# Women Engineering Students' Self-Efficacy Beliefs – The Longitudinal Picture

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## Introduction

Many sources and historical data have shown the consistently low representation of women in undergraduate engineering curricula and in the engineering workforce. Specifically, women comprise approximately only 20% of undergraduate engineering school enrollment nationwide and only about 8.5 % of the United State's engineers [1]. Establishing WIE programs at approximately 50 colleges and universities around the United States has been one response to this situation [2]. WIE programs serve many functions, but their primary responsibilities focus on recruitment of women into engineering undergraduate programs and then retention and development of those same women within their programs of study. Initially, this may sound well defined, but the ways in which WIE programs work to accomplish these outcomes vary tremendously. For WIE programs to be maximally effective, they must have access to validated assessment instruments for measuring the effectiveness of their recruitment and retention activities for WIE studies. Such assessment results can provide the basis for the development and revamping of effective activities designed to meet program objectives and missions.

This paper reports the first longitudinal results of a survey undertaken as part of the National Science Foundation-funded Assessing Women in Engineering (AWE) project. The instrument is designed to measure undergraduate women students' self-efficacy in studying engineering. Self-efficacy is "belief in one's capabilities to organize and execute the sources of action necessary to manage prospective situations" [3]. Prior work from Blaisdell[4] has shown that feelings of efficaciousness can be an important predictor in the success of women studying engineering. In our project, we developed a survey instrument designed to measure self-efficacy in engineering, feelings of inclusion and outcomes expectations, and have collected longitudinal responses from undergraduate women studying engineering at four institutions: Penn State University (PSU), Georgia Institute of Technology (GA Tech), University of Texas – Austin (UT Austin) and Rensselaer Polytechnic Institute (RPI).

The data were analyzed to examine the following questions.

1. Did students' responses change longitudinally from early spring 2003 to fall 2003?
2. Do students' responses vary longitudinally from one institution to another?

3. Do WIE program participating students have different longitudinal responses from non-participants?

Background and Related Literature

WIE programs serve to both widen the pipeline for K-12 women and girls and then become a reservoir and pumping station for many of the undergraduate, graduate and sometimes women faculty in the colleges or university. Anecdotal and research results on specific programs show that WIE programs do have an impact on the goal expressed by the National Science Foundation (NSF) and other engineering and science industrial and academic leaders to broaden participation of girls and young women in engineering and technology [5,6,7,8,9]. Nonetheless, the development of effective and consistent assessment and evaluation of WIE program's activities (e.g. the recruitment and retention activities) and the overall programs themselves is still in its infancy.

Self-efficacy and Engineering Self-Efficacy

Self-efficacy is an extensively researched psychological construct grounded in social cognitive theory. The construct has been applied to a range of human endeavors, including educational and career choices and achievement. The research literature, which originates from the fields of social and cognitive psychology and to a lesser extent specific application areas such as science and engineering education, makes a convincing case that a strong sense of self-efficacy is integral to students' entry and persistence in engineering.

The term "self-efficacy" is often used interchangeably with several others, notably "confidence". Understanding the differences in these words is important in accurately interpreting the research literature and in developing programs or activities to influence self-efficacy, as well as accompanying assessment instruments. There are also many kinds of self-efficacy. Consider the following.

Self-efficacy, as defined by Albert Bandura [10], "refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p.3). The term "perceived self-efficacy" is often used, because the individuals who hold them subjectively develop self-beliefs. Although the idea of "general," "global." or "omnibus" self-efficacy are sometimes considered (see [11]), self-efficacy is more often discussed in terms of specific or "domain-linked" activities, such as engineering self-efficacy. Bandura [10] explains that in a general measurement of self-efficacy, items are decontexutalized and cast in general terms. This is problematic because respondents are forced to guess what is being asked of them and each respondent will come to a different conclusion.

Confidence, while often used interchangeably with self-efficacy, refers only to the strength of certainty of one's beliefs, but does not require a positive outcome – for example, a person may be absolutely confident in failure[10]. Although the term "confidence" is not synonymous with self-efficacy, it can be understood as a component of self-efficacy when expressed positively.

Since self-efficacy is task-specific, there are many different kinds of self-efficacy. Some more commonly investigated types of self-efficacy relevant to women in engineering are mathematics self-efficacy [12], science self-efficacy [13], academic milestones self-efficacy [14], career decision-making self-efficacy [15], career self-efficacy [16] and agentic self-efficacy [17].

