

Thinking *Inside* the Box: Self-Efficacy of Women in Engineering*

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We describe an initiative to investigate how institutional practices implementing information technology can promote retention of women in engineering through enhancing their self-perceptions and motivations. The initiative uses the self-efficacy theory to implement teaching techniques designed to promote educational attributes: greater motivation, effort, and persistence. The particular method we chose was to design and teach a course to educate women in the area of computer problem diagnosis and repair. Continued demonstration and reinforcement of the proficiency attained by the women throughout the course in computer technology distinguished them among colleagues and established an environment conducive to enhancing students' feelings of self-efficacy and associated control beliefs.

INTRODUCTION

AT THE BEGINNING of the new millennium, women remain a minority in the engineering disciplines. Despite recent gains in the number of women enrolled and earning undergraduate engineering degrees [1] university engineering programs nationwide continue to struggle to attract and retain women [2]. Today, women students represent approximately 18% of the total number of students studying in engineering undergraduate programs in the United States (US). At The Pennsylvania State University (Penn State) University Park campus, the number of women enrolled and earning undergraduate degrees closely approaches that figure. However, at the Penn State Altoona campus, at approximately 12% the percentage of female engineering students is significantly below the US average. While the number of women entering the engineering program continues to increase, strategies directed toward improving the representation which are particular to this campus and to this region are imperative.

The majority of the student enrollment at the Altoona campus is drawn from the surrounding area—rural south-central Pennsylvania [3]. The predominate demography of south-central Pennsylvania is a middle-class workforce with conservative attitudes and traditional family values. Consequently, the women engineering students tend to be representatives of their environment.

Although various factors may account for the absence of women from science and engineering, we do know that 'environmental' influences contribute significantly [4]. Isolation, exclusion from networks and lack of role models constitute a major source of deterrence for women in engineering. As a result of the environmental influences,

women aspiring to become engineers tend to have weaker beliefs in their self-worth or competence to successfully complete an engineering program than their male counterparts [5]. Additionally, unlike young boys, girls are not encouraged to investigate the 'hands-on' nature of mechanical/practical problems—an important issue in laboratory settings. In response, young girls interested in these programs are discouraged, or, at best, provided with little educational foundation in this area and arrive at the university with these perceived 'odds against them' [6].

Considerable research is available that examines such gender differences in self-perception and on women students who feel compelled to leave engineering programs due to loss of self-confidence in a competitive environment [7]. In one particular area, using the self-efficacy theory, researchers have explored the relationship between the above perceptions and their attendant effects on academic achievement and success [8]. Fewer studies explore how the method of teaching engineering could be fundamentally altered to foster self-efficacy while still mastering the discipline.

Self-efficacy is the judgment that an individual makes about his or her ability to execute a particular behavior [9]. Self-efficacy has been used as the theoretical framework in the present study because it has consistently been found to be associated with academic motivation, performance and achievement [8]. However, we have little information about the types of institutional practices or climate that foster students' confidences and motivations to pursue engineering degrees or careers [10]. It seems propitious to explore how the method of teaching in the engineering and science fields can be fundamentally altered to foster self-efficacy while still mastering the discipline. To that end, this work describes our current efforts to develop a mechanism to empower women both

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by instilling confidence in their abilities to approach and solve ‘hands-on’ engineering problems and by attacking both societal beliefs and self-perceptions regarding the role of women pursuing engineering degrees. The purpose of this paper is to acquaint the reader generally with the defining characteristics of self-efficacy beliefs and outline the use of the self-efficacy construct in our model teaching methods in computer repair courses. This is followed by a description of the methodology employed, a presentation of the results, and finally, a discussion of the findings, including strategies for future direction in effective instruction and learning.

More than two decades have passed since Professor Bandura first introduced the construct of self-efficacy with the seminal publication ‘Self-efficacy: Toward a Unifying Theory of Behavioral Change’ [9]. We briefly review his construct to place our initiative in perspective.

CONSTRUCT OF SELF-EFFICACY— A BRIEF OVERVIEW

Bandura defined self-efficacy as a ‘judgment of one’s ability to execute a particular behavior pattern’ [11]. Self-efficacy beliefs form a central role in the regulatory process through which an individual’s motivation and performance attainments are governed. According to this view, what people know, the skills they possess, or what they have previously accomplished are not always good predictors of subsequent attainments because the beliefs they hold about their capabilities powerfully influence the ways in which they behave. Self-efficacy judgments also determine how much effort people will spend on a task and how long they will persist with it. People with strong self-efficacy beliefs exert greater efforts to master a challenge

while those with weak self-efficacy beliefs are likely to reduce their efforts or even quit [12].

Self-efficacy beliefs have received increasing attention in educational research, primarily in the area of academic motivation [8]. Researchers have reported that students’ self-efficacy beliefs are correlated with academic performance and achievement [13]. Consequently, their academic performances are, in part, the result of what they come to believe that they have accomplished and can accomplish and, as such, explains why students’ academic performances differ markedly when they have similar ability [13].

