Self-efficacy in female and male undergraduate engineering students: Comparisons among four institutions

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Abstract – Researchers from four universities with strong engineering colleges collaborated on a project that seeks to isolate those factors and experiences that contribute most to the development of positive self-efficacy beliefs and, ultimately, to the increased retention of women in undergraduate engineering majors. A survey was developed to administer to students at each institution during their sophomore, junior, and senior years. Two of the engineering colleges require participation in cooperative education programs for fulfillment of the program of study and two do not. We suggest that a work experience could result in an increase in work self-efficacy that would bolster academic and career self-efficacy. Data analyses show similarities and differences between and among female and male students at these institutions with regard to their current self-efficacy levels (academic, work, and career), amount of support provided for female students, and how likely females are to take advantage of services provided.

Keywords: self-efficacy, undergraduate retention, women in engineering, co-op education.

INTRODUCTION

The importance of engineering and technology to the economic and intellectual growth of the United States cannot be overstated. In today's knowledge-driven society, and despite the recent economic downturn, the number of U.S. citizens with education and training in engineering and technology has barely kept up with demand. Women, racial and ethnic minorities, and persons with disabilities are severely underrepresented in college engineering majors and in the engineering workforce [NSF, 30]. The overarching goal of the present work is to increase our knowledge about how to support and encourage women in engineering in the most efficacious manner. [Kuh, 23, Peterson, 33].

Findings from several meta-analyses of studies documenting research into the underlying reasons for the disparities in participation by women in science, engineering, and technology (SET) high school courses, community college and university majors, and careers [AAUW, 2, NSF, 31] have been published. These studies, as well as those about the efficacy of interventions at all educational levels, found that we must use a more integrative approach to build on past successes and to institutionalize those programs and activities that work. Unfortunately, the majority of programs supported by outside funding that have shown success over a three to five year period were not then institutionalized or adopted by others [NSF, 31].

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Women have been and continue to be underrepresented in engineering, earning only 19.3% of bachelor's degrees in engineering [Gibbons, 17] and holding only 11% of engineering positions in 2003 [National Science Board, 29]. Although they are as academically prepared and successful as men [Adelman, 1; Brainard, 6], they self-report lower levels of academic satisfaction and lack of self-confidence [Felder, 13; Huang, 22; Campbell, 8]. Traditional assumptions about career options for women have been reinforced in our culture and have projected stereotypes that discourage talented women from continuing in engineering careers [AAUW, 2]. A number of studies have revealed a dramatic drop in women's self-efficacy over the course of engineering programs [see, e.g., Brainard, 6; Huang, 22]. In an in-depth study of students who switched out of SET majors, 77.9% of women cited discouragement and loss of self-esteem as factors in switching [Seymour, 40]. While self-esteem is a global concept and self-efficacy refers to confidence about a particular content area or set of tasks, general self-esteem tends to be related to an individual's feelings of self-efficacy. Research suggests that decreased self-esteem and self-efficacy of women in engineering majors are significant obstacles to persistence [Somers, 41]. Since college is a point at which many women exit the engineering pipeline, it is essential to foster conditions that promote retention. While many engineering programs are characterized by low rates of persistence for both women and men, this is particularly troubling for women because so few enter engineering majors in the first place.

The proposed study draws on research from cooperative education and self-efficacy theory. U.S. colleges and universities are placing growing emphasis on experiential programs that allow students to gain work experience and thereby define success by more than just academic learning. These programs comprise such formal activities as co-op jobs, internships, apprenticeships, service learning, and others that integrate experience in the job world with experience in the classroom. These approaches are becoming increasingly relevant in a work culture characterized by the need to continuously reflect and learn from ongoing experience [Raelin, 37]. They help student's transition into full-time work more easily, helping them overcome the "reality shock" attributed to first job experiences for uninitiated novices [Raelin, 36; Wanous, 45; Elfering, 12].

