Women Engineering Students' Self Efficacy – A Longitudinal Multi-Institution Study

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Abstract This paper describes the results of a longitudinal study of women engineering self-efficacy at five institutions across the U.S. Results are mixed indicating that while students show positive progress on some self–efficacy and related subscales, the isolation subscale shows a decrease from the first to second measure. Further, individual students do not show growth in these subscales as they move from one year to the next in their degree programs.

Background

Self-efficacy has been found to be an important factor in the success of women studying engineering (Blaisdell, 2000; Marra, Schuurman, Moore & Bogue, 2005). Self-efficacy is "belief in one's capabilities to organize and execute the sources of action necessary to manage prospective situations" (Bandura, 1986). Although efficaciousness applies to any situation, it is particularly important in choosing and executing constructive actions in situations that are perceived as negative or a barrier to success (e.g. lack of a meaningful role in a team project). Given that women are generally under-represented in engineering classrooms, a strong sense of efficacy can help them to persist in such situations.

This paper will report on a longitudinal study of women engineering student self-efficacy with data collected from five institutions across the United States. We measured self-efficacy via the LAESE survey instrument (longitudinal assessment of engineering self-efficacy) (see aweonline.org). LAESE is a validated instrument developed via the NSF-funded Assessing Women in Engineering (AWE) project. LAESE provides results in six sub-scales. Our analysis examined the data for longitudinal differences in the subscales and includes disaggregated analysis by institution, year-standing and ethnicity.

Self-efficacy and Engineering Self-Efficacy

Self-efficacy is an extensively researched psychological construct grounded in social cognitive theory. Self-efficacy, as defined by Albert Bandura (1997), "refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p.3). Bandura (1997) 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. Lent, Brown, & Larkin, 1986) and to career choice (e.g. Betz & Hackett, 1981). The self-efficacy research literature 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. 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 (Bandura, 1997). Although the term "confidence" is not synonymous with self-efficacy, it can be understood as a component of self-efficacy when expressed positively.

Literature about the experiences of women in engineering frequently addresses self-efficacy and its related constructs (e.g. confidence, self-esteem) showing a general pattern of loss emerges throughout the engineering education. Women enter engineering reporting high levels of self-confidence and self-esteem (O'Hare, 1995). Their self-confidence declines precipitously during the first year and, although it does begin to elevate, it will never again reach the same heights (Brainard & Carlin, 1998). During this time, women compare themselves unfavorably to their male peers and judge themselves more harshly than the men judge themselves (Hawks & Spade, 1998). Women are aware of this and identify low self-confidence as a major barrier to completing their engineering degree (Brainard, 1993). 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 (Brainard & Carlin, 1998; Jackson, Gardner, & Sullivan, 1993). 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.

While gender differences in "confidence" are often reported (Brainard & Carlin, 1998), gender differences in *self-efficacy* are difficult to locate in the literature on women who are already enrolled in engineering programs. In contrast to studies that did not find gender differences for engineering self efficacy or sources of efficacy (e.g. Shaefers, 1993) three studies did find gender differences in self-efficacy of engineering students in relation to participants' perceived sources of self-efficacy. Bradburn (1995) found differences in self-efficacy, partially due to differences in negative persuasion (e.g. statements indicating that women can't do certain things) and anxiety signals. These differences were strong enough that, when the self-efficacy differences were eliminated statistically, gender differences in attrition were also eliminated. Zeldin and Pajares (2000) 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 (e.g. experiencing a task or activity "second hand" through someone else's accomplishment of it). A recent mixed methods study from Hutchison et al. (2006) also found gender differences in sources of self-efficacy with substantial differences in how many men and women attributed computing abilities as either a positive or negative contributor to self-efficacy.

