AC 2010-1946: SUCCESSFUL WOMEN ENGINEERING STUDENTS: A SURVEY ASSESSMENT TO GUIDE OUR EFFORTS TO BOOST WOMEN'S RETENTION

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Successful Women Engineering Students: A Survey Assessment to Guide Our Efforts to Boost Women's Retention

Abstract

In the fall of 2009, a college of engineering and applied science at a public, Rocky Mountain region university embarked on a new inclusive excellence initiative called Broadening Opportunity through Leadership & Diversity (BOLD). The BOLD Center is a new K-16 organizational structure to increase the performance, representation and retention through graduation of students who are underrepresented in engineering, including women, students of color, low income and first generation college attendees. A BOLD Center focus of concern is the declining retention rate of women that has dipped below that of men recently in our College. A survey consisting of 41 questions was distributed to all undergraduate engineering women in the college that incorporates scales from the Assessing Women in Engineering (AWE) assessment and from the Academic Pathways of People Learning Engineering Survey (APPLES). Five research questions were posed in the survey design:

- Do women express a loss of interest during their program?
- Is there a chilly climate for women in the college?
- Do women's self-efficacy levels change during the program?
- Do academic performance levels play a role in women's retention in engineering?
- Do women have an adequate support structure in the college?

The survey generated 116 responses from 2 solicitations, with women students represented from every major across all four undergraduate years. An unintended outcome was that the sample largely consists of women with high grade point averages. Thus, this paper offers insight on top performing women's self-efficacy and their views on the college climate, the benefits from various support systems – advising, mentoring, social and financial – and the existing programming and initiatives that can play a role in their achievements.

The results indicate that women students are interested and efficacious with respect to obtaining an engineering degree, and that the college climate is, on average, warm and accepting. However, women were less satisfied with advising, mentoring, and their financial support. Women students also perceive that they must sacrifice their outside interests to "succeed" in engineering and in order to handle the course workload that they perceive as overly heavy. These results and others to be presented in this paper will shed light on the factors we can address to increase women's retention and success in engineering education.

Introduction

This paper analyzes the experiences of undergraduate women in engineering and applied science majors at a public, Rocky Mountain region university with about 30,000 undergraduate students. The survey and research were initiated to address two disturbing trends seen in undergraduate education in the United States. While women have historically been underrepresented in Science, Technology, Engineering and Mathematics (STEM) fields, the

number of women in the biological and life sciences has grown to nearly one half, and nearly one third of chemists are women; nevertheless, women compose less than 15% of the engineering population.[1] Additionally, the proportion of women over the last 20 years has merely grown 5%, despite numerous efforts including scholarships, curriculum improvements, and mentorship programs across the country.[2] The declining retention rates in universities and slow growth occurs in spite of the fact that overall, the qualifications of women tend to be equal or slightly better than their male counterparts.[3]

The university tracks undergraduate student six-year graduation rate by gender. Upon entering a degree program in the College of Engineering and Applied Science, student progress is monitored for up to six years. The figure below illustrates a concerning trend within the college. In recent years, the retention rate for women has declined and dropped below the rate at which the College retains men. An analysis of graduation rates in other colleges at the university did not reflect the same pattern, indicating this pattern is specific to the college of engineering.