The influence of self-efficacy on human endeavors is far-reaching. Bandura [10]claims that self-efficacy determines "the courses of action people choose to pursue, how much effort they put forth in given endeavors, how long they will persevere in the face of obstacles and failures, their resilience to adversity, whether their thought patterns are self-hindering or self-aiding, how much stress and depression they experience in coping with taxing environmental demands, and the level of accomplishments they realize." (p. 3) In fact, a substantial amount of research is available to support these claims. Most relevant to women in engineering is the prolific research on self-efficacy beliefs in relation to academic achievement (e.g. [14]) and to career choice (e.g. [18]).

Literature about the experiences of women in engineering frequently addresses self-efficacy and its related constructs (e.g. confidence, self-esteem). In terms of self-appraisal, a general pattern of loss emerges throughout the engineering education. Women enter engineering reporting high levels of self-confidence and self-esteem [19]. Their self-confidence declines precipitously during the first year and, although it does begin to elevate, it will never again reach the same heights [20]. During this time, women compare themselves unfavorably to their male peers and judge themselves more harshly than the men judge themselves [21]. Women are aware of this and identify low self-confidence as a major barrier to completing their engineering degree [22]. Women who leave engineering consistently express less confidence in their abilities than the men and women who stay, regardless of the fact that their actual performance is the same or better than their peers who do not leave [20,23]. The discouraging nature of low-self confidence is reflected in the fact that women faced with actually failing a course are likely to leave the engineering program altogether, while their male peers are more likely to repeat the course and continue to pursue their engineering degree [24].

Note, however, that the above studies do not adhere to strict definitions of self-efficacy and are not part of the literature that specifically addresses self-efficacy in academic achievement and career/major choice. While gender differences in "confidence" are often reported [20], gender differences in *self-efficacy* are difficult to locate in the literature on women who are already enrolled in engineering programs. In contrast to several studies that did not find gender differences for engineering self efficacy (e.g. [25, 26]) two studies did find some statistically significant gender differences in self-efficacy of engineering students, both in relation to participants' perceived sources of self-efficacy. Bradburn [27] found differences in self-efficacy, partially due to differences in negative persuasion and anxiety signals. Differences in self-efficacy found in this study were strong enough that, when eliminated statistically, gender differences in attrition were also eliminated. Zeldin and Pajares [28] also found gender differences in self-efficacy sources through their qualitative study of men and women who had entered into and continued to succeed in SMET professional careers. Narrative analysis revealed that men perceived mastery experiences as critical to their self-efficacy beliefs, while women valued verbal persuasion and vicarious experiences.

In general, studies of self-efficacy of engineering students have shown a positive correlation between self-efficacy and academic achievement in this highly selective and academically homogenous group. Studies on gender differences have focused on students enrolled in engineering at the time of the study and have sometimes declined to include male students for a basis of comparison. In our literature review efforts, we have not found any studies that have compared self-efficacy scores of male and female engineering students with those who have left the major and those who never entered the major. This may account for the fact that gender differences in self-efficacy for science, math, and technology are sometimes found prior to entering the major, but not among already-enrolled students. Related research does suggest that factors such as self-concept, self-esteem, and confidence may influence women to leave the engineering major (or never choose it at all), but these studies cannot be used to draw conclusions on self-efficacy per say. Research including multiple comparison groups over time would have to be conducted to clearly reveal the nature of the nexus of gender, self-efficacy, sources of self-efficacy and engineering.

Although building of self-efficacy is likely an element of many WIE activities, there are only a few programs with this mission explicitly stated. It is notable, however, that confidence and self-efficacy are closely related and that there are many programs designed to address confidence. Additionally, many WIE programs seek to enhance the sources of self-efficacy without ever mentioning an end goal improving self-efficacy. Some examples may include hands-on experiences that offer a chance for mastery experiences, role modeling and mentoring programs that provide for vicarious learning, stress reducing programming designed to address physiological responses and verbal persuasion as a likely component of most or all WIE activities. Given the prevalence of activities oriented towards improving self-efficacy, the authors, as part of an NSF-sponsored grant designed to develop assessment tools for WIE programs focused our initial assessment efforts on designing, testing and analyzing the results of an engineering self-efficacy instrument.

## Methodology

### Subjects

Subjects were undergraduate women studying engineering at the following institutions: The Pennsylvania State University, Georgia Institute of Technology, Rensselaer Polytechnic Institute and the University of Texas – Austin. These four programs collectively represent a variety of private and public, years of experience for WIE directors and student body characteristics that provide a women engineering student sample that is largely representative of undergraduate women studying engineering in the US.

