

ASSESSING WOMEN IN ENGINEERING STUDENTS' EFFICACY BELIEFS

Rose M. Marra, Cherith Moore¹ / Mieke Schuurman; Barbara Bogue²

Abstract — This paper reports the preliminary results of a newly developed and validated survey on self-efficacy of women engineering students undertaken as part of the National Science Foundation (NSF) -funded Assessing Women in Engineering (AWE) project. Self-efficacy is “belief in one’s capabilities to organize and execute the sources of action necessary to manage prospective situations.”² Prior work from Blaisdell³ has shown that feelings of efficaciousness can be an important predictor in the success of women studying engineering. The focus of our initial data collection effort was to collect data to be used to determine and refine the reliability and validity of the instrument. Our initial results from the cross-sectional data collected show that the instrument is both reliable and valid. Preliminary results on questions concerning differences in self-efficacy across students of different year standing did not prove conclusive primarily because of the cross-section (rather than longitudinal) nature of the data.

Index terms — self efficacy, assessment, evaluation, AWE, instruments

INTRODUCTION

This paper reports the preliminary results of a newly developed and validated survey on self-efficacy of women engineering students undertaken as part of the National Science Foundation (NSF) -funded Assessing Women in Engineering (AWE) project. Self-efficacy is “belief in one’s capabilities to organize and execute the sources of action necessary to manage prospective situations.”² Prior work from Blaisdell³ has shown that feelings of efficaciousness can be an important predictor in the success of women studying engineering.

The paper describes the development process for developing reliable and valid instruments as a part of the AWE Project, reports the results of statistical reliability tests, and also the preliminary self-efficacy results from the data collected from undergraduate women studying engineering at four partner AWE institutions: Penn State University (PSU), Georgia Institute of Technology (GA Tech), University of Texas – Austin (UT Austin) and Rensselaer Polytechnic Institute (RPI).

Background and Related Literature

WIE Programs and the Need for Assessment

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 U.S.’s engineers⁴. WIE programs, established at about 50 U.S. colleges/universities⁵, serve many functions, but their primary responsibilities focus on recruitment of women into engineering undergraduate programs and retention of those women within their programs of study.

WIE programs serve to both widen the pipeline for K-12 women and girls and then become a reservoir for many of the undergraduate, graduate and sometimes women faculty in the colleges. Anecdotal and research results on specific programs show that WIE programs do have an impact on the goal expressed by NSF and other engineering and science industrial and academic leaders to broaden participation of girls and young women in engineering and technology^{1,6,7,8,9}. Nonetheless, the development of effective and consistent assessment and evaluation of WIE program's activities and the overall programs themselves is still in its infancy.

We recognize there are good reasons for the state of assessment activities in WIE programs. The Women's Experiences in College Engineering Project's (WECE) interviews with WIE directors from 26 institutions provide several valuable insights on WIE assessment and evaluation^{4,9}. First, time is of the essence. The WIE directors described their time as generally being divided between four major activities: recruiting, retention, fundraising and advising students. Secondly, at most institutions the WIE staff is very small and fragmented. In their sample, Thompson, et al⁹ found that only 9 of the 28 directors interviewed indicated they had full time staff and it was not reported whether these were financed via "hard" or "soft" funding. Additionally, not all directors were full time on WIE.

The result is that WIE staffing is fragmented, making continuity and comprehensiveness in activity execution and follow-up difficult if not impossible. Regarding assessment in particular, there is little time to devote to developing valid and reliable assessment instruments, and even if data are

¹ Rose Marra and Cherith Moore, University of Missouri – Columbia , 6731 O Neal Road, Columbia, MO 65202, rmarra@m.issouri.edu; cmb5x4@mizzou.edu

² Barbara Bogue and Mieke Schuurman, Penn State, Women in Engineering Program, 208 Hammond, University Park, PA 16802, mschuurman@engr.psu.edu; bbogue@psu.edu.

collected, there may not be adequate time or expertise to usefully analyze or even compare the results longitudinally.

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 makes a convincing case that a strong sense of self-efficacy is integral to students' entry and persistence in engineering.