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. The current study applies this instrument to women engineering students at five institutions and further analyzes the results based on pertinent sample characteristics: ethnicity, school and year in school. Further examination of self-efficacy differences by year standing are warranted given the prior pattern of "loss" in similar concepts such as confidence. Examining potential differences between schools is of interest in order to determine if certain schools demonstrate different patterns of self-efficacy trends – which may in turn be an indicator of differing climates that may either contribute or detract from self-efficacy. Lastly, prior research has shown that self-efficacy beliefs can vary by race and ethnicity (Graham, 1994); thus additional exploration of this potential difference is warranted.

Methods

Subjects

Subjects were 164 undergraduate women studying engineering at Penn State University, Georgia Institute of Technology, University of Texas – Austin, University of Arizona and the University of Louisville *who responded to the LAESE – our self-efficacy survey instrument-- both in 2003 and then again in 2004*. The five institutions for the subjects are all partner institutions in the NSF AWE grant and collectively represent a variety of private and public, years of experience for Women in Engineering (WIE) directors and student body characteristics that provide a women engineering student sample that is largely representative of undergraduate women studying engineering in the U.S. The distribution of our sample is shown in Table 1 by institution and year standing. The year standing data represent are for 2004 when respondents completed the self-efficacy instrument for the second time. There were 51 ethnic minorities in the sample.

			Academic year standing at 2nd data collection: 2004					
			First Year	Second Year	Third Year	Fourth Year	Fifth +	Unknown
Institution	Georgia Tech	28	0	4	9	5	10	0
	Penn State	29	0	4	7	14	4	0
	Arizona	12	0	2	5	2	3	0
	Louisville	12	1	3	2	0	6	0
	UT – Austin	83	0	30	22	22	9	0
Total		164	1	43	45	43	32	0

Table 1. Distribution of participants by institution and year at second data collection point.

Instrument

The LAESE (longitudinal assessment of engineering self-efficacy) instrument used in the study is a tested and validated survey designed to measure the self-efficacy of women studying engineering, feelings of inclusion and outcomes expectations (Marra et al., 2005; Marra, Moore, Schuurman, Bogue, 2004; aweonline.org). 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 (2000) and Betz and Hackett (1981), was developed and pilot tested to ensure reliability and validity.

Results of our validity and reliability analyses showed that the survey measured several factors that are related to the concepts of self-efficacy, inclusion and outcomes expectations. 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 including factor analyses to ensure construct validity and external expert reviews to ensure content validity. These analyses resulted in six subscales that are listed in Figure 1.

Subscales
1. Engineering self-efficacy I (5 items, alpha = .82)
2. Engineering career expectations (7 items, alpha = .84)
3. Engineering self-efficacy II (6 items, alpha = .82)
4. Feeling of inclusion (4 items, alpha = .73)
5. Efficacy in coping with difficulties (6 items, alpha = .78)
6. Math outcomes efficacy (3 items, alpha = .84)

Figure 1. LAESE subscales.

Sample items from several subscales are shown in Figure 2.

Subscale: Engineering career expectations (strongly disagree (= 0), to strongly agree (= 4)) A woman can succeed in an engineering career (19) A degree in engineering will allow me to obtain a well paying job
Subscale: Engineering Self Efficacy I (strongly disagree (= 0), to strongly agree (= 4)) I can succeed in an engineering curriculum (17) I can succeed in an engineering curriculum while not having to give up participation in my outside interests (e.g. extra curricular activities, family, sports)
Subscale: Feelings of Inclusion. (strongly disagree (= 0) to strongly agree (= 4)) I can relate to the people around me in my class (16) I have a lot in common with the other students in my classes
Subscale: Coping efficacy (strongly disagree (= 0) to strongly agree (= 9)) I can cope with not doing well on a test (32) I can make friends with people from different backgrounds and/or values

Figure 2. Sample items for selected subscales.

The instrument is best used as a longitudinal tool for all women engineering undergraduate students (both WIE participants and non participants) *annually* at the beginning of the academic year. This longitudinal data collection combined with tracking of student participation in WIE 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.