A 1998 co-op census found that approximately 250,000 U.S. students were placed in co-op jobs that year [Pettit, 34]. A survey in 2001 of 1,830 college members of the National Association of Colleges and Employers (NACE) found that the majority (93%) of the institutions offered internship opportunities [Gold, 18], and in 2006, the career publisher Vault.com reported in its third Internship Survey that 62% of undergraduate students completed an internship that year [Vault.com, 44]. Self-efficacy is an individual's perceived level of competence or the degree to which an individual believes she is capable of completing a task. Self-efficacy is a dynamic trait that changes over time and can be influenced by experience. Self-efficacy expectations are considered the primary cognitive determinant of whether or not an individual will attempt a given behavior. Bandura [3] identified four sources of information that shape self-efficacy: (1) performance accomplishments, (2) vicarious experience, (3) verbal persuasion, and (4) physiological and affective states.

Cooperative Education Research: In terms of outcome studies regarding co-op, the majority of research was conducted in the 1970s and 1980s due to the influx of federal funding to cooperative education. There has been only modest research since that time. Studies can be divided into five outcome categories: career development, academic benefits, initial employment, economic benefits, and personal growth, most of which include student populations from a variety of undergraduate majors. Students who participated in co-op benefited in all categories. They had greater certainty about career choice [Weinstein, 46]; greater persistence to graduation [Somers, 41] and higher standardized test scores Van Gyn [43]; were more likely to be hired [Brown, 7] and be self-reliant in adjusting to their first jobs [Gardner & Koslowski, 15]; received higher salaries [Gardner, 16]; and, in the area of personal growth, had increased self-confidence, higher self-concept, and enhanced career identity [Cornelius, 9; Ducat, 10; Weston, 47], an increase in autonomy and independence [Wilson, 50] , had social maturity and interpersonal skills, such as tolerance, understanding, and the ability to express thoughts and feelings [Marks, 27; Wilson, 50; Morton, 28]; and had developed practical intelligence and tacit knowledge [Williams, 49].

Although the aforementioned suggests a substantial body of co-op literature, most research is limited to reporting outcomes [Parks, 32]. Few studies related outcomes to processes or examined the characteristics of co-op experiences thought to influence favorable outcomes. For example, it is not known how long it takes for these programs to take effect, although one study found that co-op experiences lasting as little as five months can produce a demonstrable effect [Williams, 49]. There is a dearth of literature and theory to explain what happens during the co-op experience that produces beneficial outcomes, leading some researchers to refer to this as the "black box" of co-op [Ricks, 38].

Self-Efficacy Research: One promising avenue that can be used to tie practice-oriented processes to outcomes is Bandura's concept of self-efficacy [Eames, 12].

Fletcher [14] suggested that co-op increases self-efficacy through performance accomplishments, one source of efficacy information. Performance accomplishments could be co-op experiences where individuals use skills, abilities, and coping strategies to perform tasks. Successful experiences can result in a feedback loop where performance accomplishments lead to increased self-efficacy, which, in turn, enhance a person's subsequent performance, further strengthening self-efficacy beliefs. The possibility that co-op can be a source of efficacy information through performance accomplishments is provocative, given that performance accomplishments are generally viewed as the most potent source of self-efficacy information [Bandura, 3; Lent, 24]. However, workplace experience also exposes students to successful peer models, mentor figures, and verbal encouragement that can provide self-efficacy information through two of Bandura's other sources: vicarious experiences and verbal persuasion.

Hackett and Betz [19] were the first to use self-efficacy to explain the career development of women, especially in male-dominated career areas [Hackett, 20]. They found that societal factors created gender differences in gaining access to primary sources of self-efficacy information. For example, women are thought to have fewer performance opportunities relative to pursuits in male-dominated careers; gain less exposure to role models; receive less encouragement for career pursuits; and experience higher internal physiological responses (e.g., anxiety) that decrease perceptions of self-efficacy [Hackett, 20]. Empirical studies pointed out that college-aged women's self-efficacy for traditionally female occupations was significantly higher than within nontraditional fields [Betz, 4; Wheeler, 48; Post-Kammer, 35]. Nevertheless, when exposed to positive experiences in what is known as Holland's [21] career theme of "realistic" learning experiences, which includes engineering, young women were reported to enhance their self-efficacy [Tokar, 42].