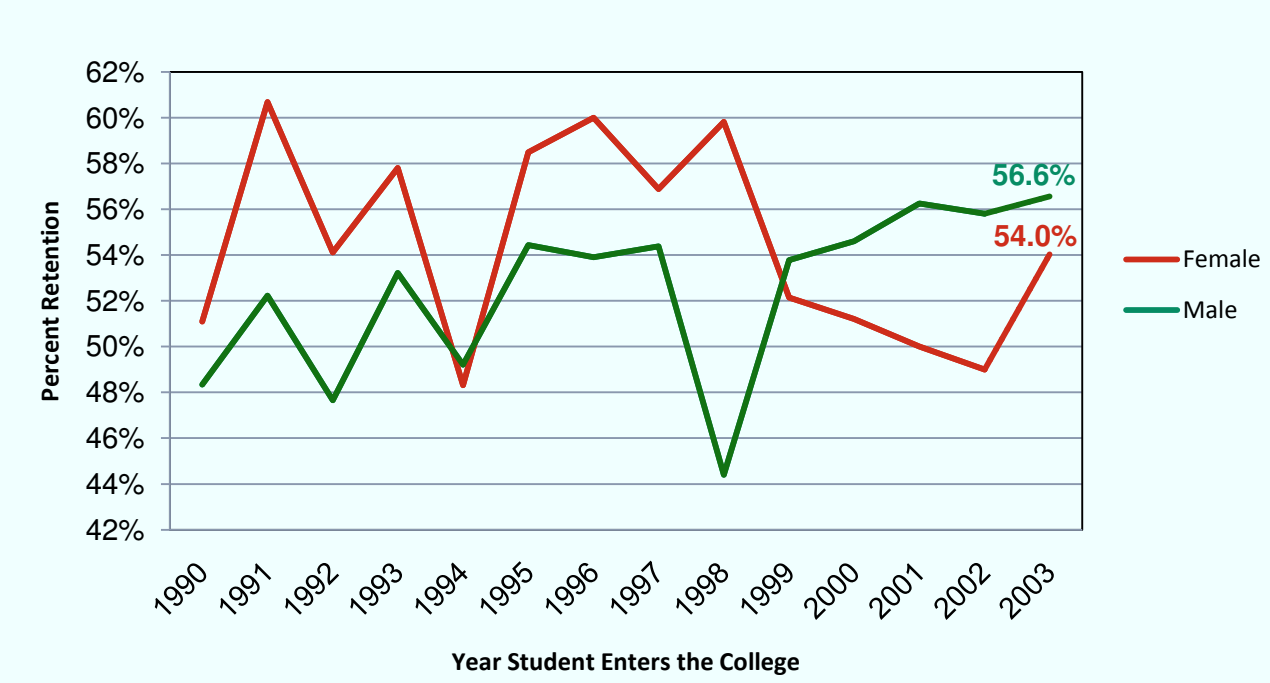

Figure 1: Six Year Graduation Rate by Gender

This study was designed to address this trend by investigating the following five research questions about undergraduate women in engineering majors:

- Do women express a loss of interest during their program?
- Is there a chilly climate for women in the college?
- Do women's self-efficacy levels change during the program?
- Do academic performance levels play a role in women's retention in engineering?
- Do women have an adequate support structures in the college?

Literature Review

The published STEM research studies serve as a framework to shape this study. Research studies have been previously conducted in these areas. However, few studies focus on how the aforementioned factors apply to the top-performing women in the colleges. Thus, while this study may confirm the conclusions found by others, the findings as applied to top-performing women expand on previous research. Additionally, while some of the studies address STEM fields, this study focuses on engineering undergraduate women.

Previous research has found that women, more than men, tend to lose interest in their program during their undergraduate years. In a study conducted in 2006, it was found that at the beginning of students' first academic year, there was no difference between males and females in their interest or determination to pursue a STEM degree; however, by the end of the academic year, many students were considering leaving. Most notably, 31% of women who were not included in a living-learning community intended to declare a non-STEM major.[4] Maintaining women's interest during their program is paramount, as it has been found to be one of the primary reasons they leave the college.[5]

The second question aims to analyze the climate for women within the College. The hypothesis of a "chilly climate" for women in higher education was first developed in general higher education literature.[3] The concept of a chilly climate is especially relevant for groups with low female representation, such as STEM fields. In a study on women at 4-year institutions, Whitt found that 43% of female students disagree or strongly disagree with the statement, "I have never observed discriminatory words, behaviors, or gestures directed towards female students."[6] While not all studies report women perceiving gender-based discrimination on college campuses, the literature supporting the chilly climate hypothesis is considerably more conclusive.[3] It has been found that male students and faculty exacerbate discriminatory experiences for women, through much subtle and some obvious written and verbal communication; furthermore, these women are not necessarily aware that they have been discriminated against.[3] These experiences can lead to a lowered sense of belonging and community, which literature has found to play a role in women's success. In fact, Seymour says about a sense of community, "Its absence is credited as a source for women leaving, and its presence is a source for the decision to persist."[7] Another component of a chilly climate is the isolation felt by its members. When the numbers of women remain low in a discipline, "spotlighting" or "tokenism" of minorities is a larger issue; the intrusiveness of these effects begins to drop off after a population reaches greater than a critical mass of 15%-20%.[8]

