planners to better meet the needs of women in engineering programs and likely help to reduce the attrition rates of women in engineering.

Keywords: women engineering persistence environment motivation force-field

While there is a general shortage of engineers, the need is acute in the under-represented areas such as women and minorities. According to the Building Engineering and Science Talent (BEST)¹ report, the U.S. is not developing an appropriate scientific and technical workforce for the future and calls for greater efforts to increase the representation of women and minorities. This shortage isn't limited to the United States. Hersh², in longitudinal research conducted at 130 institutions in 55 countries on the changing position of women engineers worldwide, found that while conditions for women in engineering are improving, "there are still so few women engineers as to make them seem unusual or even abnormal" (p. 357). Attracting qualified women into engineering programs is only the beginning; it is also essential to retain the women in the pipeline through completion and successful entry into the workforce.

The under-representation of women in engineering is widely reported and many marketing and mentoring programs have been developed by various engineering groups. However, attraction of more women is not enough. It is both inefficient and ineffective to push more women into the so called education "pipeline" without consideration of the probability of their completion and long term service to the engineering community. "Direct or vicarious encouragement (academic

integration) or discouragement (discrimination) from a teacher will affect both one's sense of self and ensuing motivation to strive for academic mastery by using self-regulated learning strategies" ³ (p. 222). Given the goals of increasing the number of women in the engineering field and the importance of helping faculty to increase the success and persistence of female students, this study sought to extend prior research findings on the connection between support factors and persistence in engineering programs and beyond to the workforce. This study explored this issue through two facets. The first was a review of recent empirical studies on support factors for increasing persistence of women in engineering programs to better identify the most effective elements of support. The second part, a qualitative study, explored those relevant support factors in-depth and extended the field of study to include practicing women engineers.

Career Choice and Persistence of Women in Engineering

The dilemma is multi-faceted; therefore, it is useful to summarize important factors related to increasing the number of women engineers in the workforce. They include but are not limited to: (a) the manner in which career goals are set (ambition, motivation, and commitment), (b) gender and personality variables, and (c) contextual issues like alienation and lack of interest, gender balance, and college and workplace environmental variables. While many of these elements are beyond the teacher's direct control, the teacher can affect the response of women students by providing information, modeling effective behaviors, and connecting the women to support networks.

Of equal importance to selecting engineering as a career is the decision to continue in the program, to complete the degree, and to remain in the engineering field after graduation. Information on why women persist in the program and the career would be beneficial to teachers by helping them to encourage and support women through the engineering pipeline. Wood and Fitzgerald⁴ looked at factors, such as mentoring, that influence females' entry into and journey through the "engineering pipeline" and decisions made at key junctures: (a) whether or not to enter or stay in an engineering degree program, (b) whether or not to pursue an advanced engineering degree, and (c) whether or not to be a practicing engineer. It is important to identify methods for reducing the loss of women from the programs and from the engineering field. Astronaut and physics professor, Sally Ride, maintains that social pressures and stereotypes still cause girls to lose interest in science and math after elementary school⁵. A preliminary report by the Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology (CAWMSET) documents the barriers preventing minorities, women, and people with disabilities from participating proportionally in science and engineering⁶. A suggestion for retaining women in engineering comes from Cohoon⁷, discussing the under-representation of women in academic computer science both in the U.S. and internationally, and describes effective interventions at the undergraduate level including: actively recruiting women, encouraging women to persist, and mentoring. With the many factors in mind, it is important to identify the problem under investigations.

Problem Statement

Stated simply, the problem is a lack of engineers to fill an increasing number of positions. More specifically, the problem is that the number of women engineers continues to fall short in comparison to the gender ratio of women to men in the population in the U.S.¹ and worldwide². More women engineers are needed in general and in proportion to male engineers. The obvious solution is to attract more women into engineering programs, and this task has been undertaken admirably by schools, companies, and professional organizations. Their current actions might be sufficient were it not for the hemorrhaging of students from the entire length of the education program and even beyond graduation. Attrition factors include inadequate or inappropriate entry knowledge, skills, and goals that result not only in failure to complete, but also changes in major during or after completion of a degree. The failure to persist continues into the workplace⁴ where women may not thrive in the engineering work context. There is, therefore, a need to better understand what supports and helps women to persist in an engineering education and career path.

Research Questions

To move beyond previous attempts to resolve this problem, a multi-faceted approach was used. There is a need to summarize, compare, and evaluate previous empirical work through a review of the research done in this area to better understand the competencies and support measures required for women to succeed in the engineering field.

Another facet, perhaps less frequently evaluated empirically, deals with affect and the strategies that promote persistence in completing an engineering degree and pursuing an engineering career. This emphasis on theory building lends itself to a qualitative approach employing interviews with women who persist and with those who switched from engineering education or careers in order to provide insight into the key factors that promote that persistence. The following research questions were addressed in this study:

Q1 - What are the factors that support women in engineering?

Q₂ - What are the factors that attract women to and help them to persist in a career in engineering?

The answers to these questions will enable planners, administrators, and teachers to better attract and to support the success of women in the engineering field. In addition, there are opportunity costs in the form of denial of women who would successfully complete the program in favor of those who do not. Knowledge of critical factors that affect success and persistence can mean a higher rate of engineering degree completion, career entry, and persistence. The improvement of pipeline efficiency means better use of the dwindling funds available to educational organizations.