Focusing on gender, a number of studies confirmed that self-efficacy beliefs predict retention in SET majors for both male and female students [Lent, 25; Lent, 26], with one study suggesting that women may be more strongly influenced than men by self-efficacy [Post-Kammer, 35]. Longitudinal studies of engineering women's levels of self-esteem provide related evidence of the importance of self-worth on retention. Women who switch out of SET undergraduate programs tend to lose self-esteem through the course of study [Brainard, 6], citing discouragement and loss of confidence [Seymour, 40]. Preliminary evidence shows that women experience a loss of self-efficacy as they proceed through engineering curricula. Taken together, these results suggest that co-op experiences could be considered a support that strengthens self-efficacy beliefs, especially among women, resulting in increased retention in engineering programs.

Our project is the first to bridge research in co-op and research in self-efficacy. It contributes to existing knowledge in both fields by: bringing a theory-based empirical approach to the problem of retaining women in engineering, testing an innovative model that is based on self-efficacy and includes co-op and internships as well as other contextual supports, supplying longitudinal data on an underrepresented group, and identifying programmatic conditions (including qualities of co-op and internship experiences) that enhance self-efficacy and retention.

Table 1. Profile data for partner schools (engineering students only)

Data from 2007	#undergrad students	% F	Length of program. Co-op & internship participation
Northeastern	1957	18%	5 yr. program. All engineering students participate in co-op.
RIT	2010	12%	5 yr. program. All engineering students participate in co-op.
Virginia Tech	5778	15%	4 yr. program. Voluntary co-op and internship programs.
Univ. Wyoming	1157	15%	4 yr. program. Voluntary co-op and internship programs.

Our working hypothesis is that women's participation in formal undergraduate engineering programs that provide work experience while enrolled (cooperative education or internships) leads to enhanced self-efficacy and an increased likelihood of retention to graduation. Co-op education or internships are offered at UW and VT but NU and RIT require co-op for graduation.

The path model was used as the conceptual design for this study. The variable clusters are precursory **demographic**

variables, such as high school performance; formal **work experience** programs, namely co-op education and internships; **contextual supports**, such as mentorships and advising; **self-efficacy**, featuring three dimensions – work, academic, and career; and the principal dependent variable of **retention.** A path analysis was conducted to isolate not only the variables that lead to retention, but also to measure their recursiveness and directionality.

Our research questions are guided by the principal hypothesis that work experiences related to academic study increase self-efficacy and, in turn, have a positive effect on retention. This project will contribute to the current knowledge about self-efficacy and women's retention in engineering and will build on the already robust research establishing the positive relationship between self-efficacy beliefs and career behaviors. It will expand knowledge about the respective roles of work experiences and work self-efficacy among women in engineering by addressing four hypotheses:

- Self-efficacy is the principal predictor of the retention of women in undergraduate engineering programs.
- Cooperative education and internships, as formal work experience features of undergraduate programs, constitute a critical predictor of women's retention directly and indirectly through their impact on self-efficacy.
- Contextual support variables affect work, career, and academic self-efficacy as well as retention both directly and indirectly through self-efficacy.
- Demographic variables have an independent effect on retention but also interact with contextual variables and with self-efficacy to indirectly affect retention.

To this end, a plan was developed to survey students at each institution during their sophomore, junior, and senior years. Two of the engineering colleges require participation in cooperative education programs and two do not require this for fulfillment of the program of study. We suggest that, as in previous findings in the literature, a work experience could result in an increase in work self-efficacy, which would bolster academic and career self-efficacy.

FINDINGS

The team developed and refined a 96-item survey. An attempt was made to administer the survey on-line in spring 2009 at Virginia Tech. This was unsuccessful as it only captured about 12% of the sophomore class. We found that this cohort of students had moved away from email and use other technologies to keep in touch and gather information. This is a profound change from only five years ago when most surveys were conducted online. We discovered that the most effective survey administration occurred during class time. Using this method and paper surveys in fall 2009, we captured data from about 80% of the sophomore populations at Virginia Tech (Table 2).