### Procedures

Longitudinal data self-efficacy data were collected from undergraduate women studying engineering Penn State University (PSU), Georgia Institute of Technology (GA Tech), University of Texas – Austin (UT Austin) and Rensselaer Polytechnic Institute (RPI).
Two hundred and two surveys were collected from women students at four WIE programs that participate in our NSF AWE grant: Penn State University (PSU), Georgia Tech (GT), University of Texas (UT) – Austin, and Rensselaer Polytechnic Institute (RPI). Subjects were recruited via email, phone and other types of written communications at each institution.

Instrument

The instrument used in the study is designed to measure the self-efficacy of women studying engineering. Prior instrument development research has shown that self-efficacy is most validly measured by querying respondents about their feelings of efficaciousness in a very specific context – thus this instrument strives to measure engineering self-efficacy. To construct a self-efficacy instrument, one identifies the typical barriers that stand between the individual and her or his success in the domain. Thus, this self self-efficacy instrument is designed to identify the sources of barriers or obstacles in the task of obtaining an engineering degree and ascertain how capable a person feels in those situations. The survey, which includes items adapted from Blaisdell[4] and Betz and Hackett[18], was developed and pilot tested to ensure reliability and validity.

The instrument is best used as a longitudinal tool for all women engineering undergraduate students (both WIE/WISE participants and non participants) annually at the beginning of the academic year. This longitudinal data collection combined with tracking of student participation in WIE / WISE activities and tracking for retention in the engineering curriculum will allow directors / researchers to ascertain the overall impact of different levels of participation or participation in specific activities on women's self efficacy in studying engineering. Further, if such tracking and data collection is done at a national level, the women in engineering community will have data for comparisons between and among different institutions and programs nationwide.

Our construction of different scales for this instrument was based on the need to measure different types of outcomes. For instance in one set of items, we chose to use a dual scale that measures the extent to which students agree with the statement as well as their rating of the importance of the item (e.g. I feel I have a lot in common with the other people in my classes). This will allow directors/ researchers to both ascertain the student's positions on the various factors measured by the items (e.g. feelings of inclusion – see below for full list of factors) and how important participants judge each of those factors to be – thus providing guidance towards program development. Although "importance" could conceivably be measured for every item on the instrument, we determined that the dual scale design would be too much of a burden for respondents on all items, so for other items we chose to use simpler Likert-type scales.

Results of our validity and reliability analyses show that the 80-item survey measures several factors that are related to the concepts of self-efficacy, inclusion and outcomes expectations. These factors are expressed in subscales, or groups of questions designed to measure student responses to the specific factor. The subscales of items that define each of these factors are shown in Figure 1. The items use the following Likert-type answer scales.

- Subscales 1, 2 and 3: Students were asked to indicate the extent to which they agreed with the items on a five-point scale from strongly disagree (= 0), to strongly agree (= 4).
- Subscales 4 and 5: Students were asked to indicate how confident they were on a nine-point scale from not at all confident (=0) to completely confident (=8).
- Subscales 6, 7, 8 and 9: Students were asked to indicate the extent to which they agreed with the items on a ten-point scale from strongly disagree (= 0) to strongly agree (= 9).

Our statistical analyses showed acceptable Cronbach's Alpha reliability coefficients for each module; they ranged from .72 to .87 (see Figure 1). We ensured validity of our subscales with several procedures, for example factor analyses to ensure construct validity and external expert reviews to ensure content validity.

Subscales

1. Confidence that women can succeed in an engineering career. (3 items, alpha = .81)
2. Confidence in personal success in engineering curriculum. (5 items, alpha = .74)
3. Feeling of inclusion and having engineering role models(7 items, alpha = .72)
4. Confidence in doing well in engineering major. (8 items, alpha = .87)
5. Confidence in being able to cope with difficulties. (6 items, alpha = .75)
6. Expectation that math is important for career and self worth. (3 items, alpha = .81)
7. Expectation that engineering degree will result in obtaining desired lifestyle and job. (4 items, alpha = .78)
8. Expectation to get fair chance in engineering job market. (3 items, alpha = .80)
9. Expectation to be treated fairly in an engineering job and to feel part of the group. (3 items, alpha = .81)

Figure 1. Survey instrument subscales.

Sample items from several subscales are shown in Figure 2.

| |
|---|
| Subscale 2: Confidence in personal success in engineering curriculum.<br>(strongly disagree (= 0), to strongly agree (= 4))<br>I am confident that I can succeed in an engineering curriculum |
| Subscale 4: Confidence in doing well in engineering major.<br>(confident (=0) to completely confident (=8))<br>Complete the math requirements for most engineering majors? |
| Subscale 6: Expectation that math is important for career and self worth.<br>(strongly disagree (= 0) to strongly agree (= 9))<br>Doing well at math will enhance my career/job opportunities. |
| Subscale 9: Expectation to be treated fairly in an engineering job and to feel part of the group.<br>(strongly disagree (= 0) to strongly agree (= 9))<br>I expect to be fairly rewarded for the contributions I make in engineering. |

Figure 2. Sample items for selected subscales.