Literature Review

In order to establish benchmarks for the most commonly identified factors related to persistence in engineering programs, several major studies were reviewed. The first was the Women's Experiences in College Engineering project⁸, which evaluated the roles institutions, faculty, and

students play in the persistence of women in engineering. They included 53 engineering schools with approximately half having formal Women in Engineering (WIE) programs. The next study consulted was the Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (CAWMSET) study⁶ that was established by Congress on October 14, 1998. It created recommendations on how to improve the incorporation of women, minorities, and people with disabilities into the workforce and to keep minorities, disabled students, and women in the "pipeline." Another large study was the Women in Engineering Programs & Advocates Network (WEPAN) Pilot Climate Survey⁹ that assessed the perceptions of 8000 male and female undergraduate engineering students from 29 institutions about the educational climate in the United States. Factors of persistence in this study were related to student self-confidence and self-esteem. The fourth large study was completed for the Department of Education using National Center for Education Statistics data¹⁰ and identified parental education and financial support, student aspiration and self-confidence, and institutional factors which related to persistence. Additionally, several smaller scale research studies were reviewed. The first was a study by Gokhale and Stier¹¹ that studied students and alumnae on techniques related to the creation of a more appropriate learning environment for women. Next, a study by Whitten et al.¹² suggested that factors that attract and retain women include a healthy, supportive, and respectful relationship between faculty and students. The third small scale study performed by Wyer¹³ found that persistence (male and female) was related to a positive image of the engineering profession.

Additional factors related to persistence were obtained from dissertations and monographs. Graham¹⁴ wrote that persistence was a function of complex interactions of individual, environmental, and social factors. A second dissertation by Vick¹⁵ found that interpersonal style, in conjunction with social support, predicted self-esteem and persistence in the program. A third dissertation, by Schaefer¹⁶, found correlations between self-efficacy, support, barriers, and persistence. A monograph by Adelman¹⁷ identified a range of factors acting upon curricular momentum in relation to persistence. Finally, a longitudinal study¹⁸ recommended: (a) providing female role models and mentors, (b) support organizations, (c) use of cooperative learning, and (d) educating professors and advisors on the needs of women students. Table 1 lists the most common factors and their frequency of appearance in the literature reviewed.

Table 1

Factors of Persistence

Persistence Factors	Frequencies
Faculty support	8
Class environment	7
Department environment	6
Attracted to another discipline	5
Parental encouragement	5
Self-confidence	5
Teaching quality	4
Workload	4
Lack of interest in engineering	4

After relevant research literature was reviewed, the most frequently cited factors were selected for inclusion in the interview protocol for the qualitative portion of this study. They were: (a) faculty support, (b) class environment, (c) department environment, (d) attraction to another discipline, (e) parental encouragement, and (f) self-confidence.

Methods

Qualitative Interview

The general research questions for the qualitative interviews were as follows: (1) what are the differences between women who remain in the engineering program beyond the second year and those who do not? (2) What are the differences between women who complete the engineering program and those who do not? 3) What are the differences between women who remain in the engineering field for at least two years after graduation and those who do not?

Graham¹⁴ pointed out that the safest procedure for talking to switchers (female engineering students who switch out of engineering majors herein are referred as switchers, as opposed to persisters) was the individual interview format because the first two switcher interviewees in his study became emotional when reminiscing about their experiences during their freshman year in engineering. We chose to interview the switcher group members individually to avoid embarrassment and to make interviewees comfortable about speaking of the topic. The overall goal is to remain as loyal to the lived experience as possible¹⁹.

Sample

Qualitative samples tend to be purposive, rather than random²⁰. Persisters were relatively easily located through the Alumni Association at the University of Illinois at Urbana-Champaign. The purposive sample group of drop-out and non engineers were identified at University of ILLINOIS. Using a snowball sampling procedure starting with the persisters, they were asked to refer us to women they knew who dropped out of the engineering major. In order to get multiple data-sources for the purpose of triangulation, we asked engineering professional associations, (e.g. ASEE, IEEE) to forward recruitment materials to potential participants.

Essentially, the snowball sampling technique resulted in the identification of 14 persisters (12 university students and two in the workforce) and five switchers (university students). Six of the participants were Material Science and Engineering majors; three Chemical Engineering; two Civil Engineering; two Computer Science and Engineering; one Electrical Engineering; one Environmental Engineering; one Industrial engineering; one Mechanical Engineering. Among the five switchers, three switched to other STEM disciplines like Mathematics and Biology; the other two switched to non-technical disciplines (i.e., education and speech communication). The final data set also included one set of switcher data from exit interviews conducted by Amy Rickman in the WIE office at University of ILLINOIS, which was aimed at uncovering female engineering switchers' experiences. The structured interview was guided by sets of similar interview questions to the protocols in the current study.

Instrumentation

Miles and Huberman²⁰ outline criteria of a good qualitative researcher-as-instrument method: (1) some familiarity with the phenomenon under study; (2) strong conceptual interests; (3) a multidisciplinary approach, as opposed to a narrow grounding or focus in a single discipline; and (4) good investigative skills, including doggedness, the ability to draw people out, and the ability to ward off premature closure. The researchers developed questioning protocols and an interview guide to better solicit the information that assisted in the understanding of the career choice and persistence of women in engineering. Two sets of interview guides were created for the persister and switcher interviews respectively.

Data Collection

Data were collected using the protocol developed for the study in a semi-structured interview format that typically lasted 30 to 45 minutes (See Appendix I for protocol). All interviews were transcribed by a professional transcriptionist and converted to plain text for use with qualitative analysis software.

Face-to-face interview has an advantage in that non-verbal communication may be noted in process notes describing reactions to both the participants' views and the research process itself. Careful attention was paid to the nonverbal aspects of the interaction, for example, turn-taking, eye contact, pauses in interaction, patterns of speech, and analysis of conversations²¹. Other reflective information was kept in the field notes. Spradley²² recommended recording ideas, fears, mistakes, confusions, breakthroughs, and problems that arise during the data collection process to enable a person to take into account personal biases and feelings, to understand their influence on the research.

Data Analysis

The qualitative analysis included the steps outlined by Miles and Huberman²⁰. Since qualitative analysis implies that the data are in the form of words as opposed to numbers, these six steps facilitated the reduction of data into themes or categories and the interpretation of those themes and categories. Finally, to accommodate the large qualitative data set of this study, computer-assisted qualitative data analysis software (CAQDAS) Atlas-TI was used to make the coding and retrieval process faster and more efficient. More importantly, Bryman²³ stated that "CAQDAS enhances the transparency of the process of conducting qualitative data analysis" (p. 420), which makes the qualitative analysis process more explicit and hence increasing the reliability of the study.