The data were analyzed using multivariate statistical analysis. The primary scales used to assess the principal variables – work self-efficacy, career self-efficacy, academic self-efficacy, advisorship, and mentorship - were all found to produce high reliability and internal consistency. Data show similarities and differences between and among female and male students at these institutions with regard to their current self-efficacy levels (academic, work, and career), amount of support provided for female students, and how likely females are to take advantage of services provided.

The results reveal some significant differences by gender. With the exception of academic self-efficacy, which is significantly higher among males, every other significant difference favors the female population. Women were found to have higher career self-efficacy and benefit far more from mentorship. They also exceed the scores of their male counterparts in five support dimensions: they report receiving more support from professional clubs and associations, they say they are more involved in campus life, they take more advantage of living/learning communities, and they report that they not only receive more support from their friends but that their friends really matter to them.

Regression analyses on the three efficacy dimensions reveal healthy coefficients of determination for all three equations. Noteworthy is that although GPA accounts for the largest portion of the variance in *academic* self-efficacy, males account for a significant difference, even when controlling for all the other independent variables. Compared to males, women as freshmen are not as confident in their likelihood of achieving success in their engineering major.

Table 2 Overall Sample Statistics 2008-09 Academic Year

	Completed survey			Eligible to take survey			
School	**Total**	**# F**	**% F**	**Total engin. sophomores**	**# F**	**% F**	**Response rate**
NU	398	86	22%	463	98	21%	86%
RIT	177	29	16%	330	42	13%	54%
UW	75	21	28%	168	35	21%	45%
VT	340	80	24%	1288	211	16%	26%
TOTALS	**990**	**216**	**22%**	**2249**	**386**	**17%**	**44%**

Besides gender, the sample is predominantly Caucasian (81%) and upper-middle and middle class (78%) in self-reported socioeconomic status. The average SAT score is 1274, based on the original version with a 1600 maximum score (800 Math + 800 Verbal). The average GPA is 3.23 and the most popular major is mechanical engineering (at nearly a third of the sample) followed by civil, electrical, and chemical, in that order. It is noteworthy that in terms of these major demographic categories (race, SES, SAT score, GPA, and major), there are no significant gender differences.

The model for the study is series of pathways between five variable clusters. Retention is determined by self-efficacy as well as by the impact of students' demographic characteristics, the effect of work experience - in particular cooperative education, and the contextual support provided by the university. The pathways are interrelated, as disclosed below. The dependent variable of retention will be assessed at the later stages of the study.

ANALYSIS AND RESULTS

The new work self-efficacy inventory (WS-Ei), developed at the Center for Work and Learning at NU, measures behaviors and practices that relate to the non-technical and social skills necessary to achieve success in the workplace. The inventory has seven subscales: problem solving, sensitivity, communication, teamwork, learning, pressure, and politics. Academic self-efficacy was derived from the Self-Efficacy for Academic Milestones and Self-Efficacy for Technical/Scientific Fields surveys, and career self-efficacy was obtained directly from the short-form of the Career Decision-Making Self-Efficacy Scale of Betz, Klein, and Taylor. Among the contextual social support variables, most were derived from the contextual supports subscales of Lent et al., and the advisorship and mentorship scales from the rapport and apprenticeship subscales of the Advisory Working Alliance Inventory prepared by Schlosser and Gelso [39]. The survey instrument obtained the demographic data from the respondents directly or from their student record.

The first round of data analysis confirmed the reliability of these measures. Each of the three self-efficacy scales as well as the subscales in the work self-efficacy (WSE) and career self-efficacy (CSE) scales produced high reliabilities, measured by Cronbach's alpha coefficient of internal consistency. These general scales and all the embedded subscales are above the recommended .70. The advisor and mentor scales also performed well: advisorship at .95 and mentorship at .97. The three major self-efficacy scales were found to have a high degree of concurrent validity, measured initially by correlations that are high and significant but not so high as to be equivalent. Convergent validity was also established by significant correlations among discriminating variables. For example, mentorship, provided as part of programs to support women and underrepresented students, was significantly correlated with both work- and career self-efficacy. Meanwhile, GPA was found to be highly and significantly correlated with academic self-efficacy. The latter was also significantly correlated with teaching quality and prior SAT scores.