Desirable outcomes from longitudinal data collection with LAESE would be an overall trend for an increase in subscale averages as students progress through the curriculum. This would indicate that their feelings of efficacy, ability to cope, etc. are increasing as they progress in their degrees.

Procedures

Early in the fall 2003 and 2004 terms at each of the participating institutions, subjects were recruited via email, phone and other types of written communications. In all cases, subjects were women engineering students who had some affiliation with the WIE program at that institution[1]. Respondents were directed to a URL where they completed an online version of the instrument. In fall 2004, special efforts were made to gather longitudinal responses from those who had completed the instrument in 2003. Of the initial 369 respondents who we expected to still be actively pursuing their degrees in fall 2004, we garnered the 164 subjects (44% of the original figure) reported analyzed for this paper. This response rate is in alignment with expectations for collecting longitudinal data (Miller, 2002).

Results

We examined the data to answer the following research questions that are pertinent to engineering education and underrepresented groups in particular:

1. Are there longitudinal differences for the defined subscales for the overall data set? Are there longitudinal differences between institutions for the defined subscales?
2. Are there longitudinal differences between students in different years for the defined subscales?
3. Are there longitudinal differences between students of different ethnicities for the defined subscales?
4. Are there longitudinal differences between students of different institutions for the defined subscales?

To analyze the data, we computed scores for each of the six subscales for the first and second data collection instances (e.g. fall 2003 and fall 2004) and applied the appropriate statistical analysis methods.

Question 1

Are there longitudinal differences for the defined subscales for the overall data set?

In essence, we ask are there differences in the way students responded on each subscale between the first data collection and the second. For the overall data set, using paired t tests we found the

[1] Because this first data collection was designed to conduct reliability and validity testing on the self-efficacy survey, and because we designed the survey to focus on barriers for women engineering students, we limited data collection to women. Subsequent iterations will be used with men and women and we will re-analyze our items for reliability at that time.

significant differences in four of the six subscales. In one case the subscale score decreased longitudinally and in the other two the scores increased.

- Longitudinal significant decreases from 2003 to 2004 in feelings of inclusion ($t = 2.37$, $p < .05$).
- Longitudinal significant increases from 2003 to 2004 on second engineer efficacy ($t = -5.124$, $p < .01$, coping self efficacy ($t = -3.874$, $p < .01$), and math outcomes efficacy ($t = 2.864$, $p < .01$).

Questions 2, 3 and 4
Are there longitudinal differences between students in different years for the defined subscales? (e.g. Do first-year students differ from third-year students in their subscale responses?)
Are there longitudinal differences between students of different ethnicities for the defined subscales? Are there longitudinal differences between students of different institutions for the defined subscales?

We want to determine whether, say first-year students differ from third-year students in their subscale responses? In a supportive, effective curriculum we would hope to see that students that are further along in their degrees have higher feelings of efficacy than those who are just beginning. Question 3 addresses whether self-efficacy results vary longitudinally by ethnicity group and question 4 looks for differences in scores between students from the different institutions in our sample.

When we analyzed the data by ethnicity, school and year standing we found the following using a repeated measures ANOVA.

- A significant main effect for ethnicity on the inclusion subscale ($F = 2.667$, $p = .036$).

  We noticed that the inclusion subscale means for African Americans were lower than other ethnicity groups (see Table 3). To further explore we constructed a new binary ethnicity variable that indicated whether the respondent is African American or not. When one performs a multivariate analysis (repeated measures) with this new variable we find that African Americans do have significantly different inclusion means from all other ethnicity groups ($F = 4.284$, $p = .04$. In a further analysis we checked to see if this true for all non white groups and it was not – so we can isolate this result to African Americans.
- No significant differences for the respondents by school (institution), or year standing.