Data analysis methods conformed to standard constant comparative data analysis techniques and relied on inductive reasoning processes to interpret and structure the meanings derived from data²⁴. The process involved the sequential comparison of interview data in order to develop concepts about possible relation between the various experiences. As analysis continued, common patterns began to emerge from the data and were organized into ideas or codes. These ideas were coded using codes related to Lewin's field analysis theory and categorized as (a) driving forces, (b) restraining forces, and (c) bidirectional forces. The force field theory,

developed by social psychologist Kurt Lewin²⁵, provides a robust framework to holistically examine all the forces that have an impact on a specific situation. The theory proposes that the situation moves to the goal state (e.g., in our case, it's the retention of women engineering students) if the forces are driving towards the goal, or the driving forces are dominant. In any case where the restraining forces are exerting much more strength than the driving forces, the situation then moves away from the goal state. In the current study, a new category of forces emerged from data analysis – bidirectional forces. These forces in some cases work for and other cases against the movement towards the goal state, which will be discussed in detail in the results discussion section.

At the same time, the coders were sensitive to any grounded codes that may have emerged from the data. The emergent themes were identified in the literature review are described in the following section.

Results

Emergent themes

Driving Forces

In the driving forces category, eight emergent themes were identified, ranging from participation in formal support programs to successful role models. The qualitative data pertaining to each theme are described as follows.

Formal Support Programs

The majority of the participants, both persisters and switchers, in the current study cited the most positive experience as participating in the formal support program available on campus. The formal support programs included programs that were only for female engineering students, such as Society of Women in Engineering (SWE), Women in Engineering, and Alpha Epsilon Omega sorority. The above mentioned support programs for women are the most popular and visible to the women engineering students of all majors. The participants also cited their experience with support programs that are not limited to female engineering students. These included the Engineering Council, Engineering without Borders, and Women in Math, Science, and Engineering (WIMSE). The first two are general engineering groups available to both male and female engineering students. WIMSE, established in 1996 at University of ILLINOIS, is a living-learning community supporting the academic success of women in Math, Science, or Engineering.

Two participants, out of nineteen, didn't participate in any of the above mentioned formal support groups for two very different reasons. One Material Science and Engineering persister confided that she had never participated in any of the formal support groups. She added that "most of that is more a personality issue that I don't like large groups of people and being around a lot of people, so I like my small research group and the support I get from that and mostly staying within material science, I guess." Another Material Science and Engineering persister explained why she chose not to participate, "I think maybe part of the reason why I have shied

away from S.W.E. is I feel like we don't have to be outcasts in order to do that. It kind of angers me a little bit that we have to have special help, you know, but, because I think that we are just as smart and just as capable as the men.”

For the participants citing formal women’s support programs as influencing their persistence in the engineering track, most described the formal support activities as a good opportunity of meeting with those who “have the common ground of being a woman and an engineer,” and a good place to get academic help by documenting the study files, “like homework and exams from past classes.” Plus lots of additional professional development opportunities where participants network, socialize, and learn about work prospects in various engineering professions.

Job Opportunities

Job opportunity in engineering was identified as an important motivator for persisting in engineering, for both persisters and switchers. Seven persisters and two switchers cited the prospect of being able to have a well-paid engineering job as one of the reasons why they chose an engineering major and staying in the engineering track. Says one Material Science and Engineering persister, “But I do know that I would like to have a job that pays relatively well, and that I would enjoy. And so, like thinking along those lines, engineering seemed like a good idea.”

This is not in alignment with the prevailing literature that confirms female engineering students were less motivated by well-paid engineering jobs; instead, they were more likely to be motivated intrinsically by what engineering can do for the betterment of human conditions and the world we live in. However, since many female engineering students chose to leave science or engineering majors because they decided that the rewards were not worth the effort²⁶, we contend that job opportunities may serve as one of many reasons why female students persist in an engineering track.

Motivation

The participants indicated that they were motivated to choose or persist in engineering intrinsically, extrinsically, or both intrinsically and extrinsically. The female engineering participants, both persisters and switchers, who had intrinsic motivation viewed the engineering profession as finding “suitable material for humans so that they can live better,” or designing and manufacturing something that “makes people's lives better or easier.” On the other hand, the extrinsically motivated female engineering students described their reasons of starting and remaining in engineering majors as being that they “would have a very stable job” “that pays relatively well” once they finish the degree, and they would have the pride of being regarded as “smart women engineers.” The flip side of it, lack of motivation, was cited by many as the killer of the positive energy or other driving forces.

Peer Support

Most of the persisters, as well as switchers, cited the importance of peer support in assisting them when they are having troubles with engineering coursework. One computer engineering major went further to explain why she preferred the peer support rather than teaching assistant support. She related that “If a teaching assistant describes something, they know it very well, and they might describe it in high-end terms, and you may or may not get it. But if someone is learning it right now and it clicks with them, then they are probably going to explain it better to another student than if you go to a T.A. or even the professor.” There was, however, one civil major persister said she had stayed away from study groups or any other types of peer support activities available. “I don't think it's a good idea to talk to your classmates, because classmates are so young, too, and they don't really know.” Her preferred sources of help were the TA and the professor with whom she did research.

Peer support serves two major functions: academic and personal support. Most of the participants sought help with the homework that was conceptually difficult to them through support activities like peer tutoring and study groups. They also reported that they had found that personal interaction with their peers was a major source of their emotional support or other personal needs. One material science and engineering persister shared her rationale for preferring peer support, “I think it's really having people who have been there, either have been there or are going through what you are going through, so that you have a sounding board for what's reasonable or what's not reasonable, to expect.”

Personal Interests in Engineering

Personal interests play important roles in getting the persisters to persist in the engineering track when facing major discouragements in the process. Many persisters identified personal interests as the single most important factors that contributed to their decision to pursue an engineering degree. One material science and engineering major related that, “I am really lucky that I really enjoy learning it (engineering). So I think that is the primary thing that's kind of kept me in it, and the other stuff is kind of secondary. That's what has kept me in it, and the other stuff has kept me from dropping out of it.” Switchers, however, may show some interest early on in pursuing careers in science and engineering; their interests in engineering will fizzle out as they remain in the engineering major for a longer period of time.