Bivariate Gender Differences: There are some significant bivariate gender differences. With the exception of academic self-efficacy, which is significantly higher among the males, every other significant difference favors the females. Women have higher career self-efficacy, in contrast to what has been reported in the literature for college students who have already chosen engineering, and benefit far more from mentorship (though this can be expected given that these program, as noted above, are designed exclusively for this purpose). They exceed the scores of their male counterparts in four support dimensions: they report receiving more support from professional clubs and associations, they say they are more involved in campus life, and they also report that they not only receive more support from their friends but that their friends really matter to them. Subsequent data provide one caution to these preliminary bivariate findings: some of these results may be moderated when

controlling for socioeconomic status. For example, the value of friends, found to be relatively high among women, is not shared among women of the lowest socioeconomic strata (Table 3).

Table 3. Average responses from female and male sophomore engineering students (aggregate of four schools)

	ASE	CSE	MENTOR-SHIP	PROF. SUPPORT	FRIEND SUPPORT	FRIENDS MATTER	INVOLVE-MENT
Males	**3.88**	3.67	3.98	3.54	4.25	4.19	3.60
Females	3.74	**3.74**	**4.24**	**3.75**	**4.49**	**4.43**	**3.78**
F-ratio	5.60	2.42	2.23	6.07	12.51	14.60	4.57
Sig.	.018	.120	.137	.014	.000	.000	.033

Differences for Living/Learning Communities: The study considered the impact of students choosing residence in selective living/learning communities, such as special floors or houses in engineering, honors, or leadership. Nearly half of the sample took advantage of these special residential arrangements, but women were significantly more likely to have chosen this residential option. Specifically, 64% of women chose a living/learning community in their freshman year, compared to 43% of men. Those in living/learning communities reported greater effects among several of the study's support variables. In particular, they were more likely to receive financial and professional support, were more involved in campus life, and declared that both their friends and the university as a whole mattered more to them.

Regressions for the Efficacy Scales: The data analysis considered the impact of the independent variables on the three separate dimensions of self-efficacy. Three regression equations were initially calculated. The purpose was to determine how much of the variance in each of these dependent variables can be explained at this early stage of the study by the demographic and support variables. At this stage, given that none of the students in our sample had been exposed to formal university-sponsored work experience programs, such as cooperative education, the regression results for work self-efficacy were modest with only an r-square [equivalent to the variance explained] at 13%.

With respect to career self-efficacy, the regression analysis was run in two ways. In the first equation, the analysis was run without entering the variable, mentorship. As indicated earlier, mentorship constitutes a specialized variable because it applies to (and was only answered by) students who receive special support from programs for women and those otherwise underrepresented in engineering. Thus, only 221 respondents answered this question (representing approximately 22% of the sample). Regression equations results run with rigorous properties, such as listwise deletions, become unstable when their degrees of freedom are attenuated in this way. Nevertheless, prior correlation analyses had revealed the possible effect of mentorship especially on career self-efficacy. Indeed, when the career self-efficacy regression was run without the addition of mentorship, only 21% of the variance was explained. When mentorship was entered, nearly 39 percent of the variance was explained and the degrees of freedom are sufficient in this case. Clearly, special mentorship helps to focus students on the value of an engineering career. Professional and financial support and teaching quality are also significant predictors of career self-efficacy. Unexpected among these results is that the direction of financial support is negative. (Data not shown) Those receiving financial aid appear to be less confident in pursuing an engineering career than those who fund their own college education.

The regression equation for academic self-efficacy (without the mentorship variable) explains a full 43.6% of the variance. Not surprisingly, GPA accounts for the largest portion. Some of the now familiar support variables are also present. What is most interesting is that the negative numbers for gender signify that males account for a significant difference in academic self-efficacy, even when controlling for all the other independent variables. (Data not shown) Compared to males, freshmen women are not as confident in their likelihood of achieving success in their engineering major.