## Analysis

To analyze the longitudinal data, for each student we calculated a score per subscale with the spring 2003 answers, and a score per subscale with the fall 2003 answers. Then we calculated a difference score by subtracting the spring 2003 subscale scores from the fall 2003 subscale scores. These difference scores were used in the analyses of variance reported in this paper. Because we are interested in the impact of participation in WIE activities on self-efficacy, we also used input from the WIE directors at the four institutions to create a variable that indicates whether a student was involved in WIE activities. This variable has a 'yes' or 'no' value.

The data were analyzed to examine the following questions.

1. Did students' responses change longitudinally from early spring 2003 to fall 2003?
2. Do students' responses vary longitudinally from one institution to another?
3. Do WIE program participating students have different longitudinal responses from non-participants?

Note that at this time, due to the relatively small longitudinal sample size we did not analyze data longitudinally by student semester standing (e.g. Did first-year students' responses change longitudinally?).

Results

The student distribution by year standing and per institution for both Spring 2003 and Fall 2003 are shown in Table 1. The first frequency is for data collected early in the Spring 2003 term and the second for data collected during the Fall 2003 term – and thus the second frequency represents the longitudinal frequencies for a total of 76 longitudinal data points.

*Table 1*: Spring 2003/ Fall 2003 participants by institution and year standing

| | | Year-standing | | | | |
|---|---|---|---|---|---|---|
| | | First year | Second year | Third year | Fourth / Fifth year [1)] | Total |
| Institution | GT | 14/5 | 3/2 | 3/2 | 11/1 | 31/10 |
| | PSU | 25/12 | 13/8 | 16/3 | 23/2 | 77/26 |
| | RPI | 8/4 | 8/5 | 13/4/ | 10/2 | 39/15 |
| | UTA | 16/8 | 10/7 | 13/6 | 11/3 | 50/25 |
| Total students (Spring / Fall 2003) | | 63/29 | 34/22 | 45/15 | 55/8 | 197/76[2)] |

[1)] Fourth and fifth year students are combined into one group.
[2)] In the spring, five students did not indicate their year, and two did not in the fall; they were excluded from further analyses

From the 76 longitudinal respondents, 17 (22%) were minorities.

As described above, we categorized each longitudinal respondent as either a WIE program participant or not based on information from each institution. Table 2 shows that 44 (58%) of the respondents had participated in WIE activities during the most recent academic year. These categorizations will be used for the third research question pertaining to self-efficacy differences between WIE participants and non-participants.

*Table 2:* Participants by institution and participation in WIE activities

| | | Participated in WIE activities? | | Total |
|---|---|---|---|---|
| | | No | Yes | |
| Institution | Georgia Tech | 0 | 10 | 10 |
| | Penn State | 8 | 18 | 26 |
| | Rensselaer Polytechnic Institute | 10 | 5 | 15 |
| | University of Texas – Austin | 14 | 11 | 25 |
| Total students | | 32 | 44 | 76 |

Question 1: Did student responses change longitudinally from early spring 2003 to fall 2003?

A multivariate analysis of variance (MANOVA) with the fall 2003 – spring 2003 subscale difference scores showed a statistically significant main effect for institutions ($p$ = .04). This means that we found differences between fall 2003 and spring 2003 subscale scores. The between-subjects effects revealed that this difference was caused by students scoring lower in fall 2003 than in spring 2003 on subscale 6 "Expectation that math is important for career and self worth", with a mean difference of -0.98 ($F$ (3, 63) = 3.70, $p$ = .02). Students also tended to score lower on subscale 9 "Expectation to be treated fairly in an engineering job and to feel part of the group", with a mean difference of -0.45 ($F$ (3, 63) = 2.62, $p$ = .06). Answer categories ranged from 0 = "strongly disagree" to 9 = "strongly agree" for both subscales. See tables 3 and 4 for means and standard deviations.