Self-efficacy, a term originally coined by Bandura, is defined as situation-specific confidence in one's abilities.[9] Self-efficacy has been studied in detail for women in engineering in past literature, but generally produces conflicting results. When entering engineering, women generally report high levels of self-confidence and self esteem, which declines abruptly in their first year; while it begins to elevate again over time, it never again reached the same levels.[10] Hawks and Spade found that women generally compare themselves unfavorably to their male peers and judge themselves more harshly than men judge themselves.[11] However, in vocational areas, Hackett found no significant differences in gender.[12] In another recent study, it was found that over time, women generally report positive changes for coping, engineering

efficacy, and math efficacy, leading to the conclusion that women are more efficacious in areas which are important to completing their degrees.[13] However, multiple studies found that the self-esteem and self-confidence of women drop during their first year of studies; for men over the same period, their self-efficacy levels remain unchanged.[3] Yet findings from Besterfield-Sacre's data would conflict with these conclusions, as they found gender differences reduced over the first year of school.[14] Overall, Malicky found that to make general conclusions about self-efficacy and gender differences, two different approaches can be used. First, if one gives the most weight to cross-institutional studies, then self-efficacy differences exist and are usually among the largest gender differences reported.[3]

The fourth research question aims to investigate if or how academic performance affects women's retention in the College. Upon entering universities, it has been found in meta-analyses completed by Malicky that women tend to be equally or slightly better qualified than their male peers.[3] Adelman found that women tend to carry a small, but significantly higher credit load than male students, and that generally their grades are similar. However, the academic performance between women and men differs by discipline, with men performing better in computer engineering and women performing better in mechanical engineering, industrial engineering, and engineering math.[15] At the University of Washington, Brainard found that when comparing women who leave the college and stay, no GPA difference appears, suggesting that women do not leave because they are not performing; Seymour and Hewitt have found this as well.[7]

The final question intends to evaluate and understand the effectiveness of support structures within the College offered to women. In this research, support is analyzed in following areas: advising, mentoring, and financial support. Malikcy's meta-analysis concludes that women receive more support from their high school teachers than their university professors. Generous support from high school teachers allows women to develop high science and math self-efficacy, providing them with equal abilities to men. Yet the high performance reports are conditional upon teacher support. When entering college, the support is withdrawn and professors have higher performance expectations.[3] Living conditions are another form of support for students. Some universities have piloted "living and learning" communities, where women live together in a residence hall on campus. Kahveci et al. found that significantly more woman in living and learning communities remained in engineering majors than men or women who were not in the community.[4]

In 1988, the College initiated a program dedicated to supporting women studying at the university called the Women in Engineering Program (WIEP). In 2009, the WIEP and the Multicultural Engineering Program (MEP) merged to become a new organization known as the Broadening Opportunity through Leadership and Diversity (BOLD) Center. The BOLD Center continues to offer scholarship support, education and career advice, as well as social networking opportunities to students underrepresented in engineering. Female community building events such as department luncheons, Girl Scout technology badge volunteer days, and other K-12 outreach events are also offered through the BOLD Center. In the fall of 2009, the BOLD Center launched a new living-learning community in the university residence halls. This living and learning hall is a shared space with the Engineering Honors Program and offers them additional mentorship, community building, and academic support.

The initiatives driven by the BOLD Center at the university are meant to embrace the value of diversity in the College of Engineering and Applied Sciences. From the data analysis offered in this paper, past programs can be evaluated and modified to increase effectiveness and impact. Additionally, future programs can be generated to provide future benefit for women in the College.

Method

Participants

The participants in this study were all undergraduate, female engineering students during the 2008-2009 academic year. Two survey solicitations of 603 women in the College of engineering were sent out, providing a sample of 116 participants for a return rate of 19%. The sample includes women from all 12 engineering majors offered in the College of Engineering and Applied Science across all four undergraduate years.