Self-efficacy¹¹ "refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p.3). Although the idea of "general self-efficacy is sometimes considered (see¹²), self-efficacy is more often discussed in terms of specific or "domain-linked" activities, such as engineering self-efficacy. Bandura¹¹ explains that in a general measurement of self-efficacy, items are decontextualized. This is problematic because respondents are forced to guess what is being asked of them and each respondent may come to a different conclusion.

Literature about the experiences of women in engineering frequently addresses self-efficacy and its related constructs (e.g. confidence). In terms of self-appraisal, a general pattern of loss emerges throughout engineering education. Women enter engineering reporting high levels of self-confidence and self-esteem²². Their self-confidence declines precipitously during the first year and, although it does begin to elevate, it never reaches its initial height¹⁰. Women who leave engineering consistently express less confidence in their abilities than the men and women who stay^{10,26}. This discouraging low-self confidence is reflected in the fact that women faced with failing a course are likely to leave engineering altogether, while males are more likely to repeat the course and continue to pursue engineering²⁷.

Note, that while gender differences in "confidence" are often reported¹⁰, 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.^{14, 15}) two studies did find some statistically significant gender differences in participants' perceived sources of self-efficacy of engineering students. Bradburn¹⁶ found differences in self-efficacy, partially due to differences in negative persuasion and anxiety signals. These differences were so strong that, when eliminated statistically, gender differences in attrition were also eliminated.

Although building of self-efficacy is likely an implicit 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 activities designed to address confidence. 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 designed, tested and analyzed the results of an engineering self-efficacy instrument.

Methodology

Before describing our methodology it is important to recall that our primary purpose was to conduct statistical reliability and validity testing with the data collected. To this end, even though the instrument is ultimately intended to be used longitudinally with student cohorts to track changes in self-efficacy, the cross-sectional data reported here are from WIE programs in AWE partner institutions that was gathered over only a one-year period to test the reliability and validity of the instrument. These data are limited in that they do not allow the analysis and comparisons that will be available with longitudinal data. For example, longitudinal data will allow investigation into changes in attitude or behavior of a cohort related to participation or non-participation in WIE Activities

Subjects were 202 undergraduate women studying engineering who were also participants in Women in Engineering program activities at PSU, GA Tech, UT Austin and RPI. These four programs are all partner institutions in the NSF AWE grant and 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 U.S.³ 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 institution⁴.

The student distribution per institution is shown in Table I (next page).

³ AWE has two new partner institutions – the University of Arizona and the University of Louisville. The addition of both of these institutions will significantly improve the minority representation of future student samples.

⁴ 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.

Table 1: Participants by institution and by year standing

		Year-standing				
		First year	Second year	Third year	Fourth / Fifth year	Total
Institution	Georgia Tech	14	3	3	11	31
	University Penn State	25	13	16	23	77
	Rensselaer Polytechnic Institute	8	8	13	10	39
	University of Texas – Austin	16	10	13	11	50
Total students		63	34	45	55	197*

* Five students did not indicate the year they were in, and were therefore excluded from further analyses.

The instrument 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. The instrument focuses on typical barriers one encounters in the task of obtaining an engineering degree and ascertains how capable a person feels in those situations. The survey, which includes items adapted from Blaisdell³ and Betz and Hackett¹³, was developed and pilot tested to ensure reliability and validity.

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 modules, or groups of questions that gather numeric responses designed to measure student responses to the specific factor. The module descriptions are shown in Figure 1.

Modules	
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)

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| 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) |
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Figure 1. Survey instrument modules.

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 modules with several procedures, for example factor analyses to ensure construct validity and external expert reviews to ensure content validity.

Note that Figure 1 accounts for 42 items of the 80-item survey. The remaining 38 items could not be factor analyzed because of the format or content focus of these items. For instance, several items gathered background data on the respondent and their perceptions on the process of choosing an engineering major; other items were “short answer” format and thus were not appropriate for the statistical analyses reported here but will be addressed in subsequent reports.

Preliminary Results – Effects of Year Standing

In addition to testing the validity and reliability of the instrument, the initial administration of the instruments yielded some preliminary cross-sectional results for women students studying engineering. Our results, presented here in brief form due to page limits, therefore focus on examining potential differences between students with varying class standings.