*Table 3*: Means and standard deviations across institutions for subscale 6, "Expectation that math is important for career and self worth"

| | **Mean*** | **SD** | **Total students** |
|---|---|---|---|
| Spring 2003 | 6.80 | 1.71 | 67 |
| Fall 2003 | 5.82 | 1.98 | 67 |

* Answer categories ranged from 0 = “strongly disagree” to 9 = “strongly agree”

*Table 4*: Means and standard deviations across institutions for subscale 9, “Expectation to be treated fairly in an engineering job and to feel part of the group”

| | **Mean*** | **SD** | **Total students** |
|---|---|---|---|
| Spring 2003 | 7.42 | 1.41 | 67 |
| Fall 2003 | 6.97 | 1.67 | 67 |

* Answer categories ranged from 0 = “strongly disagree” to 9 = “strongly agree”

Question 2: Do student responses vary longitudinally from one institution to another?

To test which institutions’ mean differences were statistically significant for subscales 6 and 9, we conducted a pair wise comparison analysis within MANOVA. The statistically significant difference for subscale 6 reported for research question one was due to the difference between students from Penn State and the University of Texas-Austin. Penn State students showed a larger decrease in their subscale 6 scores from spring 2003 to fall 2003 ($M = -1.80$) than students from the University of Texas-Austin ($M = 0.26$). This difference was significant at the .05 level. Differences between the other institutions were not statistically significant for this subscale. See Table 5 for means and standard deviations by institution.

*Table 5*: Means and standard deviations by institutions for subscale 6, "Expectation that math is important for career and self worth"

| **Institution** | **Semester** | **Mean*** | **SD** | **Total students** |
|---|---|---|---|---|
| Georgia Tech | Spring 2003 | 7.11 | 1.86 | 9 |
| | Fall 2003 | 6.26 | 2.11 | 9 |
| Penn State | Spring 2003 | 7.10 | 1.33 | 23 |
| | Fall 2003 | 5.31 | 2.04 | 23 |
| Rensselaer Polytechnic Institute | Spring 2003 | 6.08 | 1.80 | 13 |
| | Fall 2003 | 5.22 | 1.99 | 13 |
| University of Texas – Austin | Spring 2003 | 6.79 | 1.92 | 22 |
| | Fall 2003 | 6.53 | 1.69 | 22 |

*Answer categories ranged from 0 = "strongly disagree" to 9 = "strongly agree"

The non-significant trend for subscale 9 was caused by students from RPI ($M = -1.50$), who showed a larger decrease in their subscale scores than students from the University of Texas-Austin ($M = -0.39$) and from Penn State ($M = 0.03$). These differences were significant at the .05 level. Differences between the other institutions were not statistically significant. See Table 6 for means and standard deviations by institution.

*Table 6*: Means and standard deviations by institutions for subscale 9, "Expectation to be treated fairly in an engineering job and to feel part of the group"

| **Institution** | **Semester** | **Mean*** | **SD** | **Total students** |
|---|---|---|---|---|
| Georgia Tech | Spring 2003 | 7.81 | 1.07 | 9 |
| | Fall 2003 | 7.50 | 1.37 | 9 |
| Penn State | Spring 2003 | 7.71 | .99 | 23 |
| | Fall 2003 | 7.74 | 1.26 | 23 |
| Rensselaer Polytechnic Institute | Spring 2003 | 7.13 | 1.70 | 13 |
| | Fall 2003 | 5.63 | 1.77 | 13 |
| University of Texas – Austin | Spring 2003 | 7.14 | 1.69 | 22 |
| | Fall 2003 | 6.75 | 1.64 | 22 |

* Answer categories ranged from 0 = "strongly disagree" to 9 = "strongly agree"

Question 3: Did students who were involved in WIE activities change differently between fall 2003 and spring 2003 than students who did not participate?

Multivariate analysis of variance (MANOVA) with the difference scores showed a non-significant trend that the WIE participants differed from non-participants ($p$ = .06) in their responses. The between-subjects effects revealed that the non-significant trend was caused by non-WIE participant students scoring lower in fall 2003 than in spring 2003 on subscale 7 "Expectation that engineering degree will result in obtaining desired lifestyle and job" and subscale 9 "Expectation to be treated fairly in an engineering job and to feel part of the group".

On subscale 7, WIE participants showed only a slight decrease in their expectation that engineering will result in obtaining desired lifestyle and job compared to non-participants ($M$ = -0.31 and $M$ = -1.16 respectively, $F$ (1, 65) = 6.67, $p$ = .01). On subscale 9, WIE participants showed almost no decrease in their expectation to be treated fairly compared to non-participants ($M$ = -0.07 and $M$ = -1.06 respectively, $F$ (1, 65) = 6.13, $p$ = .02). For both subscales the answer categories ranged from 0 = "strongly disagree" to 9 = "strongly agree". See tables 7 and 8 for the means and standard deviations.

All differences for the remaining subscales were not significant.