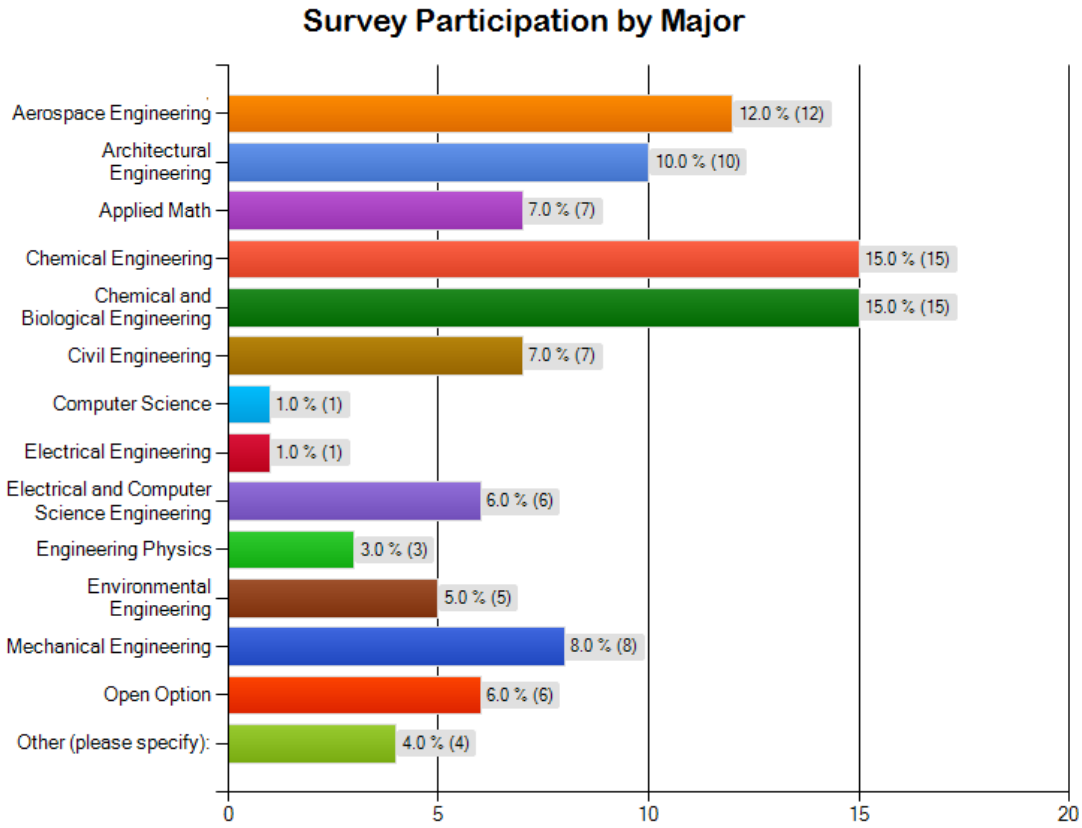

Figure 2: Survey Participation by Major

Reported GPA's for respondents were higher than the College average with 46% of participants reporting a 3.5 or above and 3% of participants reporting a GPA lower than 2.2.