Discussion

Our discussion reviews the noteworthy results of our analysis and discusses each in terms of implications for engineering support programs and curricula, as well as future data collection and analysis needed to further explore each result. We begin with the subscale main effects. For the overall data set, we saw significant gains for coping self efficacy the second engineering efficacy scale and math outcomes expectations, and a negative change in scores for feelings of inclusion.

The results for both coping and the second engineering self-efficacy scales can be considered positive. The items in the coping subscale indicate that students feel more competent in being able to take positive actions to cope with potentially difficult or barrier situations such as doing poorly on an exam or adjusting to a new campus environment. Further, the second engineering subscale asks students about their confidence in completing required portions of an engineering degree (e.g. “I am confident I can complete the physics requirements for an engineering major”) and once again, student cohort indicated an increased confidence level in the 2004 results over the 2003. In contrast, the first self-efficacy subscale showed a slight decrease from time 1 to time 2 (see means in Table 2), although the decrease was not statistically significant. These subscale items are phrased differently than the 2nd self efficacy scale – rather than saying “I am confident I can do ______”, the subscale 1 items are phrased as “I can succeed (earn an A or B) in my engineering courses” (or math courses, or engineering curriculum). This can be interpreted as a stronger statement than the items in self-efficacy subscale 2, thus our results indicate a certain positive trend from subscale 2 but not so strong that the trend extends to the “succeed” statements in self-efficacy subscale 1. The math outcomes scale also showed significant gains; this subscale only contains 3 items however the significant results indicated respondents show an increase in their perceptions of the potential benefit of learning and using mathematics in their careers.

		Mean	N	Std. Deviation
Pair 1	First Engineer Efficacy	2.9074	162	.82932
	First Engineer Efficacy2	2.8679	162	1.03292
Pair 2	Career Expectations	6.3122	163	1.44530
	Career Expectations2	6.3406	163	2.00582
Pair 3	Second Engineer Efficacy	6.3940	149	1.33805
	Second Engineer Efficacy2	6.9183	149	1.03298
Pair 4	Feelings of inclusion	2.6513	163	.60775
	Feelings of Inclusion2	2.4908	163	.95563
Pair 5	Coping Self efficacy	6.2796	149	1.33703
	Coping Self Efficacy2	6.6667	149	.93982
Pair 6	math expectations	6.2345	148	1.95
	Math Expectations2	6.6554	148	1.71

Table 2. Subscale Means at time 1 and time 2 (second in each pair)

These increases in means are actually in contrast to prior self-efficacy research on women engineering students (Brainard and Carlin, 1998; Felder, et al., 1995). The differences in our results may be attributable to the fact that most of these respondents were active participants in women in engineering programs. Further, we would need to track these students to graduation to look for both further evidence of the correlation between these responses and important outcomes such as graduation, as well as the potential relationship with participating in women in engineering activities.

Recall we also found a negative change in respondents’ sense of inclusion. From our subsequent analysis that showed both a main effect of ethnicity on inclusion, as well as the analysis that showed that African American respondents (n = 10) responded significantly lower than other ethnicity groups (see Table 3), we can conclude that the significant negative longitudinal effect on ethnicity can be attributed to the large drop in means for African Americans. These results are of importance given the relatively small amount of research concerning self-efficacy and related beliefs of African Americans in an engineering context (Britner & Pajeres, 2001). Other documentation of programmatic initiatives (e.g. Reyes, Anderson-Rowland, & McCartney, 1999) have indicated the need to address the relative isolation of African American students in engineering education, but formal research on this issue is needed to make a stronger case for programmatic and curricular changes.

Before we leave the inclusion results, it is important to note that the inclusion subscale means also decreased for other ethnicity groups including Native American, Latino and Caucasian. This is not to argue that all of these groups experience engineering in the same way but rather to point out that inclusion may be an issue to a lesser extent for other respondents.

