Assessing Women in Engineering (AWE) Project 2005. Self-Efficacy. AWE Research Overviews. Retrieved >date< from http://www.aweonline.org.

Overview: Self-Efficacy and Women in Engineering

Self-efficacy is an individual psychological construct that measures a person's self-perception of his or her ability to successfully achieve a specific goal. Self-efficacy is derived through four sources: mastery experiences, verbal persuasion, vicarious experience, and physiological response. Consistent with other ideas from social psychology, self-efficacy is greatly influenced by the social environment. Women in engineering do not inherently have "more" or "less" self-efficacy than men or other women solely because of their intrapersonal make up, but because of the social world surrounding them. In fact, self-efficacy can change from one experience to the next based on social inputs. For this reason, there is considerable potential for women's (and men's) perception of self-efficacy for engineering to be reduced or bolstered by all they encounter along the path to an engineering career. In doing so, it is important to remember that self-efficacy is not just a measure of how a particular woman is doing, but also how well the educational environment surrounding her is serving her.

The literature on self-efficacy is focused on measuring self-efficacy of various populations related to their achievement. In general, higher levels of self-efficacy result in higher chances of success and persistence. When gender is considered, the picture is more complicated. This may be due to women's reluctance to make confident assessments of their chances for success or to differences in sources of self-efficacy. The general trend is for girls to express lower academic self-efficacy than boys, although girls and women often reach higher levels of achievement (counter to self-efficacy's central principle of positive rather than inverse correlation). The exceptions are the domain of language (Pajares & Valiante, 2001) and self-regulated learning (Pajares, 2002). When it comes to choosing a major or career choice, there tends to be a positive correlation between self-efficacy and choice for both males and females, divided along traditional occupational lines. Once in the engineering major, male and female students indicate similar levels of self-efficacy:

- Self-efficacy is correlated with academic achievement and contributes to success beyond that suggested by ability alone. (Zimmerman, 1995)
- Domain-specific self-efficacy is correlated with achievement in that domain and with choice of career and major in that domain (Hackett, 1985).
- When gender is considered, the correlation between academic self-efficacy and achievement is less consistent, and is sometimes reversed (Britner & Pajares, 2001).
- Evidence exists suggesting that sources of self-efficacy may be different for men and women in STEM (Science, Technology, Engineering and Mathematics). Women may experience a reduction in self-efficacy relative to male peers due to negative persuasion and anxiety, (Bradburn,1995) and report receiving a greater portion from verbal persuasion and vicarious experience than male counterparts who cite mastery experiences as more important (Zeldin, 2001; Zeldin & Pajares, 2000).
- Gender influences perception of self-efficacy for a particular type of career and consequently affects career choices (Betz & Hackett, 1981).
- There is little evidence of gender differences in self-efficacy in engineering majors who persist (Schaefers, Epperson, & Nauta, 1997).

- There are no studies comparing self-efficacy, gender, and academic achievement of students who left engineering to those who stayed in the field.
- There is a lack of longitudinal and meta-analytic studies in self-efficacy research addressing gender, which could provide a means of addressing apparently contradictory findings.

These bullet points summarize the literature on self-efficacy, gender and achievement as it relates to SMET (covered in the full overview). Most of the research focuses on measuring women's self-efficacy at various stages of life and in relation to various tasks. The literature has not focused as much on the sources of self-efficacy or the kinds of environments that support or reduce self-efficacy. Information on assessing self-efficacy is plentiful. By using the instruments provided by AWE or those listed in this document, WIE directors can discover and document the kinds of environments that are supportive to women's success in engineering.

Self-Efficacy and Women in Engineering Sections

Self-Efficacy

Self-efficacy is an extensively researched psychological construct grounded in social cognitive theory. This 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 student entry and persistence in engineering. This information is promising in that ample opportunities to enhance women's self-efficacy exist along the engineering path. Although self-efficacy is an individual construct, it is derived through social interactions and contexts. For that reason, institutions possess significant potential to increase (or reduce) women's self-efficacy for engineering goals through their own actions and attitudes. The concept of self-efficacy is especially useful to WIE programs because it is a measurable indicator of success that may be achieved at multiple institutional levels. The following information is meant to assist practitioners working with in WIE programs to develop goals, activities and assessments that improve the number of women entering and persisting in four year engineering programs.