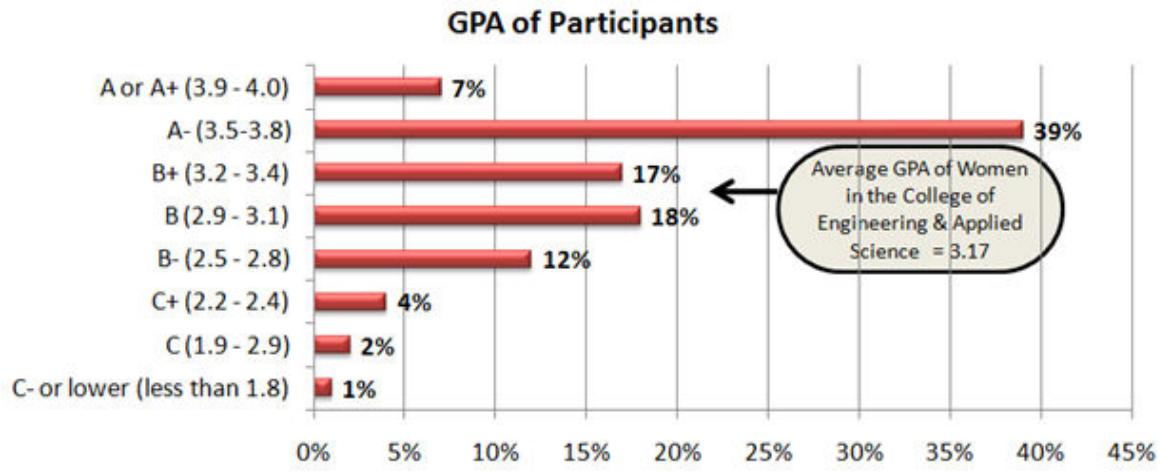

Figure 3: Grade Point Average of Participants

Procedures and Assessment

The survey questions were designed to address the five major research questions of the project. The survey incorporated questions and scales from two well-known assessment tools: the Assessing Women and Men in Engineering (AWE) [13] Longitudinal Assessment of Engineering Self-Efficacy (LAESE) survey and the Academic Pathways of People Learning Engineering Survey (APPLES)[16]. The other questions on the survey were created to specifically address areas of concern or specific groups related to the university. Most questions were constructed with either a Likert-type response format or an open-ended response format.

The table below depicts representative questions from the survey.

Scale Used	Purpose	Representative Question
AWE	Inclusiveness	To what extent do you agree? (e.g. I have a lot in common with other students in my classes.)
AWE	Self-Efficacy	To what extent do you agree? (e.g. I can succeed in an engineering curriculum.)
APPLES	Motivation	We are interested in knowing your main reasons for choosing engineering as your major. Please indicate below the extent to which each of the following reasons apply to you: (e.g. I think engineering is interesting.)
APPLES	Satisfaction	Please rate your satisfaction with this institution on each aspect of campus life listed below. (e.g. Academic Advising)

Table 1: Representative Survey Questions

Results and Discussion

Results will be discussed according to each research question. For the first research question, Do women express a loss of interest during their program; respondents were first asked a question from the APPLES survey to explore, "your main reasons for choosing engineering as

your major." The response most frequently selected as a "moderate" or "major" reason was "I think engineering is interesting," selected by 93% of participants. With this as the strongest reported reason for studying engineering, an investigation of loss of interest seems all the more compelling.

Women were asked to what extent their interest in getting a degree in engineering increased or decreased during their program. Figure 1 below depicts the results where 87% of women maintained or gained in interest in obtaining an engineering degree which is a more favorable result than previous research which found 31% of women who had lost interest in engineering after the first year. Four reasons cited for loss of interest include weed out classes, boring and difficult material and poor advising. However, it must be noted that the present study includes high GPA students, so a 13.2% loss of interest in such high performing women is a concern and a target for future research.