*Table 7*: Means and standard deviations by institutions for subscale 7, "Expectation that engineering degree will result in obtaining desired lifestyle and job"

| Participation in WIE activities | Semester | Mean* | SD | Total students |
|---|---|---|---|---|
| No | Spring 2003 | 7.21 | 1.36 | 26 |
| | Fall 2003 | 6.05 | 1.78 | 26 |
| Yes | Spring 2003 | 7.29 | 1.00 | 41 |
| | Fall 2003 | 6.98 | 1.36 | 41 |

* Answer categories ranged from 0 = "strongly disagree" to 9 = "strongly agree"

*Table 8*: Means and standard deviations by participation in WIE activities for subscale 9, "Expectation to be treated fairly in an engineering job and to feel part of the group"

| Participation in WIE activities | Semester | Mean* | SD | Total students |
|---|---|---|---|---|
| No | Spring 2003 | 7.31 | 1.62 | 26 |
| | Fall 2003 | 6.25 | 1.70 | 26 |
| Yes | Spring 2003 | 7.50 | 1.28 | 41 |
| | Fall 2003 | 7.43 | 1.50 | 41 |

* Answer categories ranged from 0 = "strongly disagree" to 9 = "strongly agree"

Discussion

The first research question examined whether there had been statistically significant longitudinal changes in the subscale scores. We found significant changes for subscales 6 and 7, which address mathematics and engineering relative to a desirable lifestyle. Both showed statistically significant decreases from the first to second instrument administration (see Table 9 for means).

One possible explanation is that there was not a full calendar year between the first and second administration of the instrument. Ideally the instrument should be completed at one-year intervals (e.g. the beginning of every academic year) however this was not possible for the 2002 – 2003 academic year as the instrument was under development resulting in approximately 7 months time between the first and second data collections.

Thus the relatively flat means we see for subscales 1 – 5 may simply be explained by this data collection schedule. Data collection for this project continues and now occurs at one-year intervals during the fall academic term. These future data should allow us to ascertain whether the current results are anomalous or reflect a trend.

However, even with the reduced data collection time period our results are worth discussing in light of prior research. Our results that show a negative trend for the self-efficacy and outcomes expectations scales are consistent with results from both Brainard and Carlin[20] and Felder[29]. In a longitudinal study of Chemical Engineering students, Felder and his colleagues found several differences between male and female students including, that female students' (who began their studies exhibiting equal levels of academic ability as their male counterparts) expectations about their performance in engineering courses dropped as they proceeded through the curriculum and they also reported lower levels of basic problem solving ability than men.

Although both studies show that women students' self reported levels of confidence, ability or expectations dropped as they proceeded through the curriculum Brainard and Carlin[20]specifically show that levels of confidence in their academic abilities in math and science drop from the beginning of the first year through junior years and then begin to rise again at the end of the senior year but *never regain their initial levels*. Thus our initial results that showed a significant drop in subscale 6 that addresses mathematics, although preliminary, is still consistent with this prior research. Given these prior results, it is also possible that subscales 8 and 9 – which also saw a larger downward difference, and address expectations about working in engineering– may also be indicators of a trend similar to the one found by Brainard and Carlin[20].

*Table 9:* Means for Spring 2003 to Fall 2003 All Subscales

| | Spring 2003 | Fall 2003 | Difference Score |
|---|---|---|---|
| Subscale 1 * | 3.74 | 3.63 | -.11 |
| Subscale 2 * | 3.11 | 3.12 | -.01 |
| Subscale 3 * | 2.70 | 2.75 | .05 |
| Subscale 4 ** | 6.85 | 6.82 | -.03 |
| Subscale 5 ** | 6.52 | 6.56 | .04 |
| Subscale 6 & | 6.80 | 5.82 | -.98 |
| Subscale 7 & | 7.26 | 6.62 | -.64 |
| Subscale 8 & | 4.14 | 3.62 | -.52 |
| Subscale 9 & | 7.42 | 6.97 | -.56 |

* Responses 0 –4
** Responses 0 – 8
& Responses 0 - 9

The between institution longitudinal results are, at this time, more difficult to interpret. Our analysis found significant differences between institutions for subscale 6 between PSU and UT-Austin, and for subscale 9 for RPI, PSU and UT-Austin. The longitudinal results seen for subscale 6 – which addresses expectations regarding math – are consistent with cross sectional results we reported last year where we found, again, statistically significant differences for this subscale between the same two institutions – PSU and UT-Austin[30]. At this time we do not have a coherent explanation for this phenomenon nor for the differences seen in subscale 9. However these results do illustrate what we have previously observed about results from this quantitative instrument and many others – namely that we must interpret these results in conjunction with other data regarding institutional curricula and other per institution data that may help us understand these reported differences.