Self-Efficacy Definitions

The term "self-efficacy" is often used interchangeably with several others, notably "self-esteem", "confidence", and "self-concept". Understanding the differences between these terms 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, “refers to beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” (1997, p.3). The term “perceived self-efficacy” is often used, because self-beliefs are subjectively developed by the individuals who hold them. Although the idea of “general,” “global.” or “omnibus” self-efficacy is sometimes considered (e.g. Chen, Gully, & Eden, 2001), self-efficacy is more often discussed in terms of specific or “domain-linked” activities. Bandura (1997) 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. Further, a general test will include a list of set items that will have little relevance to other areas of functioning. For example, a global measure of scholastic self-efficacy may not specify which subjects in which students are being asked to rate themselves. Students will have to guess which activities the assessor had in mind, or develop some aggregate judgment. Therefore, self-efficacy will mean different things to different students and perceived self-efficacy for one subject might not be the same as perceived self-efficacy for another subject.

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 (Pajares, in press), science self-efficacy (Luzzo, Hasper, Albert, Bibby, & Martinellin, 1999), academic milestones self-efficacy (Lent, Brown, & Larkin, 1986), career decision-making self-efficacy (Taylor & Betz, 1983), career self-efficacy (Turner & Lapan, 2002) and agentic self-efficacy (Ancis & Phillips, 1996).

Self-Concept is a “composite view of oneself that is presumed to be formed through direct experience and evaluations adopted from significant others”. It is usually not specific to any one particular activity, but is a judgment generalized to the whole self (Bandura, 1997, p. 11).

Self-Esteem is a person’s judgment of their own self-worth, as opposed to a person’s judgments of personal capability in attaining a particular goal that defines a sense of self-efficacy (Bandura, 1997, p. 10).

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. A person may be absolutely confident in failure, for example (Bandura, 1997, p.382). Although the term “confidence” is not synonymous with self-efficacy, it can be understood as a component of self-efficacy when expressed positively (Pajares, 2003b). In this overview, the terms will be reported as defined in the original literature. That is, if researchers have taken pains to define and research “self-efficacy” but an instance occurs of using the word “confidence” synonymously with “self-efficacy”, we will go with the researchers’ intent and use the word “self-efficacy”. Conversely, if the original writer has not defined “self-efficacy” as the major construct of concern in their reporting and has off-handedly interchanged “confidence” with “self-efficacy”, we will use “confidence.”

It should be noted that this overview focuses on literature explicitly addressing self-efficacy. In doing so, it undoubtedly excludes studies and intervention programs that claim to address confidence, even though the construct they deal with may more accurately be considered self-efficacy. An example of this can be found in The National Science Foundation publication, *New Formulas For America's Workforce: Girls in Science and Engineering* (2003), which lists 69 funded programs that address confidence, but only two addressing self-efficacy. Although we do not discuss research focusing specifically on self-confidence for this overview, it may be worthwhile for the inquisitive program director to investigate research and programming on confidence when seeking exemplary models for programming on self-efficacy.

Self-Efficacy Theory

The construct of self-efficacy originated with Albert Bandura's "Self-efficacy: Toward a Unifying Theory of Behavioral Change" (Bandura, 1977) and was later situated within a social cognitive theory of human behavior (Pajares, 1997). The association of self-efficacy theory with social cognitive theory emphasizes the mutually influencing connections among internal and external environments and individual behavior; Bandura (1997) labeled these interactions "triadic reciprocal causation" (p. 6). Thus self-efficacy is not an isolated internal event, but a personal factor that interacts reciprocally with the behavioral and environmental realms of human experience.

There are four sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion and physiological states. Pajares (1997) provides a summary of these, beginning with the most influential. Mastery experiences, the interpreted result of one's performance towards a desired goal (called "purposive performance" by some theorists), are the most powerful. Outcomes interpreted as successful raise self-efficacy, while those interpreted as failure lower it. Vicarious experiences have a weaker influence on self-efficacy beliefs, but people become more sensitive to them when they are uncertain about their own abilities or have limited experience with the task at hand. Verbal persuasions are weaker still and have more potential to reduce self-efficacy than to increase it. Physiological states, such as anxiety or fatigue, give individuals information to use in interpreting their level of anticipated success. Mastery and vicarious experiences, verbal persuasion, and physiological states do not translate directly and uniformly into self-efficacy judgments. Individuals interpret and integrate them in their own unique ways (Pajares, 2003a).