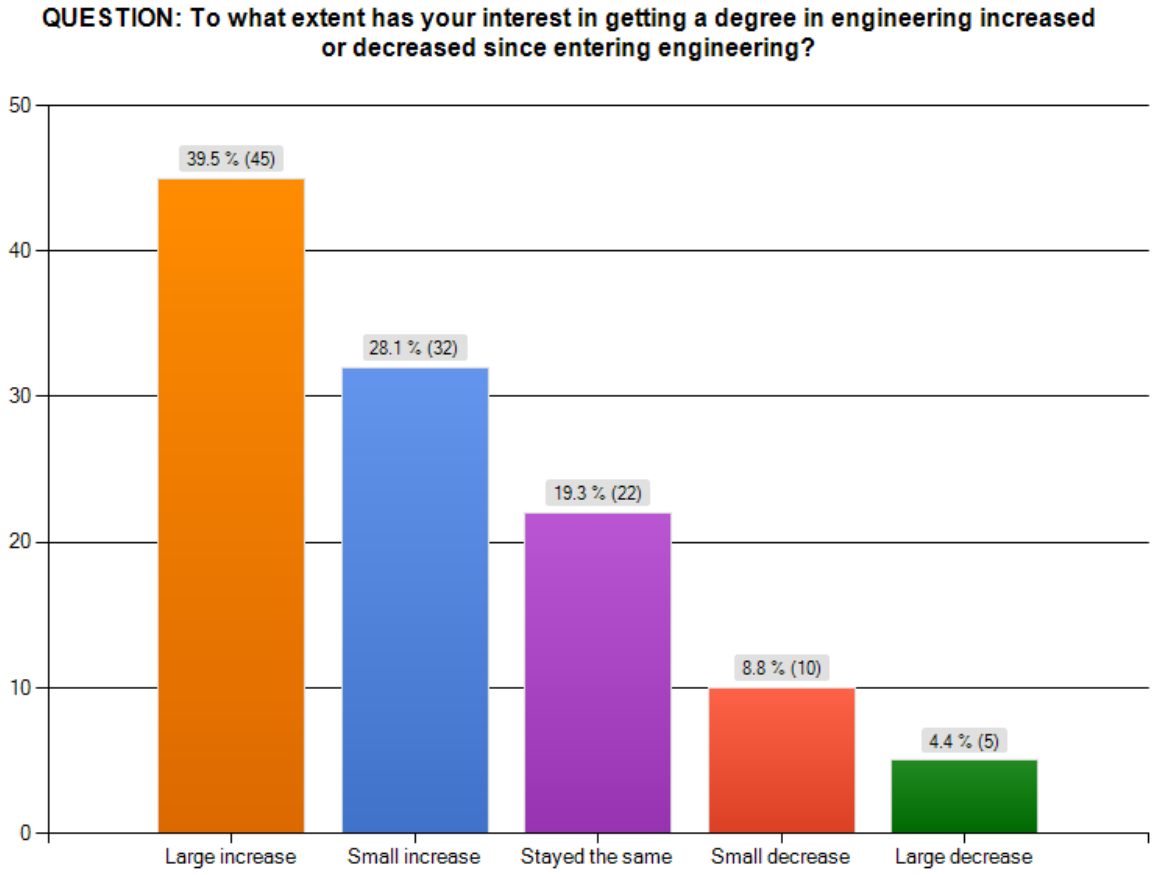

Figure 4: The development of interest in engineering during the curriculum

Research question number two considers, *"Is there a chilly climate for women in the college?"* The AWE Survey exclusion and isolation scale was used to assess for a chilly climate. Table 2 below depicts the results. Students were assessed on a 1-7 scale with a rating of 7 equal to Strongly Agree. Results indicate an overall mean across the scale of 5.25/7 indicating a climate that is, on average, warm and accepting. However, a high standard deviation of 1.41 averaged

across items suggests a wide variety of experiences with at least a portion of women experiencing some chill in the air. For example, one woman bemoaned, "the arrogant professors I run into, the lack of friends, the arrogant 'I-used-to-be-in-the-AP/IB-program-in-high-school' kids, and the ridiculous cost of coming here." Another was more mixed, "Overall, I really do feel like the male students encourage me to succeed as a woman engineer more than the female students do, at least the female students in my major and my classes, who seem to be catty and competitive more than the boys do. The boys help me out when I need it, and they often tell me that it's great that I'm a woman in engineering." In contrast, another reported in a more positive fashion, "The males were surprisingly helpful and very open to helping me out."

The third research question is, *"*D*o women's self*-efficacy levels change during the program? This question was assessed by AWE LAESE self-efficacy scales with women generally scoring quite high on self-efficacy. For example, 85% of respondents answered "agree" or "strongly agree," to the question, "I can succeed in an engineering curriculum." Average self-efficacy scores were hiring than those found in LAESE normative testing.[13] Furthermore, self-efficacy was high across all four years, a result that conflicts with some previous findings.[10] Perhaps this is due to the high performing character of the women in the sample.

Question	**Mean** Scale, 1-7 w/ 7 = Strongly Agree	**Std. Deviation**
I have a lot in common with other students in my classes.	5.24	1.47
I can relate to the people around me in my classes.	5.52	1.31
The other students in my classes share my same personal interests.	4.97	1.37
I can relate to the people around me in my extra-curricular activities.	5.31	1.48

Table 2: AWE Exclusion and Isolation Ratings for Women in Engineering

The only concern with respect to self-efficacy is for the item, "I can succeed in an engineering curriculum while not giving up participation in my outside interests (e.g. extracurricular activities, family, sports)," where women rated their self-efficacy markedly lower than other items with only 40% of respondents agreeing or strongly agreeing with the item. These findings point out the challenges faced, even by high performing women, of maintaining a life outside of the rigors of engineering study. One woman commented, "I find my extracurricular activities are a nice break from engineering. However, at times, they just get in the way and cause you to stay up even later to finish your homework." Another said, "It's really the only way to cope with all the stress. Hobbies are DEFINITELY needed outside."