On the other hand, the lack of interest in engineering can be the precursor to seeking out interests other than engineering. A switcher who switched from electrical engineering to mathematics explained her experience of discovering an interest in other majors. At the end of the freshmen year, she totally lost interest in pursuing an engineering degree after receiving a probation warning from the college of engineering because of her far below average academic performance. Her response was to seek opportunities in other disciplines. The first semester in her sophomore year, she was successfully transferred into the mathematics department and made the dean's list that semester.

Self-Confidence

The persister participants in general were self-confident about their intellectual capability and mostly held the firm belief that the two genders are equally capable and all the help that they

possibly need was readily available. The persisters with strong self-efficacy beliefs knew that help is available and all they needed to do was to locate it. A material science and engineering major believed that women students were “just as smart and just as capable as the men,” and also acknowledged that there was some difference between genders. Says an industrial engineering persister of her conviction about the ubiquitous nature of help: “I never thought there was a problem with what was available or with what the College of Engineering offered. I think the problem has to do with the students, you know, asking for help or looking for it. So, maybe if there is a way for students to know what is out there and it is compiled in one place, maybe they wouldn't be afraid to open up and ask for help.”

Stress Coping Skills

Stress is the by-product of rigorously applied engineering curricula and a very heavy course workload. Six persisters and switchers reported explicitly that they had experienced extremely stressed-out situations. Some also reported that they successfully exploited the stress by using coping strategies to lower the stress level: such as time management and stress relief (e.g., hanging out with peers in casual situation; yoga practice). An industrial engineering persister shared her experience about how the time management skills she learned helped her cope with taking control of a stressed-out situation. Says she: “It was a hard balance (between study and having fun) for sure, and in the beginning I think my grades suffered because of that, but now, now it's like second nature. Just time management, I learned a lot.”

Successful Role Model

Several persisters also specifically spoke about their exciting experience with their role model. A mechanical engineering major mentioned about how having a successful role model helped her in pursuing her engineering degree: “when people who are engineers already and they tell me what they do. That helps me because it sounds interesting because I have a friend who just graduated last semester, and she is going to be working at GE, and that helps me, and that was really good.” A civil engineering major confided that the professor in her research group served as a great role model to her. The professor's passion about engineering research and teaching deeply inspired her to be a driven person in seeking an engineering career in the non-women-friendly civil engineering field.

Consistent Source of Help

Several persisters cited the individuals who served as a consistent source of help as a major positive impact on their confidence in pursuing an engineering career. Many women engineering students, as minorities in the engineering major, more or less have the tendency to underestimate their capability, and thus are easily overwhelmed by any degree of set-back, major or minor. Knowing of the presence of a consistent source of help, therefore, gives female engineering students reassurance of the potential for help somehow, somewhere by someone. Two of the switchers, one mathematics and one speech communication major, had experience with the striking difference between their respective academic advisors. Their engineering advisors referred them out to other parties for help; and never followed up with email or phone to inquire whether or not they got the help they were seeking. The speech communication switcher, after

describing his engineering academic advisor as “mean” and “horrible,” mentioned her diametrically opposite experience with the advisor in speech communication:

“she just, you know, like we're going to do this together; I'm here for you; like I will give you my E-mail address, and I'm going to look this up for you. Like if you have a question about this certain thing, okay, I am going to find out an answer for you. She never sent me anywhere else. And if she sent me somewhere, she knew that I was going to get the answer once I got there, like, just really took me under her wing. And I just felt like wow, like she's going to help me, like this is what I thought an advisor was supposed to do, you know, and it was wonderful.”

Restraining Forces

In the restraining forces category, six emergent themes were identified, ranging from conceptual difficulty to the rigor of the engineering curriculum. These factors are the barriers that diminish the success rate of retaining women engineering students.

Conceptual Difficulty

Both persister and switcher participants identified the conceptual difficulty of the course work as the major restraining force that hindered the success of retention. Seven of the participants cited conceptual difficulty as the single most discouraging factor that prohibited their success in pursuing an engineering degree. Some direct quotes from these participants are: “It (the course material) was hard. I couldn't figure it out, and then I wasn't interested.” “The difficulty of the subject material itself is the most discouraging factor in pursuing an engineering degree.” “It's just a really hard program, and so we were all trying to get through the weed-out classes.”

Individualist Atmosphere

Typical women engineering students are better team players and like working with other people, yet the individualism and low social interaction really had a negative impact on women engineering student retention. One electrical engineering switcher found the “different kind of atmosphere in class” where it seemed “in class nobody is willing to talk to other people,” even though they were encouraged to have study groups and to “meet more people in your classes.” One computer science persister reminisced about her experience in the JAVA programming class, “even if they (students) sat next to each other, I remember nobody ever talked to each other. And pretty much it just seemed like individual work.” Her recollection was that “they certainly knew how to program ... I felt like I was the only one who didn't know what was going on.”

Work Life Conflict

Some participants talked about their experience with how tough it is to balance their course work and personal life in the university; others expressed their deep concern about work and life conflict as they had observed the negative impact in the engineering career pursuit. One

mathematics switcher shared her first year experience as a freshman student: “I guess I might say it was very tough, stretching, I guess in every way not just academically. When I came here, I played soccer too, so it was kind of hard to balance everything.” She remembered one of the instances when she compared her physics homework with one sports management major soccer teammate, she found out the minimum amount that her teammate needed to do to balance the conflict between the course work and involvement in soccer practice and matches. One industrial engineering persister related that “it was hard seeing them (some L.A.S. friends) having fun a lot when I would have to go study,” it was a hard balance between course work and life.

One material engineering persister articulated that “trying to have a family” is the most discouraging factor in pursuing an engineering career. One of her research teammates was recently pregnant and had a very unpleasant experience. The negative experience gave her the impression that women had to apologize if they want to have kids. She was deeply concerned about this type of work and family conflict that would be one of the biggest obstacles in her future work as a female engineer. It was discouraging for one electrical engineering switcher to realize that “a lot of really successful women, they don’t have kids, and they don’t have families.”