The influence of self-efficacy on human endeavors is far-reaching. 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). A substantial amount of research is available to support these claims. Self-efficacy beliefs have been correlated with success in an array of activities and conditions, such as computer use (Hasan, 2003), smoking (Joseph, Manafi, Iakovaki, & Cooper, 2003), high-risk sports (Slanger & Rudestam, 1997), depression (Tucker, Brust, & Richardson, 2002), alcohol addiction (Brown, Carello, Vik, & Porter, 1998) and maternal behavior (Leerkes & Crockenberg, 2002) to name a few. Most relevant to women in engineering is the prolific research on self-efficacy beliefs in relation to academic achievement (e.g. Lent, Brown, & Larkin, 1984) and to career choice (e.g. Betz & Hackett, 1981).

Gender Differences in Science, Math and Technology Self-Efficacy and Achievement Prior to Choosing Engineering Major[1]

Since engineering is not typically taught in the pre-college curriculum, self-efficacy in the areas of science, math and technology (namely computer use) are most relevant to preparation for undergraduate engineering education. Research on academic self-efficacy consistently shows that higher levels of self-efficacy produce greater levels of persistence and higher levels of achievement, even when ability levels are the same (Zimmerman, 1995; Schunk, 1995). This relationship is less consistent when gender and academic subject are considered. In the late 1980s there was ample evidence of girls' lower computer related self-efficacy compared to boys (Bandura, 1997) but there is more recent evidence that this relationship has changed (Solvberg, 2003). In science, girls sometimes report higher self-efficacy and achieve higher grades than do boys, but not always. Looking at high school students, Smist (1996) found that boys had significantly higher self-efficacy for chemistry and laboratory work, while there were no gender differences for biology and physics. Brittner's (2002) and Britner and Pajares' (2001) studies found that middle school girls reported stronger science self-efficacy and also received higher grades in science class. There are no longitudinal or meta-analytic studies on self-efficacy and science or technology, so it is difficult to draw firm conclusions on gender differences at different educational levels in these areas. Further, studies use different instruments and sampling procedures do not always allow for generalizability of findings. More research, perhaps examining gender differences in the sources of self-efficacy or investigating how measurement instruments may produce different findings, may offer more clarity regarding why the above noted gender differences appear.

Gender Differences on Nationally Administered Science Achievement Tests

Contradictory evidence on gender differences in science achievement abounds. Science score differences in 1999 on a 30 year longitudinal assessment favor males at ages 13 (score of 253 for girls and 257 for boys) and 17 (score of 297 for girls and 314 for boys), while males and females had similar scores at age 9 (score of 223 for girls and 228 for boys) (Results Over Time - NAEP Long-Term Trend Summary Data Tables, 2000. NAEP is the National Assessment of Educational Progress). The Nation's Report Card: Science shows that males had a higher average score than females in 2000 at grades 4 (147 for girls and 153 for boys) and 8 (147 for girls and 154 for boys), but the two had similar scores in grade 12, 145 for girls and 148 for boys) (O'Sullivan, Lauko, Grigg, Qian, & Zhang, 2003). Differences are statistically significant.

Self-efficacy researchers have devoted more attention to mathematics than the previously mentioned subjects, perhaps because assessment instruments in mathematics are more clear-cut (Britner & Pajares, 2001). Girls in mathematics very rarely report higher levels of self efficacy than their male peers, but do sometimes exhibit higher achievement levels. For example, Pajares' (1996) found that gifted girls in a mainstreamed algebra class performed better than boys in mathematical problem solving, although girls did not differ from their male peers in level of expressed self-efficacy for mathematical problem solving. After presenting an extensive review of current research on gender differences in mathematics self-efficacy, Pajares (in press) summarizes the findings along four points. First, although a number of studies have failed to find differences, most studies show that male students report stronger perceived mathematics self-efficacy than do female students. Second, any differences detected tend to begin in middle school and increase with age. Third, gender differences in mathematics self-efficacy do not favor female students at any academic level. And finally, self-efficacy gender differences favoring boys are present when actual achievement is equivalent and even when girls perform better.

Gender Differences on Nationally Administered Mathematics Achievement Tests

Gender differences in average mathematics scores are not always found, and are small when present. The NAEP's Long Term Trend Assessment shows no statistically significant gender differences in mathematics scores for students at any age and also shows that males and females took advanced levels of mathematics courses in relatively the same proportions (Results Over Time - NAEP Long-Term Trend Summary Data Tables, 2000) In contrast, the Nation's Report Card: Mathematics shows that girls in grades eight (274 for girls compared to 277 for boys) and twelve (299 for girls compared to 305 for boys) had a relatively small but statistically significant difference in their average mathematics scores. There were no statistically significant 0gender differences in the average mathematics scores for fourth graders (Braswell et al., 2001).