Lastly, we examined how participation in WIE activities impacted longitudinal results. We found that WIE participants experienced a non-statistically significant smaller score decrease for subscales 7 and 9 both of which address engineering career expectations (see Tables 7 and 8). The fact that both of these subscales evidenced decreases for both groups is consistent with the overall longitudinal results (see Table 9). It is somewhat encouraging that WIE participants experienced smaller decreases than non-participants however we need to see more consistent trends in these data to support any conclusions regarding the effectiveness of WIE programs on the factors measured by these subscales. Further the differences and directions of differences for the means for the other subscales when analyzed by WIE activity participation were mixed.

Considering these results in terms of prior work from the WECE study[1] and Brainard and Carlin[20]– both of which showed that WIE programs can have an impact on students' attitudes and behaviors, we plan to collect further data to investigate whether the non consistent patterns we have initially found continue.

Conclusions

This paper has reported the results of the first two years of a longitudinal study of engineering self-efficacy of women engineering students – some who have participated in WIE programs and others who have not. Initial results show that a sub set of outcomes expectations subscales showed a statistically significant decrease while self-efficacy subscales shows non-statically significant increases.

Although preliminary due to the relatively small sample size, these results show indications that some of the curricular and academic climate conditions that existed when prior longitudinal studies[20,29] were conducted may still exist at a variety of different institution types (e.g. public / private, large / small, rural / urban) that were included in our data collection. Our project will continue to collect longitudinal data at these institutions and others. As these results become available we will be able to report with more certainty if the initial findings reported here continue to validate the trends reported by Brainard and Carlin [20] and Felder[29] and his colleagues – namely that that women's reported expectations and confidence drops as they study engineering. Although our instrument measures efficacy, the constructs are related closely enough to argue for the possibility of seeing similar results.

The longitudinal data collection using this instrument will continue both with the institutions in this study and others that have already begun to use the instrument. Analysis of these future data and other activities that will inform the engineering education community include the following.

- Collect a larger longitudinal set from all institutions. During the Fall 2004 term, all institutions administered the instrument to new entering women engineering student cohorts. Having established data collection systems – including the ability for the students to complete the instrument online – we hope to have larger initial cohorts that should lead to a larger longitudinal set from each institution.
- When this larger data set is available, conduct longitudinal analysis by year standing and ethnicity status.
- Examine the institutional differences we found in this analysis and the prior cross sectional analysis in light of institutional and per institution student characteristics. With these contextual data, then try to explain the statistical differences we are seeing via the characteristics of the institutions (e.g. entering student characteristics, curricular differences).
- Collect qualitative data to investigate patterns that are not easily explainable – such as the inconsistent evidence of impact of WIE activity participation on responses.

In conclusion, the longitudinal data reported provide preliminary evidence that women may experience a loss of efficacy as they proceed through engineering curricula. As we continue the study we will be able to more confidently ascertain whether the results reported in prior longitudinal studies on women engineering students regarding a loss of self-perceived expectations and confidence are repeated in the related domain of efficacy. These findings will be significant to not only the WIE community but also the overall engineering education community as we strive to recruit and retain women in engineering in order to fill the current and projected need for their talents and skills.

References

1. Goodman, I.F.; Cunningham, C.M.; Lachapelle, C.; Thompson, M.; Bittinger, K.; Brennan, R.T.; Delci,. M. (2002). “Final report of Women’s Experiences in College Engineering (WECE) project”, Goodman Research Group Inc., Cambridge, MA. Available online at www.grginc.com.
2. Marra, R.M. and Bogue, B. (2001). “Developing Exportable Assessment Instruments and Models for Women In Engineering Programs”, NSF Award # HRD-0120642. National Science Foundation Program for Gender Equity in Science, Mathematics, Engineering and Technology (Program Announcement NSF 01-6).
3. Bandura, A. (1986). Social foundations of thought and action: a social cognitive theory. Englewood Cliffs, N.J.: Prentice-Hall.
4. Blaisdell, Stephanie (2000). Social cognitive theory predictors of entry into engineering majors for high school students. Arizona State University. Unpublished dissertation.
5. Mannix, M. (2001). Getting it right. Prism, 10(7), 14 - 21.
6. Cunningham, C. M., Thompson, M., Lachapelle, C. P., Goodman, I. F., & Bittinger, K. C. (2000). Women's experiences in college engineering and support programs: Findings from the WECE project. Paper presented at the WEPAN 2000.
7. Heller, R. S., & Martin, C. D. (1994). Attracting young minority women to engineering and science: Necessary characteristics for exemplary programs. IEEE Transactions on Education, 37(1), 8-12.
8. National Science Foundation (2001). Program for Gender Equity in Science, Mathematics, Engineering and Technology (Program Announcement NSF 01-6): National Science Foundation.
9. Thompson, M., Cunningham, C., Lachapelle, C., Bittinger, K., & Goodman, I. (2001). The Women's Experiences in College Engineering Project: WIE Directors.: Goodman Research Group, Inc.
10. Bandura, A. (1997). Self-Efficacy: The Exercise of Control. New York: W.H. Freeman and Company.