Low Female Ratio

The low female ratio in a typical engineering class environment has been identified as one factor that they don’t particularly like even though it did not always have a huge impact in their switching decision. One general engineering switcher remembered in the ECE class “there weren’t as many women as men;” the fact that only two female engineering students in the whole class made her feel “a little intimidated” and “a little out of place.” Another civil persister also acknowledged that “it’s true that sometimes girls do get discouraged because there are so many men.”

Discouragement by Poor Grades

The transcription data showed that all the participants, both persisters and switchers, all performed very well academically in high school and the vast majority of them passed advanced placement tests for mathematics, and science before their matriculation into engineering programs. The tougher competition in engineering programs, the lower most of the engineering students’ grades are; women engineering students, however, are easily discouraged by the drop in academic performance. One material engineering persister considered poor grades the most discouraging factor when responding to the question about the most discouraging factor. After doing so poorly on a test, she started questioning herself, “what should I do? This is my concentration, and I have to do well, and maybe I should switch out, or maybe I should drop the class. So, I think that kind of thing ...I think that's probably just the most discouraging thing.” Fortunately, she had some other forms of strong support that counteracted this restraining force and she had already graduated from the engineering program by the time this study was concluded. Her experience was shared by one electrical engineering switcher who cited the low grades as the reason of her decreasing confidence level, which will be explored in more detail in the representative switcher case in the following section.

Rigor of the Curriculum

Many engineering curricula are prescribed, especially for the first two years. One electrical engineering major related that “when you are in the engineering program, there are a lot of required things you have to take at a certain time to fit it in.” For the electives in engineering, she said, “you have a certain amount of electives you have to take, so it’s either like more math or science classes or classes in another engineering field.” One mechanical engineering switcher pointed out that she felt “a lot of pressure because the schedule is so you take this now and this next semester . . . if I don’t get this one done, then I am going to be way behind, and this little chart (course plan) they have worked out for me isn’t going to work.” Two of the switchers cited that being unable to timely fulfill one of the core prerequisites on their respective prescribed curriculum plan resulted in them being asked to leave the engineering program. One already knew she was not going to pursue an engineering degree at the time, while the other didn’t know exactly what she was going to study if she left engineering and later decided to switch to mathematics because staying in mathematics still “used some of the same skills.”

Weed-out Courses

Switchers and persisters alike cited having trouble going through the weed-out courses as one of the most discouraging obstacles in the way of their pursuit of an engineering degree. Three switchers identified a frustrating experience with a weed-out course as the last-straw leading to their decision to leave the engineering program. One persister thought her experience with the weed-out course was the most discouraging factor in pursuing engineering degree. One electrical engineering switcher had so much trouble with one weed-out course that she was put on an academic probation. Having to drop engineering, she transferred to mathematics where she could still “used some of the same skills,” and her being put on the dean’s list in mathematics department proved her judicious judgment.

Bi-Directional Forces

During the process of analyzing the transcription data set in the light of Kurt Lewin’s force field analysis framework, the researchers found there were several factors could not be assigned solely under either the driving forces or the restraining forces. Whether the factor drives or restrains the retention of female engineering student depends on the specific case scenario. For example, family influence can be positive when parents encourage the female students’ pursuit of an engineering degree or anything she is intrinsically motivated to study; it can also be negative when parents dissuade them from engineering by telling them engineering is “not good for a woman” or very subtly suggest otherwise by asking “are you sure this is what you want to do?” In the bidirectional forces category, four emergent themes were identified. Besides family influence, the other three are Faculty/TA support, teaching quality, and department environment.

Faculty/T.A. Support

The vast majority of the participants cited their positive experience with both faculty members and T.A.’s. One industrial engineering persister had regularly attended the professor’s office hours in the reliability engineering class, and found that he would “stay extra just to help” her.

And consequently, she “did well on the homework,” understood it conceptually, and “did well on the test as well.” There are, however, several students who didn’t feel they had been helped by either faculty members or T.A.’s. One mechanical engineering major observed that her problem was with “the T.A. that he definitely made me feel like he didn’t take me seriously,” and she finally decided to stop “going to his office hours, because he made me feel like an idiot.”

Teaching Quality

Quite the opposite, most participants didn’t feel the way many professors taught was stimulating and easy to be understood; thus suggested changes in the teaching styles of the professors in their department. The typical engineering courses are, as one electrical engineering switcher mentioned, like “oh, well, you just need to know these concepts, and we are going to teach you these concepts, but they are not thinking about how to present the concepts in a way that students will be better able to understand them or just be more interested in it.” And to make the situation ever worse, “it’s harder to understand what they are talking about when you don’t know how it relates to other parts or other aspects.” The researchers expected that women engineering students might typically like the ways female engineering professors teach, yet to their surprise, one industrial engineering persister confided that she had never liked the female engineering professors that taught her “because they are very, they are just kind of all of over the place, and they kind of act very motherly.”

Department Environment

It is in alignment with the literature that, in general, female engineering students don’t think the departmental environment is women friendly. Many of the persisters and switchers perceived the department environment as a negative force that was restraining the success of retaining female engineering students. One electrical engineering major believed that “College of Engineering tells you that you are not supposed to talk, ask about classes or class work or things ... you can’t ask them about like life counseling types of things.” She also thought that “a lot of people on campus aren’t very supportive. One general engineering major “didn’t talk at all to my academic advisor. He was like non-existent and not helpful at all.” Recalling her conversation with the dean about her decision to switch to mathematics, the response she had was as simple as “do whatever you want” which was “a lot faster and a lot quicker” than she thought.

On the other hand, one civil engineering persister found that the college of engineering had been “extremely supportive towards women” and didn’t think women engineering students need any more women support programs to ensure higher success probability of women students in engineering. And different departments have their own style, one material engineering major took classes in both material science and engineering and electrical engineering and felt that she had “more interaction with the material science faculty” than she did with the electrical engineering faculty.