When gender differences in self-efficacy in relation to academic achievement are found, Pajares (2002) presents several possible explanations. The first factor is that previous academic achievement provides opportunities to develop skills as well as mastery experiences that improve self-perceptions of efficacy. When controlled for, these experiences can result in the disappearance of gender differences in self-efficacy (see Pajares, 1996). The next factor is response bias, in which girls are not as willing as boys to promise that they will live up to their reported level of self-efficacy and so report lower levels of self-efficacy than they actually have. The third factor Pajares (2002) proposes as a contributor to gender differences in self-efficacy research is related to the way in which self-efficacy is usually assessed. Typically, students are asked to judge their confidence of successfully completing a certain task without comparing themselves to others. A difference in the average level of self-efficacy reported by girls compared to that reported by boys is interpreted as a gender difference in self-efficacy. In two separate studies of writing self-efficacy (Pajares, Miller, & Johnson, 1999); (Pajares & Valiante, 1999) girls reported self-efficacy equal to that of boys when assessed in the above manner but when asked to compare themselves to the boys, they believed they were better writers. A fourth and final explanation suggests that individual respondents' gender orientation – the extent to which they hold gender stereotypic beliefs – is at the heart of their responses, rather than their biological sex. For example, gender differences in motivation and achievement variables (except performance-approach goal orientation) in writing became non-significant when the researchers controlled for "feminine orientation beliefs" held by both boys and girls (Pajares & Valiante, 2001). While these explanations are offered in relation to academic self-efficacy, they may also provide insight into gender differences found in the related concept of career self-efficacy.

In summary, the research support for self-efficacy's contribution to academic achievement beyond that of ability (as demonstrated by test scores, grade point average, aptitude tests, etc.) is strong. However, when gender is considered, the connection is much less consistent. Boys may tend to overestimate their abilities and express higher self-efficacy than girls when they are actually not able to perform to their predicted level (Solberg, in press; cited in Solvberg, 2003) while girls may underestimate their abilities and report lower than necessary self-efficacy (Pajares, 2002). Gender differences in self-efficacy for science, mathematics, and technology vary by study. Finally, the correlation between self-efficacy and achievement is not consistent when gender is considered. Girls sometimes report lower or equivalent self-efficacy with respect to their male peers yet perform better than them. As subsequent sections of this literature review will suggest, it is precisely this under-researched nuance that may remain problematic for women deciding to leave undergraduate engineering programs despite their actual performance (Adelman, 1998).

Gender Differences in Self-Efficacy related to Career and Major Choice

Research findings suggest that self-efficacy for various academic disciplines can be predictive of choice of college major as well as achievement in that field. Scales designed to assess self-efficacy for completing the educational requirements for science and engineering fields correlate with students' choice of major in these fields (Lent et al., 1986). Mathematics self-efficacy is predictive of choice of mathematics-related majors (Hackett, 1985) (O'Brien, Martinez-Pons, & Kopala, 1999), and of choosing engineering in particular (Mau, 2003). Mathematics self-efficacy is also predictive of expectations of career satisfaction (McCormick, 1997). Because of this connection, it is predicted that gender differences in self-efficacy result in gender differences in major choice, but Hackett (1985) explains that the path is not direct. Mathematics preparation and gender-related socialization influences predict mathematics achievement, which in turn predicts mathematics self-efficacy. Mathematics self-efficacy then predicts both math anxiety and choosing a math-related major.

Gender differences in self-efficacy for performing certain job activities and completing various educational requirements have also been correlated with self-efficacy for success in a particular career. Betz and Hackett (1981) were the first to apply self-efficacy theory to women's career development (Blaisdell, 1998). Betz and Hackett considered self-efficacy expectations to be particularly helpful in developing their model because they saw women's sex role socialization as less likely than that of males to facilitate the development of strong career–related self-efficacy expectations, especially in fields in which women are typically underrepresented (Betz & Hackett, 1981). In their research, Betz & Hackett (1981) found that women reported significantly higher levels of self-efficacy with regard to traditional occupations compared to non-traditional occupations, while males reported no significant differences for either class of occupations. Engineering was the occupation with the greatest gender difference in self-efficacy, with 70% of males compared to 30% of females believing that they could complete the educational requirements for the occupation. Of those saying they could complete the requirements, males express a significantly higher degree of confidence. Of the twenty occupations used in the scale, women perceived the duties of an engineer to be the most difficult.