For all items, a higher module score indicates the student has “more” of this skill (e.g. better coping skills). Because WIE programs are designed to cumulatively positively impact skills and attitudes through their programmatic offerings, we would hope to see that overall, WIE student participants’ scores should improve the further they are in their education and the more they have participated in WIE activities. The associated research questions are as follows.

1. Do students with different year-standings answer the module items differently across all institutions?
2. At each institution, do students with different year-standings answer the module items differently?

For question one, we found that the mean module scores for students in different years of their degree (e.g. first year) at all institutions combined were significantly differently for modules 4 ($F(3, 175) = 3.13, p < .05$), 5 ($F(3, 175) = 2.65, p < .05$) and 6 ($F(3, 175) = 4.94, p < .01$). From Figure 1 we see that these modules represent confidence in doing well in engineering major, confidence in being able to cope with difficulties and expectation that math is important for career and self worth respectively.

When the initial results show statistically significant differences for several levels of a variable (year standing in this case) it is appropriate to conduct pair-wise comparisons to determine if particular pairs of the variable levels have statistically significant differences. For module five, pair wise comparisons showed that first year students (mean = 6.15) differed significantly from fourth / fifth year students (mean = 6.73, $p < .05$). For module six, pair wise comparisons showed that third year students differed significantly from first year students ($p < .05$) and from second year students ($p < .01$), with third year students scoring lower (mean = 6.00) than either first or second year students (means 7.05 and 7.44, respectively).

The second question examines differences by year standing at each individual institution. At Penn State, we found statistically significant differences among students of different year-standings for modules six ($F(3, 65) = 3.99, p < .05$) and nine ($F(3, 65) = 2.95, p < .05$). For module six, at PSU, pair wise comparisons showed a significant difference ($p < .01$) between second (mean = 7.56) and third year students (mean = 5.43). There were no significant pair wise differences for module nine.

At UT- Austin, we found statistically significant differences among students of different year-standings for modules two ($F(3, 46) = 1.31, p < .05$), four ($F(3, 46) = 5.65, p < .05$), six ($F(3, 46) = 8.75, p < .05$) and seven ($F(3, 46) = 5.35, p < .05$). For module two, pair wise comparisons showed that first year students (mean = 2.73) score significantly lower than second year students (mean = 3.48, $p < .05$). Likewise, for module four, pair wise comparisons showed that first year students (mean = 6.06) score significantly lower than second year students (mean = 7.73, $p < .05$). For module six, pair wise comparisons found two separate significant differences. Year two students (mean = 8.00) differed significantly from year three students (mean = 6.11, $p < .05$) and year three students differed significantly from year four students (mean = 8.00, $p < .05$). For module seven, pair wise comparisons found that second year students (mean = 8.16) scored higher than fourth / fifth year students (mean = 6.30, $p < .05$).

Discussion

The following two noteworthy results are briefly discussed.

Regarding research question 1—*do students with different year-standings answer the module items differently across all institutions*—we do not see in our cross-sectional data a consistent pattern of significant differences between students in the lower year standings and those in higher year standings for the modules of items.

The above-described “pattern” of results also occurred for research question 2.

These observations are most likely due to two factors; first, (and probably most pertinent) the fact that this data set is cross-sectional and not longitudinal, and secondly the

relatively small number of data points we have for each year standing or grade level. Referring back to Table 1, one can see that there were 63, 34, 45 and 55 responses for first, second, third and fourth / fifth year students for all institutions combined. Most likely because these are cross-sectional data, we did not see means that increased with year standing. We still hope to see this result in longitudinal data as students with more advanced year standing status that had participated in WIE activities would evidence stronger self-efficacy than “younger” students who had experienced fewer WIE activities. For our current data set, module means by year standing are shown in Table II.

Table II: Averages for all modules by year standing.