Overall, all the above identified factors are by no means exhaustive and mutually exclusive to each other. Each of them plays an important role in retaining female engineering students. However, the researchers recognize that all the factors are intertwined with other factors or other

sets of factors. It's not practical to single out one factor to analyze its individual contribution to the success of increasing the probability of retaining female engineering students.

Main Forces Identified

Any single factor, or subset of these factors, does not have adequate power to predict the success of retaining any individual female engineering students. However, when we observe all the factors holistically and understand how each factor interacts with others, we have a much more accurate understanding of the persist or switcher situation in terms that we might be able to successfully recommend one or one set of interventions to increase the overall success probability of retaining women engineering students. All of the major forces that play important roles in women engineering students' retention are listed in the Table 2:

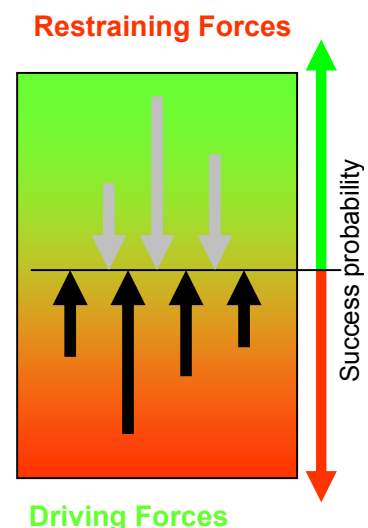
Table 2 – Main Forces

Driving forces	Bidirectional forces	Restraining forces
Consistent source of help	<i>Department environment</i>	Conceptual difficulty
Formal support program	<i>Faculty/T.A. support</i>	Course workload
Job opportunities	<i>Family influence</i>	Discouragement by poor grade
Motivation	<i>Teaching quality</i>	Individualistic atmosphere
Peer support		Interests in other disciplines
Personal interests		Low female ratio
Self-confidence		Rigor of curriculum
Stress coping skills		Week-out courses
Successful role models		Work life conflict

In Kurt Lewin's force field analysis framework, the equilibrium of the status quo, as shown in the Figure 1, will only be moved when driving forces and restraining forces become unequal. The driving forces, therefore, are driving the movement towards the goal, namely, the greater probability of retaining women engineering students; the restraining forces, then, are blocking the movement towards the goal. In any specific case, when driving forces become dominant, the equilibrium will be driven toward the greater success probability of retaining women engineering students; when restraining forces take control, the equilibrium will be blocked towards the goal, thus the success probability of retaining women engineering students becomes slighter.

If we can identify, for each single persist or switcher, the sets of restraining and driving forces that she perceives, we then will be able to understand what makes one leave and the other stay even though their preparation and other related conditions are very similar. Further, we may recommend the best interventions to support each individual by understanding the

Figure 1. Force field analysis

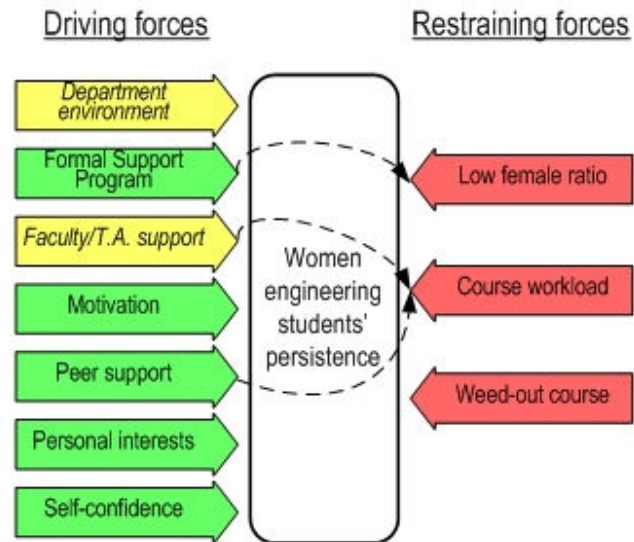


individual's best strength and weaknesses in the pursuit of engineering degree. Next, the cases of a representative persister and switcher are explored in detail.

A Persisters Force Analysis

Phoebe (pseudonym) is a twenty year old Caucasian and a senior in the Department of Material Science and Engineering. Like many other women engineering students, in high school, Phoebe passed the AP Physics (all three levels), AP Chemistry, and first half of AP biology. She actually swore that she would not go into engineering because she didn't want to follow her parents' steps. However, she had intrinsic interests in electrical matters and started talking to one high school teacher who introduced an engineering scholarship opportunity to her. She got the scholarship and was accepted into the Department of Electrical Engineering and later switched to the current department because she was trying to find a discipline that would use more chemistry.

Figure 2. Persister Case



During the interview, Phoebe talked about her experience as a woman engineering student. She identified the following driving and restraining forces in her pursuit of an engineering career. As shown in Figure 2, in the Diving-forces category, she identified five factors out of the original nine; three restraining factors out of the original nine in the Restraining-forces category; two factors in the Bidirectional-forces category (printed in italics) were identified as driving forces and moved to Driving- forces column. The three arrowed lines will be further discussed in the “Force Interplay Analysis” part in the following.

Driving-forces identified by Phoebe:

Formal support program: Phoebe was involved in the engineering council, Alpha Omega Epsilon, and one Material Science Honors Society. She felt that she was “pretty content with the situation” where she “gets pampered a lot more than” she really needs.

Motivation: When she explained her motivation for being in engineering, she said: “it's just engineering challenges me more than the other classes, so I guess that's why I'm here.” Engineering in the senior year meant “being able to apply scientific research to the world rather than doing it for the sake of knowing.”

Peer support: Phoebe had a tight knit group of about eight friends, and they always got together and did homework, so it was a big homework party. She preferred to go to study group first for help and then if needed resort to faculty/T.A.

Personal interests: Her early interest in chemistry led her to a scholarship in engineering major – the start of her engineering career pursuit. Phoebe thought her liking “the material that she was dealing with,” that is her personal interests in her major, was the overall factor that contributed to her pursuit of material science and engineering degree.