Recently, researchers interested in career development have also investigated the connections among gender, self-efficacy, career choice, and the Occupational Themes developed by John Holland (Holland, 1966). According to Holland's theory of career development, individuals' personalities can be classified into one of six types: Realistic, Investigative, Artistic, Social, Enterprising, or Conventional. For each classification there are lists of accompanying occupations considered a good match for that type of person. Betz and Schifano (2000) explain that when interest and confidence in Realistic activities are combined with those in the Investigative theme, "a large array of engineering and technical specialties becomes viable for career exploration." Gender differences in interest among the six themes occur early in life. Research on middle school students and Holland Themes shows that students believe that men are more likely to be employed in Realistic careers, that men and women are likely to be equally employed in Enterprising and Investigative careers (the category in which engineering belongs) and that women are most likely to be employed in Social careers, followed by Conventional and finally Artistic careers. Girls express the greatest interest and self-efficacy for the Holland themes in which they believed most women were employed (Lapan, Adams, Turner, & Hinkelman, 2000). Subsequent research (Turner & Lapan, 2002) produced slightly different results, with gender and career gender-typing still predicting middle school student's interest in Realistic, Investigative, and Social careers. In this study, career self-efficacy, career planning/exploration efficacy, and perceived parental support also predicted interest in all of the Holland themes. These findings are consistent with those of Bandura (2001) in which perceived occupational self-efficacy of children aged twelve through fifteen predicts "traditionality" of career choice (p. 187).

In summary, individuals choose careers and majors for which they perceive a high level of self-efficacy for the academic discipline, the job tasks, the occupation as a whole, or for the occupational classification (i.e. Holland Themes)[2]. Innovative research in the 1980s revealed the connection between women's self-efficacy in science and mathematics and major and career choices. This aspect of career choice may be changing because girls are now taking similar courses to boys in their pre-college education, are obtaining similar achievement scores and are at least sometimes reporting the same or higher self-efficacy in these areas as their male counterparts (see above). However, other aspects of gender differences in career choices, like self-efficacy for various Holland Themes, remain salient and appear to be based on traditional gender stereotypes. Self-efficacy's contribution to interest and persistence, then, may be more important for women considering engineering than its contribution to achievement (as the latter is not difficult for these talented students).

Gender Differences in Self-Efficacy of Undergraduate Engineering Students

Literature about the experiences of women in engineering frequently addresses self-efficacy and its related constructs. 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 (O'Hare, 1995; Anderson, 1994). 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 behavior 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 whether 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 (Adelman, 1998).

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 and major choice. While gender differences in "confidence" are often reported (e.g. 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 the earliest studies, Lent, Brown, and Larkin (1984 & 1987) found self-efficacy ratings to be related to better grades and longer persistence for students in technical and scientific majors but did not report findings by gender. Hackett, Betz, Casas & Tocha-Singh (1992) used several self-efficacy scales to predict academic achievement of students in engineering and found that for academic milestones self-efficacy was consistently the strongest performance predictor, as measured by grade point average. Although Hacket et al. (1992) considered gender as a variable, they found no significant gender differences in self-efficacy in their study. The authors suggest that this

[2] For further summary of research to date on career related self-efficacy, see Betz, N. (2000). Self-efficacy theory as a basis for career assessment. *Journal of Career Assessment, 8*(3), 205-222.

finding is typical of research on highly selective samples. Engineering students such as those used in their study inherently have similar backgrounds and characteristics as required by admission standards, continued enrollment in the university, et cetera. By comparing students who persisted with those who did not on factors such as level and sources of self-efficacy, Sheafers (1993) confirmed that at the college level, factors influencing the decision to persist in engineering are similar for men and women. While mastery experiences were the best predictor of self-efficacy, followed by ability and then vicarious learning, there were no differences by gender. Schaefers, Epperson, & Nauta, (1997) found that science and math self-efficacy added to the predictive ability of Schaefer's proposed model of persistence in engineering. Again, there were no significant differences in self-efficacy due to gender. Meinholdt and Murray (1999) administered the academic self-efficacy scale to a randomly selected undergraduate student sample, of which ninety percent were STEM students. Although the authors concluded that male students judge themselves as more successful than their female peers, gender differences in self-efficacy were considered "marginal" and were not statistically significant. Like all studies above, Nauta's (1997) study found a correlation between self-efficacy and the career aspirations of undergraduate women in engineering, but this study did not include male peers as a basis for comparison.

Two studies did find some statistically significant 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 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 (Zeldin, 2001; Zeldin & Pajares, 2000) 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. No studies were found that 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 se. 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.