Research question number four ponders, *"*Do academic performance levels play a role in *women's retention in engineering?"* To assess this question, women were asked for their GPA,

their satisfaction with their academic performance, and their expectations about academic performance when entering the college of engineering. Satisfaction results are depicted below in Figure 2. Results indicated that 27% of high GPA women were “dissatisfied” or “very dissatisfied” with their academic performance. The majority of women, 55%, also expected a different academic performance in their first year of college after coming from high school. The concern these high performing women have for their grades is palpable, “My GPA dropped from 3.95 to 3.82. Not a huge decrease, but some...” and “I didn't receive a C- my first time taking Thermodynamics and seriously considered changing my major.” This highlights the retention risk for women whose grades might not trouble other students.

The final research question asks, “Do women have an adequate support structure in the college? This inquiry was assessed by questions related to student advising, mentoring, and financial aid support. Student advising and mentoring were assessed by asking for the level of support received from engineering college staff and faculty as advisors and mentors. Results were generally unfavorable with only faculty advising meeting the expectations of the majority of women with 58% of women indicating that the faculty advisor “met” or “exceeded” expectations. All other items were below the 50% mark with only 48% of staff advising, 41% of faculty mentoring and 37% of staff advising meeting the expectations of the high performing women in our college. Numerous comments support these concerns, “My advisor has less knowledge about what I need to do to graduate than I do, and he can't answer any of my