Self-confident: Phoebe never had anyone make her feel different. If anything, she felt special because of “the fact that she was unique.” She never had a T.A. or a professor treat her differently because she was a girl. She strongly felt that women engineering students have no different needs than guys because she was here “to learn the material, and they are just here to learn the material.” She believed that those women engineering students who needed special treatment “shouldn’t be in engineering.”

Bidirectional-forces identified by Phoebe:

Department environment: Overall, the department environment had a positive impact to her persistence in engineering. Phoebe found that the faculty members in the Department Material Science and Engineering were always very available. She had “more interaction with the Material science faculty” than she did with the Electrical Engineering faculty, because “the Material Science faculty all want to know their students.”

Faculty/T.A. support: If the peer support was not available, that is none of the members in the group knew the problem, they then turned to faculty members or T.A.’s for assistance. In one of the very difficult course, Phoebe and her study group members “were always at office hours for that class.”

Restraining-forces identified by Phoebe:

Course workload: The most discouraging factors in pursuing an engineering degree for her, Phoebe thought, would be “the amount of homework.” She continued to explain: “the fact that it’s overwhelming, the amount that you learn at any given time, and just the fact that there is never any down time ... there is just no such thing as relaxing or having your homework all done.”

Weed-out course: Phoebe had her discouraging moments after she took physics 460, one of the difficult courses where students rarely make good grades. She was “hoping for a 60 percent.” It turned out to be a B in the class – better than she expected. She joked about being glad that she didn’t switch out, but she felt it was “discouraging to realize that there was that much out there that I had no idea what was going on.

Low female ratio: During the interview, Phoebe acknowledged that it’s easy for women engineering students to feel not supported in “a sea of guys” in typical engineering classrooms, which might become a major obstacle of retaining female engineering students.

The Force Interplay Analysis:

In this section, the researchers try to see through this individual participant's eye how some of the forces from the driving and restraining forces interplay, as shown in Figure 2 with the arrowed line indicating one driving force overcomes one restraining force.

Faculty/T.A. support HELPS EASE course workload: Says Phoebe, "it was just a ton of stuff, and the homework was a ton, and he (the professor) would oftentimes cover more than we could go into very deeply, in much detail in class, and so it was just very difficult. So we were always at office hours for that class." Her strategy to deal with the course workload problem is to fully utilizing the faculty/T.A. support in office hours.

Peer support HELPS EASE course workload: When she had any trouble with her engineering coursework, she usually went to her friends in the department. Says Phoebe, "We actually have a pretty tight knit group of about eight friends, and we always get together and do homework, so it's a big homework party." Seeking help from peers is easy and always readily available; it was her favorite way of getting help.

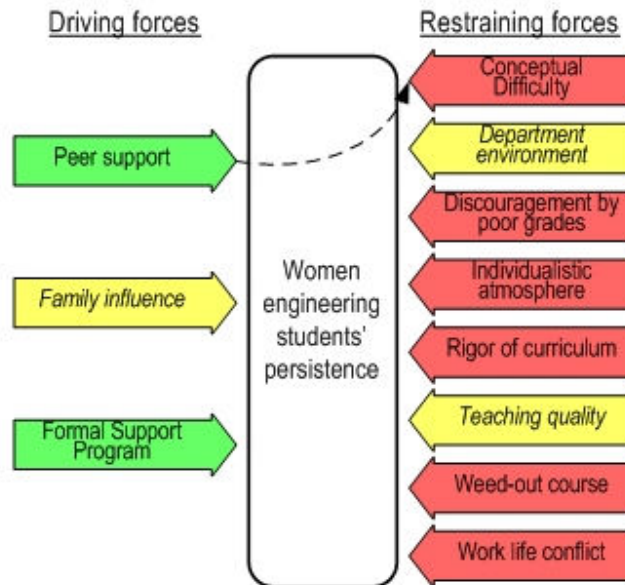
Formal support program HELPS EASE low female ratio problem: Phoebe admitted that other women in engineering may at times feel alone among many male counterparts. And she identified "I have never personally felt alone in a sea of guys or anything like that. It's just that I am involved, like I just got involved in what I was interested in, and in my case Alpha Omega Epsilon because the people were just so outreaching to me."

Looking at Phoebe's force field analysis in Figure 2, the driving forces outnumber what are identified as the restraining forces. The conclusion is very obvious that Phoebe has a great success probability in persisting in the engineering track, or from the engineering program perspective, it has great success probability in retaining Phoebe in the engineering track.

A Switcher's Force Analysis

Sue (pseudonym) is a twenty-one years old Asian student. She was originally an Electrical Engineering major and then switched to Mathematics after her sophomore year. In high school, her math and science level was average or above average. She was in the high classes with other fellow students and she really felt math and science were interesting. As she grew up, she was surrounded by engineer parents and other people in the engineering profession. She was encouraged to learn more about math and science. She was naturally coaxed into the engineering track as she didn't have anything else in mind at the time when she graduated from high school. Sue kept it in her mind that if she didn't like engineering, she could always switch to something else, and so she did after being put on engineering academic probation when she did especially poor in one class. This became the last-straw for her to decide to switch to math. The very first semester in the new department, she was put on the dean's list for exceptional academic performance. At the same time, she felt that she had "time to do other things, join clubs, or have fun." Her personal experience epitomized the idiosyncratic culture of engineering, which is different from other STEM disciplines.

Figure 3. Swicher Case



Sue's engineering pursuit force field analysis is shown in Figure 3 as below. The Driving-, Bidirectional-, and Restraining-forces will be described in detail in the following section.

Driving-forces identified by Sue:

Formal support program: Sue knew about the S.W.E. before she came to the university. After she was in the university, she was really heavily involved in its activities. She liked it because it's the place she could find lots of people with common interests, and do a lot of things. Some of them were even going through the same struggle of being at the verge of making the decision to switch majors like she was going through. She found a very strong emotional support from S.W.E. and also a lot of academic support by talking to upper class women who were in the same major.

Peer support:

For the difficulties with her engineering course work, Sue preferred to "ask my classmates for help." She had friends that were in her major and they take the same classes together. The study group later became her regular support base for academic help.