Summary of Gender Differences in Engineering Related Self-Efficacy Research

The general trend is for girls to express lower academic self-efficacy than boys (except in the domain of language (Pajares & Valiante, 2001) and self-regulated learning (Pajares, 2002), although they often reach higher levels of achievement (counter to self-efficacy's central principle of positive rather than inverse correlation). When it comes to choosing a major or career choice, there tends to be a positive correlation between self-efficacy and choice for both males and females, divided along traditional occupational lines. Once in the engineering major, male and female students indicate similar levels of self-efficacy. The following exemplify these findings:

*Self-efficacy is correlated with academic achievement and contributes to success beyond that suggested by ability alone (Zimmerman, 1995).

*Domain-specific self-efficacy is correlated with achievement in that domain and with choice of career and major in that domain (Hackett, 1985).

*When gender is considered, the correlation between academic self-efficacy and achievement is less consistent, and is sometimes reversed (Britner & Pajares, 2001).

*Gender influences perception of self-efficacy for a particular type of career and consequently affects career choices (Betz & Hackett, 1981).

*There is little evidence of gender differences in self-efficacy in engineering majors who persist (Schaefers et al., 1997).

*No studies were found comparing self-efficacy, gender, and academic achievement of students who left engineering to those who stayed.

*There is a lack of longitudinal and meta-analytic studies in self-efficacy research addressing gender that could provide a means of addressing apparently contradictory findings.

Self-Efficacy Interventions

While building 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 of improving self-efficacy. Some examples may include hands-on experiences offering 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 likely components of most or all WIE activities. For the sake of clarity and length considerations this writing maintains a focus solely on self-efficacy interventions. However, in the real world of WIE programming, self-efficacy enhancing activities are likely to be found just about everywhere.

Formal self-efficacy interventions tend to focus either on academic or career self-efficacy, although some use a combined approach. Interventions focused on career self-efficacy usually seek to decrease career indecision by improving self-efficacy in successfully performing the tasks required to come to a well-informed decision. While these interventions have general applications across disciplines, they are particularly applicable to WIE programs. Inadequacies in career counseling have been implicated in both the failure to steer qualified women in the direction of engineering, and in the disillusionment experienced by those who do enter an undergraduate program without an accurate picture of the field (Graham, 1997; Adelman, 1998).

Interventions based on academic self-efficacy either encourage pre-college women to continue in STEM coursework or attempt to reconcile actual high achievement with perceived low-self efficacy in order to improve retention in college. Most interventions are based on enhancing one or more of the four sources of self-efficacy as originally defined by Bandura (1997): mastery experiences, vicarious experiences, verbal persuasion and physiological states, and can target participants at any age and stage of development.

As early as elementary school, children's self-efficacy for career preparation is improved through career preparation and career exposure (Ferrari, 1999), but interventions are more likely to occur at the middle or high school level. Such interventions are typically reported as in the example provided by Kraus and Hughey (1999). In their intervention, high school juniors met with a counselor twice a week for four consecutive weeks for 50 minutes. Topics included: self-appraisal, gathering occupational information, selecting goals, making future plans, and problem solving. At completion, female students' perceived career decision-making self-efficacy was greater than that of female peers in the control group, which did not receive the intervention. The impact of the intervention was assessed using the Career Decision-Making Self-Efficacy Scale-Short Form (Betz, Klein, & Taylor, 1996).

A similar treatment was developed for undergraduates by Sullivan and Mahalik (2000), who provide rich and detailed reporting of the intervention. As part of their research, undergraduate women participated in a 6-week treatment group designed to increase career self-efficacy for those with moderate to high career indecision. Participants exhibited gains in self-efficacy lasting through the 6-week follow-up period compared to women in the control group who did not receive the treatment. The intervention included discussion and experiential exercises highlighting the four sources of self-efficacy. These exercises included constructing a brief vocational history in which previous task mastery experiences were revisited; successfully completing self-appraisal and occupational exploration activities; integrating information obtained from self-assessing interests, values, goals, abilities and personal characteristics; successfully presenting their findings with other group members; researching information about occupations of interest and formulating future goals; and successfully completing initial steps in those goals.

Similarly, Solberg, Good and Nord (1994) make suggestions for enhancing career search self-efficacy based on the four sources of self-efficacy (Bandura, 1997). Interventionists can create opportunities for mastery experiences in several ways. Practice interviews, seminars, and workshops can provide participants the opportunity to practice networking, personal exploration and job search activities as well as to receive feedback on their efforts. Vicarious experiences (most helpful when the model is perceived to be similar to oneself) can be provided by allowing participants to watch others role play an interview. Examples of interventions using verbal persuasion include career counselors providing information about desirable career search behaviors, offering encouragement in acting out these behaviors, and using the seminar format to describe what actions might be necessary for achieving participants' career goals (Solberg et al., 1994). Suggestions regarding physiological arousal include developing stress management and relaxation skills. Examples such as the ones described above are prolific in the literature, providing a broad outline of an intervention and offering empirical support for self-efficacy interventions.