11. Chen, G., Gully, S., & Eden, D. (2001). Validation of a new general self-efficacy scale. Organizational Research Methods, 4(1), 62-83.
12. Pajares, F. (in press). Gender differences in mathematics self-efficacy beliefs. In A. M. Gallagher & J. Kaufman (Eds.), Mind the gap: Gender differences in mathematics. Boston, MA: Cambridge University Press.
13. Luzzo, D. A., Hasper, P., Albert, K. A., Bibby, M. A., & Martinellin, E. A. (1999). Effects of self-efficacy-enhancing interventions on the math/science self-efficacy and career interests, goals, and actions of career undecided college students. Journal of Counseling Psychology, 46(2), 233-243.
14. Lent, R., Brown, S. D., & Larkin, K. (1986). Self-efficacy in the prediction of academic performance and perceived career options. Journal of Counseling Psychology, 33(3), 265-269.
15. Taylor, K., & Betz, N. (1983). Applications of self-efficacy theory to the understanding and treatment of career indecision. Journal of Vocational Behavior, 22, 63-81.
16. Turner, S., & Lapan, R. (2002). Career self-efficacy and perceptions of parent support in adolescent career development. The Career Development Quarterly, 51, 44-55.
17. Ancis, J. R., & Phillips, S. D. (1996). Academic gender bias and women's behavioral agency self-efficacy. Journal of Counseling & Development, 75(2), 131-137.
18. Betz, N.E., & Hackett, G. (1981). The relationship of career-related self-efficacy expectations to perceived career options in college women and men. Journal of Counseling Psychology, 28(5), 399-410.
19. O'Hare, S. (1995). Freshmen women in engineering: Comparison of their backgrounds, abilities, values, and goals with science and humanities majors. Journal of Women and Minorities in Science and Engineering, 2, 33-47.
20. Brainard, S., & Carlin, L. (1998). A six-year longitudinal study of undergraduate women in engineering and science. Journal of Engineering Education, 87(4), 369-375.
21. Hawks, B. K., & Spade, J. Z. (1998). Women and men engineering students: Anticipation of family and work roles. Journal of Engineering Education, 249-256.
22. Brainard, S.G. (1993). Student Ownership: The Key to Successful Intervention Programs. Initiatives, 55(3), 23-30.
23. Jackson, L. A., Gardner, P. D., & Sullivan, L. A. (1993). Engineering persistence: Past, present, and future factors and gender differences. Higher Education, 26, 227-246.
24. Adelman (1998). Women and men of the engineering path: A model for analysis of undergraduate careers. Washington, D.C.: U.S. Department of Education and The National Institute for Science Education.
25. Shaefers, K. G. (1993). Women in engineering: factors affecting persistence and attrition in college majors. Unpublished Ph.D., Iowa State University, Iowa.
26. Schaefers, K., Epperson, D. L., & Nauta, M. M. (1997). Women's career development: Can theoretically derived variables predict persistence in engineering majors? Journal of Counseling Psychology, 44(2), 173-183.
27. Bradburn, E. M. (1995). Engineering gender roles: A self-efficacy model of occupational choice and persistence. Cornell U, US, 1.
28. Zeldin, A., & Pajares, F. (2000). Against the odds: Self-efficacy beliefs of women in mathematical, scientific, and technical careers. American Educational Research Journal, 37(1), 215-246.
29. Felder, R., Felder, G., Mauney, M., Hamrin, C., & Dietz, J. (1995). A longitudinal study of engineering student performance and retention. III. Gender differences in student performance and attitudes. Journal of Engineering Education, 84(2), 151-163.
30. Marra, R.M., Moore, C., Schuurman, M., & Bogue, B. (2004). "Assessing Women in Engineering (AWE): Assessment Results on Women Engineering Students Beliefs". Proceedings of the Annual Conference of American Society for Engineering Education, (June 20 – 23, 2004); Salt Lake City, UT. Available at http://www.asee.org/acPapers/2004-58_Final.pdf.

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