CONCLUSIONS

These preliminary results sustain longstanding research conclusions that women have lower academic self-efficacy than men at the point of entry in their undergraduate engineering education. As a result, women continue to be at risk of prematurely terminating their engineering careers. However, it appears that colleges of engineering are taking active steps to counteract this critical condition by providing support to women in their early college years.

Furthermore, these results suggest that women are taking advantage of these support mechanisms. For example, their reliance on special mentorship opportunities certainly enhances their career self-efficacy. Women also take full advantage of special opportunities afforded by universities to take up residences in specialized living/learning communities, which, in turn, increases their connection to the university. Although not ascertained by this study, it can be speculated that the social support and resulting involvement of women might come more naturally to them than to their male counterparts. In the next surveys to be conducted through this study, the research team hopes to determine whether formal work experiences offered to students in their sophomore and subsequent years might also contribute to equalizing the balance in self-efficacy [especially academic] among women and men undergraduates.

Our ongoing study will provide data that compare outcomes from those schools that require co-op experiences with those that do not. The results could suggest curricular reforms which could result in retention of students – especially women – through their engineering majors and on into engineering and technical careers.

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Biographical Information

Carol J. Burger, Ph.D., Virginia Tech, is the founder and editor-in-chief of the *Journal of Women and Minorities in Science and Engineering*, which is now in its 15th year of publication. She served as Senior Program Director, Program for Women and Girls, Human Resource Development Division, Education and Human Resources Directorate, National Science Foundation in 1996. She teaches Introduction to Women's Studies, and developed and teaches Biology of Women and Women and Science courses. She has co-authored a number of book chapters, over 40 peer-reviewed publications, and is the co-editor of *Reconfiguring the Firewall: Recruiting Women to Information Technology across Cultures and Continents* [published May, 2007].

Joseph A. Raelin, Ph.D., Northeaster University, has a 35-year career on human resource scholarship. Raelin is the director of the Center for Work and Learning. A Ph.D. in policy studies from the State University of New York at Buffalo, Raelin received his formal training as an employment researcher. Since then, he has produced 100 journal publications. His first of seven books was the frame-breaking *Building A Career*, an Upjohn Institute-sponsored analysis of the effect of first job experiences on subsequent employment and one of the first volumes to use path analysis to identify career patterns among young men and women.

Rachell M. Reisberg, MEE. Northeastern University, is the Director of Northeastern's Women in Engineering program and Associate Director of Connections, a program to strengthen the pathways for women to pursue careers in engineering and science. She was responsible for the institutionalization phase of Connections, which entails the delivery of middle/high school outreach programs as well as college level programs, such as academic support, residential life programs, work study opportunities, career management classes, and scholarships for women studying engineering. She has extensive management experience from industry including running a profitable startup company.

Margaret B. Bailey, Ph.D., Rochester Institute of Technology, led efforts to promote gender diversity within engineering since 1998 when she began her academic career as an Assistant Professor at the U. S. Military Academy at West Point, being the first woman civilian faculty member in her department. In 2003, Bailey accepted the first Kate Gleason Chair position at RIT and has since created and led the development of WE@RIT Women Engineering the Future program. WE@RIT includes a comprehensive series of outreach, recruitment, and retention initiatives with a unifying goal of expanding the pipeline of women pursuing studies and careers within engineering. She maintains a research program in the area of advanced thermodynamic analyses and health monitoring of energy intensive systems and half of her research mentees have been women.

David I. Whitman, Ph.D., University of Wyoming, has been involved, as both a faculty member and a former Associate Dean, in many activities that are associated with recruitment and retention of engineering undergraduates – especially women. Some of these projects include the formation of Power Groups [a blocked schedule for incoming freshmen to promote the development of study groups], two floors in the residence halls that are specifically for engineering majors [including 25% women], and working with the Middle School Girls Camp in the summer.