Most interventions take place in an academic setting where students, either individually or in a group, are provided with some form of treatment. Hall (2003) points out that career self-efficacy intervention could have a longer lasting effect when the student's family is also included. An academic or career choice perceived to be a threat to a family's culture will either be avoided or result in negative emotional consequences. Conversely, there is a high number of engineering students who have family members in engineering (Adelman, 1998). Contextual, solution-focused, and narrative approaches can help students and their families make career decisions that will be respectful of unique family identities and family dynamics.

Another type of intervention focuses on improving self-efficacy for a particular career or major choice. This type of intervention is based on the empirically supported idea, (e.g. Lent, Brown, & Larkin, 1986) that improved self-efficacy in a given discipline or skill set will improve both perceived self-efficacy in careers related to that academic discipline as well as the chances of that career being chosen. One such intervention focused on increasing self-efficacy on the Holland Themes relevant to engineering for college students (N. Betz & R. S. Schifano, 2000). In this study college women with a moderate interest but low confidence in realistic careers showed improved self-efficacy for realistic careers (using tools, assembling, building, operating machinery) following a hands-on intervention. The intervention focused on building, repairing and construction activities. First professional men and women demonstrated how to complete the tasks (vicarious experience), and then participants completed the tasks themselves (mastery experience), receiving encouragement from each other and the instructors along the way. Participants also did relaxation exercises to reduce anxiety during scheduled breaks between activities. Several measurement instruments were used: the Skills Confidence Inventory (see below), the Occupational Self-efficacy Scale (see below) and a researcher-developed measure of interest in Realistic activities (included in article). Self-efficacy expectations of participants increased significantly for both the Realistic and, to a lesser degree, the Investigative theme.

The engineering educational environment offers multiple avenues for intervention focused on the four sources of self-efficacy. For example, hands-on experiences with tools and laboratory equipment offer an opportunity for mastery where women and girls might have had less exposure than their male counterparts, thus providing for a more equal playing ground in the laboratory (Adelman, 1998). Role models and mentors can also provide for vicarious experiences, noted to be especially important in more challenging situations where one's image is not well represented (Bandura, 1994). Positive relationships with faculty and feedback mechanisms that include positive verbal persuasion may be too rare in engineering (Seymour, 1995), and an increase could provide the encouragement talented women need to stay in the program. Interventions based on the physiological component of self-efficacy tend to focus on biofeedback for stress and anxiety reduction. Such interventions could be useful for students in stressful situations such as taking tests or giving presentations. Upon close inspection, most WIE programs are likely to be implicitly infused with self-efficacy enhancing measures. The following programs have made the improvement of participant's self-efficacy an explicit goal.

Multiply Your Options (MYO) is a one-day, two session conference for middle school girls designed to expose them to female role models in science, mathematics, engineering and technology. The first session involves hands-on workshops or problem solving activities conducted by female facilitators with science, mathematics, engineering and technology focused careers. The second session consists of an interactive panel activity called "tool clues". During this session, female role models display objects brought from their work places that provide clues about their profession. In small groups, the girls try to determine what each woman does for a living. The program seeks to address all four sources of self-efficacy: vicarious learning and verbal persuasion is provided by the invited speakers, mastery experiences are provided through hands-on and problem solving activities, and physiological arousal is reduced by the exclusion of male peer pressure, teacher scrutiny, and grading. More details are available online at: http://www.engr.uconn.edu/~edpweb/myo/detail.html (Multiply your options: program detail, 2003).

RISE: Research Internship in Science and Engineering consists of several mentoring and hands-on components. Freshmen participate in a hands-on program with mentoring provided by upper class students. Upper class students participate in all-female research teams monitored by female faculty or advanced students. Faculty members are compensated for their contributions so that they do not become an extra burden, and the entire team attends a series of workshops that include the basic psychological foundation for the project. For online information, visit: http://www.engr.umd.edu/wie/riseII.html (New Formulas for America's Workforce: Girls in Science and Engineering, 2003).

WISE Scholars Do Engineering Research offers an eight week paid research experience during the summer for women between their senior and junior years of engineering. Bi-weekly workshops and seminars provide information meant to encourage participants to attend graduate school. Monthly networking events and mentoring are also included. This activity offers mastery experiences, mentoring, and verbal persuasion.