	First Year	Second Year	Third Year	Fourth / Fifth Year
Module 1 *	3.70	3.59	3.47	3.62
Module 2 *	2.82	3.00	3.06	2.97
Module 3 *	2.61	2.59	2.63	2.61
Module 4 **	6.35	7.00	6.84	6.90
Module 5 **	6.15	6.33	6.34	6.73
Module 6 &	7.05	7.44	6.00	6.75
Module 7 &	7.19	7.54	6.92	6.85
Module 8 &	5.05	4.80	5.32	4.84
Module 9 &	7.21	7.93	7.13	7.31

* Responses 0 –4

** Responses 0 – 8

& Responses 0 - 9

As the reader can observe, there is no discernable pattern to these means and they certainly do not, with the possible exceptions of modules 4 and 5 where they are relatively flat and rising respectively, show steadily increasing means with increasing year standing. This leads us to our first explanation – namely that these are cross-sectional data rather than longitudinal. Although it is not unreasonable to expect that, for instance, a group of first year students taken as a whole would have consistently lower mean module scores than a *different* group of third or fourth year students, it is a more feasible hypothesis that we would see such progress by following the mean scores a single cohort of women students from their first year through to matriculation.

Conclusions and Future Directions

This paper has reported the preliminary results of a newly designed and validated instrument designed to measure self-efficacy of women studying engineering. The instrument was designed based on prior research and theoretical foundations from social psychology theory^{2,3} regarding barriers women face in studying engineering, as well as from expert review from women in engineering directors and other personnel with expertise on the barriers women face in an undergraduate engineering curriculum.

The preliminary nature of these results clearly calls for future work items to strengthen or redirect these findings. Future work will include:

- Collecting and analyzing more data from a wider variety of institutions and a larger number of women

engineering students. Additionally, collect more data at *each institution*. Larger sample sizes from each institution (which are currently being collected and analyzed) will provide us with a clearer picture of how responses do or do not vary amongst institutions.

- Collecting and analyzing *longitudinal* data. All data reported here are cross-sectional and as such the results of these data are preliminary at best. The instrument is intended to be 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. When used longitudinally with individual student cohorts we would expect to see steadily increasing self-efficacy particularly in students who are regular participants in WIE activities. 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 on women's self efficacy in studying engineering. Further, if such tracking and data collection is done at a national level, the WIE community will have data for comparisons between and among different institutions and programs nationwide. We anticipate that longitudinal data will become available during the 2004 – 2005 timeframe.
- Use the instrument to collect data from a more diverse set of women students. We recognize the limitation of the lack of diversity of the sample reported in these preliminary results. Once again, our main intent for these data collection processes was to collect data to conduct reliability and validity test of our instrument. These data have provided a strong initial basis for concluding that the instrument is both reliable and valid. Our subsequent data sets will include data from the University of Louisville and the University of Arizona; inclusion of both of these institutions will significantly boost the minority representation in our data set.
- Use the instrument to collect data from men students as well as women. We recognize that it is critical to be able to compare responses based on gender. However, because we designed the instrument to focus on barriers for women engineering students and also because the first data collection was in part designed to validate the self-efficacy instrument, we chose to limit this initial effort to women. Subsequent iterations will be used with men and women and we will re-analyze our items for reliability at that time.

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References

1. Mannix, M. (2001). Getting it right. *Prism*, 10(7), 14 - 21.
2. Bandura, A. (1986). Social foundations of thought and action: a social cognitive theory. Englewood Cliffs, N.J.: Prentice-Hall.
3. Blaisdell, Stephanie (2000). Social cognitive theory predictors of entry into engineering majors for high school students. Arizona State University. Unpublished dissertation.
4. 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.
5. 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).
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. 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.
11. Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. New York: W.H. Freeman and Company.
12. Chen, G., Gully, S., & Eden, D. (2001). Validation of a new general self-efficacy scale. *Organizational Research Methods*, 4(1), 62-83.
13. 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.
14. Shaefers, K. G. (1993). Women in engineering: factors affecting persistence and attrition in college majors. Unpublished Ph.D., Iowa State University, Iowa.
 15. Schaefer, 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.
 16. Bradburn, E. M. (1995). Engineering gender roles: A self-efficacy model of occupational choice and persistence. Cornell U, US, 1.