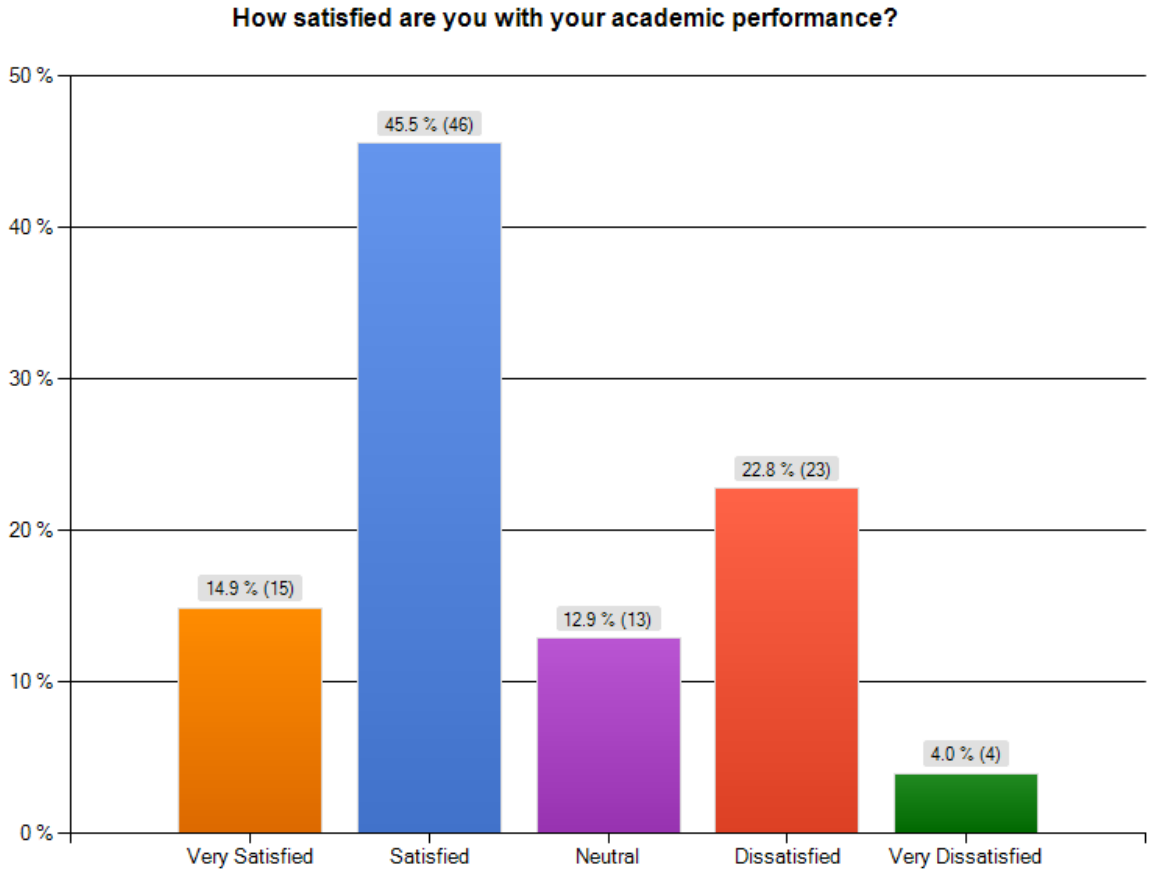

Figure 5: Women’s Satisfaction with Academic Performance

questions," and again, "I feel like a mentor is the one thing I lack. None of my advisors/mentor/peers really have time nor want to sit down and talk to me about whether or not I'm making the right choices."

The following table summarizes the financial costs for resident and non-resident engineering students.

Student Classification	**Estimated Cost of Attendance/Year for Engineering and Applied Science degree**
Resident	$25,000
Non-Resident	$47,700

Table 3: Financial Obligation for Students at a large Rocky Mountain Public University

Regarding financial aid, 88% of respondents rely on grants and scholarships to support their education while only 30% indicate that the amount of financial aid is "about right." This can be contrasted with the 60% who indicated that the financial aid was less than adequate. Women commented on the impact of financial stress on their education, "Because of my financial situation, I had to take fewer courses each semester," and "It's very hard to work and study engineering."

Implications

To recap, positive results from this survey indicate that most women in the College of Engineering and Applied Science maintained or gained in interest in obtaining an engineering degree and demonstrated high self-efficacy about graduating. On average, the climate in the college was not chilly towards the high-performing women. Survey results also yielded concerns, especially in the area of support for our women students. Women were largely dissatisfied with their mentoring and advising, and found it difficult to find time to pursue any activities outside of studying engineering. Financial stress was an additional burden, and high performing women were deeply concerned about their grades.

These results imply the need to improve the support structure for women in the college. Overall, women are excited and confident in their studies, but lacking in the additional support necessary for an underrepresented population in engineering. Suggestions for improvement include additional mentoring programs in the College staffed with female mentors and more training for advisors in working with high performing women. Advisors could be trained to modify the high GPA expectations of these students when they enter the college, and explain the likely differences in rigor between the high school and university engineering curriculum. In addition, more merit scholarship money should be found to support high performing women. The College's new BOLD Center, with an emphasis on meeting the needs of underrepresented students, seems well placed to address these concerns.

Suggestions for Future Research

This pilot study of the experiences of women in a college of engineering answered some questions and concerns regarding retention but raised many other questions. We wonder why 12% of women would have lost interest in engineering, but still maintained high GPA's. Also, we wonder why women have varied experiences on the issue of a chilly climate. High standard deviations indicate women were all over the place with respect to climate issues in the college. More research is needed to determine the discriminating factors with respect to climate and gender. One method for digging deeper into these issues would be the use of focus groups to more deeply explore women's interest and climate issues, and this is the next planned step in the research program.

Open-ended responses to some questions indicated the importance of certain courses and professors in women's retention decisions and this issue needs to be explored more directly in future research. Also, a larger sample size for our survey with a better GPA distribution would shed additional light on women's retention issues. Finally, this study focused on women enrolled in a college of engineering, while other demographics might be taken into consideration such as women who have already left a college of engineering or adding in responses from males to provide a comparison sample.

Summary

To better understand a declining retention rate for women in the College of Engineering and Applied Science at a public, Rocky Mountain region university, five research questions were proposed related to interest, climate, self-efficacy, academic performance and academic support structures. Responses from 116 women indicated a high performing group of women who were both interested and confident regarding their engineering studies, but under-supported socially and financially. Suggested efforts to improve these conditions include more mentoring programs, additional training for advisors, and additional merit scholarship aid.

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