Finally, the lack of significant differences by school and school year is also worth noting. The lack of significant differences by year in school is an initial indication that overall students are not reporting a pattern of increasing feelings of efficacy (for example) as they progress through the curriculum. If we had seen such a trend, we may have been able to conclude that students are feeling "better" about the factors measured by the subscales – but this was not the case. This lack of self-efficacy growth is in alignment with prior results from both Brainard and Carlin (1998) and Felder et al. (1995). 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 (1998) 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*.

We also wanted to determine if self-efficacy varied by the institutions; our results provide evidence that in terms of self-efficacy and the related constructs measured by LAESE that these institutions are more similar than different. This information provides initial evidence that results from this instrument may be applicable to a wide variety of engineering programs.

		Feelings of Inclusion	
Ethnicity	**N**	**Time 1 Mean**	**Time 2 Mean**
African/Black American	10	2.65	1.95
Native American	1	2.0	1.5
Asian	24	2.32	2.36
Latino/Hispanic	16	2.56	2.31
Caucasian	97	2.75	2.63
Other	5	2.95	3.05

Table 3. Averages for Inclusion Subscale (Time 1 and Time 2) by Ethnicity

Implications, Conclusions and Further Research

The results of this study show that there were longitudinal "positive" statistically significant differences for the coping, mathematics, and the second self-efficacy subscales. We found a significant negative difference for the isolation subscale – which is predominantly attributable to the significant difference between African American respondents and all other groups on this subscale. Future data collection efforts using LAESE will determine if the patterns we have found continue. However, the current results imply potential implications for engineering educators.

- Encourage / expand – programs such as MEP Academic success seminar (Reyes, et al., 1999) that target developing feelings of inclusion in minority students and have been linked to good academic performance and improved retention rates. Consider expanding / growing such programs to develop feelings of inclusion between students of different races – in contexts that are not specifically for minority students only. We note that our data does not tell us if the African American students in our sample were active participants in the minority engineering programs that are available at these institutions. Future studies will collect these data.
- All of the institutions in this study have Women in Engineering (WIE) programs and our participants participated in WIE activities. Prior student self-report results from the WECE study (Goodman et al., 2002) showed the positive impact of participation in WIE programs. The positive significant differences for the coping, mathematics and second self-efficacy scales are both in contrast to prior research (Brainard & Carlin, 1998; Felder et al., 1995) and provide additional support for participation in WIE activities.
- Having said this, we did not see a trend of scale growth by school year – which would be a strong positive indication of students feeling more efficacious as they proceed through the degree. This result provides preliminary evidence that either curricula are not designed to promote self-efficacy or that the existing curricular or extra curricular experiences impeded self-efficacy growth. Further studies are needed to determine which is the case.

As is often the case, the results of one study engender the need for several other studies.

- Examine – perhaps via qualitative studies to supplement quantitative data how African American students experience the engineering environment. Such work would need to document and test whether our current results hold true for both participants and non participants of minority engineering and other support programs. Expand these methods to all students as our data show that other student groups also do not experience positive growth in feeling connected to the engineering environment.
- Examine gender comparative results by gathering and analyzing data from male students with LAESE. We are currently engaged in gathering our first data sets for males using LAESE. These data will allow us to examine both cross sectional and longitudinal differences by gender.
- Examine the relationship between self-efficacy results and an important outcomes measure for students such as GPA and persistence in engineering. While it is important to determine how students' sense of engineering efficacy, prior work in self-efficacy has shown it can be a predictor of other important outcomes (Britner & Pajeres, 2001). Future work with LAESE should attempt to establish this relationship in engineering education.

This study examined longitudinal self-efficacy data for a cohort of women engineering students at five institutions. Past studies have shown the importance of efficacy in retaining engineering students. Our results are mixed with some subscales showing positive growth while others are negative, including a statistically significant difference between African American students and other respondents on feelings of isolation. Although further studies (including qualitative studies) are needed to better understand these results there are implications for both external support programs (e.g. WIE programs) as well as the need to understand how the curriculum impacts these results.

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