The authors recognize that many other such interventions exist at WIE and WISE programs around the country; these interventions are provided simply as a sampling of what may be effective.

Assessment of Self-Efficacy

Researchers have given the measurement of self-efficacy considerable attention. Of primary importance in developing or choosing a self-efficacy assessment instrument is choosing one that is "domain specific." In other words, it must measure an individual's confidence in successfully completing specific tasks such as succeeding as a practicing engineer, studying engineering at the undergraduate level, etc. Since self-efficacy scales are so specific, they are also prolific, as is the research about the scales themselves. Because of the quantity of research on self-efficacy assessment, the overview will list the most popular instruments and direct the reader to informative sources of information on self-efficacy assessment.

Multiple self-efficacy scales and detailed information pertaining to self-efficacy and developing self-efficacy assessment instruments are available through the website of Professor Frank Pajares at Emory University (http://www.emory.edu/EDUCATION/mfp/self-efficacy.html). Instruments available there include self-efficacy scales for mathematics self-efficacy, writing skills self-efficacy, science laboratory skills self-efficacy, self-efficacy for self-regulated learning, academic self-efficacy and academic help-seeking, as well as an updated and version of Bandura's (2001) *Guide for constructing self-efficacy scales (Revised)* and links to other self-efficacy resources.

Self-Efficacy Instruments

The following instruments appear frequently in the literature on self-efficacy, careers, and academic achievement. There are indeed many, many more instruments available. Since self-efficacy is context sensitive, choose or create an instrument that most closely measures the exact activities the respondent is considering.

Career Decision-Making Self-Efficacy Scale (Taylor & Betz, 1983)*:* This scale is used to assess student's ability to make career decisions. The instrument consists of 50 items. Students rate their confidence in succeeding in each on a ten point Likert-type scale. More information on this scale is available in from the Educational Testing Service at: http://www.ets.org/testcoll/order.html. For more information on reliability see: (Nilsson, Schmidt, & Meek, 2002).

Mathematics Self-Efficacy Scale, Forms A and B (MSES) (Betz & Hackett, 1983)*:* This scale measures beliefs regarding ability to perform various math-related tests and behaviors for use in research and counseling. Reviews of this instrument are available in the Mental Measures Yearbook (Buros, 1938-) and from the ERIC Document Reproduction Service (see (Pajares & Langenfeld, 1993)) at http://www.edrs.com/default.cfm .

Occupational Self-Efficacy Scale (Betz & Hackett, 1981)*:* The occupational self-efficacy scale developed by Betz and Hackett for use by researchers and counselors measures the career-self-efficacy of ten traditionally male and ten traditionally female occupations. Information, including the instrument and accompanying validity studies, is available online from the authors at: http://seamonkey.ed.asu.edu/~gail/occse1.htm and from the Educational Testing Service at: http://www.ets.org/testcoll/order.html

Self-Directed Search (Holland, 1985)*:* While not a self-efficacy instrument, this is a tool sometimes used in tandem with career-related self-efficacy assessments. It is used to determine individual's level of interest and self-perceived competency each of six occupational classifications. Many variations are available, for a listing search the educational testing service site at: http://testcollection.ets.org/ .

Self-Efficacy for Academic Milestones (Lent et al., 1986)*:* Students rate their ability to successfully perform specific critical accomplishments on the path to success in science and engineering majors on a 10-point scale.

Self-Efficacy for Technical/Scientific Fields – Educational Requirements (Lent et al., 1984)*:* This scale asks respondents to indicate their confidence in their ability to complete the educational requirements of 15 science and engineering fields on a 10-point scale.

Skills Confidence Inventory *(Betz, Borgen, & Harmon, 1996)*: This 60-item instrument assesses respondents' confidence in their abilities to perform various work-related tasks for the sake of career planning.

Conclusions

There is strong research support for the role of self-efficacy in academic and career choice and achievement, although research findings regarding gender differences in self-efficacy and academic achievement are less consistent. Successful interventions can be developed to address any or all sources of self-efficacy along the educational path, and several WIE programs are utilizing this approach. The development of assessment instruments has been integral to self-efficacy theory and research, resulting in a number of useable pre-existing instruments and ample guidance for creating original assessment tools. For the WIE program director, the construct of self-efficacy provides an unusually cohesive unification of theory, research, interventions, and assessment to be used as a singular focus or integrated into multiple components of WIE activities.

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