Bidirectional-forces identified by Sue:

Department environment: From Sue's point of view, her department environment restrained her success of persisting in engineering. She believed that the College of Engineering somehow informed her that students were not supposed to talk, ask about classes or class work or things with their academic advisors. She couldn't ask them about life counseling types of things, which she also needed help with. She also thought that a lot of other people on campus were not very supportive.

Teaching quality: She made several comments about the poor teaching quality that was commonplace in typical engineering lecture-based classroom. Says Sue, "all of our lectures are chalkboard lectures or an overhead, and like someone is writing with a marker, and, you know, you can go to Econ 101 or something like that, and it's like really nice Power Point lectures." She continued to point out that "changing their teaching style" is the "main thing" that engineering department can do to keep her interested in the engineering program. The teaching quality factor is moved to the restraining forces.

Family influence: However, Sue had received very positive influence from her parents both of whom are practicing engineers. She believed her parents played a part in inspiring or encouraging her to pursue an engineering degree upon graduation from high school.

Restraining-forces identified by Sue:

Conceptual difficulty: Sue stated that the most discouraging factor for her in pursuing an engineering degree had been the difficult material. She continued to explain why she became disenchanted in engineering in general after encountering the conceptual difficulty. Continues Sue, “so then, it was hard. I couldn't figure it out, and then I wasn't interested. So, it kind of like adds up onto each other, and then so you don't do very well in your first class, and so you'll go like I didn't do well”

Discouragement by poor grades: Sue described her unpleasant experience as a student who did well in high school to someone being put on engineering probation: “most of us in the engineering program, did pretty well in high school, you know, and so we think we're kind of smart, and we know most of what we are doing. So, when you come to school, and you start doing not so well, you're not used to doing so poorly on something, so it really kind of lowers your confidence level.” Then she was deeply concerned about the amount of technical courses she had to take and the negative impact on her GPA: “with so many technical classes, if you don't do very well, you don't have anything else to kind of uphold your grades.”

Individualistic atmosphere: Sue did not particularly like the atmosphere where minimal social interaction occurred. She observed that there was a different kind of atmosphere in class. Everyone was encouraged to get to meet more people in the class and form study groups, yet the cold reality was that “no one really is willing to talk to other people.” The typical engineering class, she described, would be like “everyone comes to class, and they will sit down and listen to the lectures, and they will leave.”

Rigor of curriculum: In the engineering program, Sue described that “there are a lot of required things (courses) you have to take at a certain time to like fit it in.” She wanted to take some other interesting courses; however, she only had time for one elective. And to make it even more frustrating for her, “in engineering, like the electives, you have a certain amount of electives you have to take, so it's either like more math or science classes or classes in another engineering field.”

Weed-out course: Sue had traumatic experience with one of the hard engineering courses. She performed so poorly that she was put on academic probation – a warning saying to her “you are not doing well in this class, maybe you should take it over again.” This instance really lowered her level of interest in engineering and confidence in pursuing an engineering degree. The resultant decision was to leave the engineering department and to find another discipline where she could shine again like a star, so she switched to in the Department of Mathematics; and she found herself on the dean's list in her first semester.

Work life conflict: From her participation in the S.W.E. general meetings, she started being aware of the work life balance issue that was much talked about by upper class women and professional women who were invited back to give talks. It was discouraging for her when she discovered that “a lot of really successful women, they don't have kids, and they don't have families. They have success in their career, but they don't have it in their family life.”

The Force Interplay Analysis:

Peer support HELPS EASE conceptual difficulty: In Sue's own words, "you have friends that are in your major, so you are like, oh, let's take this class together. So, you will know other people. So, usually we would each have like study groups. So, I would ask my classmates for help." Peer support from classmates is Sue's most preferred way of getting help with engineering course work. The relation is indicated in Figure 3 as an arrowed line pointing from peer support to conceptual difficulty.

Sue's force field analysis in Figure 3 demonstrates a representative switcher's scenario, which validates Kurt Lewin's force field analysis framework. Sue perceived far more restraining forces than driving forces, hence the equilibrium will move away from the goal of retaining female engineering students. The engineering department, therefore, has less success probability in retaining Sue in pursuing an engineering career.

Conclusions

A common theme in existing research is the pipeline metaphor, which presumes that for the most part women who are attracted or recruited into the beginning of the engineering degree program will arrive at the engineering career end of the pipeline barring unexpected events (leaks). Therefore the solution to a shortage of women engineers is to pump more women into the pipeline. Failure to arrive at the output end of the pipeline is considered a defect and typically described in terms of leakage. Despite the efforts and successes of many great organizations (e.g., WIE, WISE, SWE, etc.) there continues to be a shortage of women engineers.

The pipeline is an inadequate metaphor in that it does not reflect all of the forces impacting the journey. First of all, the losses continue beyond graduation from the engineering program with women switching to alternative careers outside of engineering. Secondly, the pipeline metaphor suggests a predetermined destination (e.g., entry leads to graduation) and concerns are limited to entry skills and few deviations (leaks). Further, it does not address a lack of attraction to engineering or a greater attraction to other career paths as they are encountered, particularly during the most vulnerable freshman and sophomore years of college. You can improve the negative aspects within the pipeline but you cannot fight the outside attractions except by improving your input to the pipeline by selecting more appropriate people and increasing their career velocity by building interest and engagement.

An alternative metaphor may be found in Kurt Lewin's force field analysis where good quality factors can drive success, and poor quality factors can restrain success. It is important to recall that success in engineering is dependent on a variety of factors and attraction to alternative careers can restrain success in engineering. Therefore, force field analysis is a better metaphor for describing forces in play for undergraduate engineering students and beyond as it suggests multiple possibilities for changes in velocity and vector.

In force field analysis the probability of success is enhanced by improving the driving forces and by controlling and reducing the restraining forces. By viewing the journey to a career in engineering as a trip affected by many positive and negative forces the need to enhance the positive and reduce the negative forces becomes obvious. It is important to note that not all restraining forces are negative and one example is that students are sometimes attracted to a different field even though they possess the requisite skills to succeed in the engineering field. The results are negative to the program but not a result of a program shortcoming or negative aspect.

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