The process of creating and using these self-beliefs is an intuitive one: individuals engage in behavior, interpret the results of their actions, use these interpretations to create and develop beliefs about their capabilities to engage in subsequent behavior in similar domains, and behave in concert with the beliefs created [13]. Self-efficacy theory suggests that there are four major sources of information used by individuals when forming self-efficacy judgments (Fig. 1) [9]. In order of strength, the most influential source of these beliefs is performance accomplishments, where individuals gauge the effect of their actions and their interpretations of these effects help create their efficacy beliefs. Outcomes interpreted as successful raise self-efficacy; those interpreted as failures lower it. Bandura’s emphasis that one’s mastery experiences are the most influential sources of self-efficacy information has important implications for educational efforts which could shift emphasis and focus on efforts to raise competence and confidence primarily through successful experience with the performance at hand—through authentic mastery experience [14]. The second source is vicarious experience, often referred to as modeling, which is gained by observing others perform activities successfully. Part of one’s vicarious experience

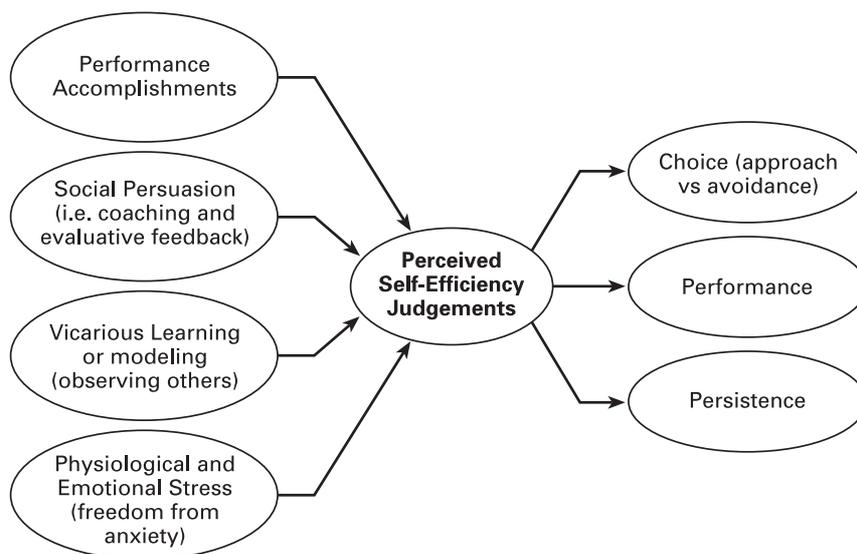


Fig. 1. Sources of self-efficacy.

also involves the social comparison made with other individuals.

Individuals also develop self-efficacy beliefs as a result of social persuasion, involving exposure to verbal judgments that others provide. Through these persuasions, people are led into believing that they can cope successfully with specific tasks. Persuaders must cultivate people's beliefs in their capabilities while at the same time ensuring that the envisioned success is attainable [15]. The final source of information is physiological and emotional states. Often, people gauge their confidence by the emotional state they experience as they contemplate an action. Emotional reactions to a task (e.g. anxiety) can lead to negative judgment of one's ability to complete the tasks [15].

Effects of self-efficacy beliefs in academic performance and career choice

Self-efficacy beliefs influence the students' educational process in several ways. Results of various studies have demonstrated the mediational role of self-efficacy beliefs in a wide variety of individual behaviors, including performance attainments and the selection of career choice. Researchers have demonstrated that self-efficacy beliefs influence these attainments by influencing efforts, persistence, and perseverance [16]. For example, researchers have reported that the mathematics self-efficacy of college undergraduates is more predictive of their mathematics interest and choice of math-related courses or majors than either their prior math achievement or math outcome expectations and that male undergraduates report higher mathematics self-efficacy than do female undergraduates [17].

Similarly, in their benchmark study comparing students persisting in the science and engineering undergraduate degree programs with those who chose to switch to another field of study or drop out, Seymour and Hewitt found that there were no real differences in high-school preparation or effort expended in their coursework between these groups [7].

In many cases, then, women avoid or leave engineering related courses because they suffer from loss of perceived academic competence or underestimate their capability rather than because they lack competence or skill [18]. The implication, then, is given the situation in which many young women find themselves as a result of lack of correspondence between their efficacy beliefs and performance attainments, enhancing these attainments alone will not correct the problem. Any program will have to be designed to enhance career and academic efficacy beliefs. Efforts to identify and alter inaccurate underestimations of such capabilities should prove beneficial.

TEACHING METHODOLOGY

The construct of self-efficacy appears to be particularly well-suited to applying to increase

the persistence of women in engineering programs. While there are many programs designed to increase the academic ability of women in engineering, this model course, simply put, is designed to increase the women's *belief* in that academic ability. In developing our model to affect a change in self-perception regarding women in engineering programs, we considered how to address the particular concerns that dissuade women from the engineering field of study. The primary perceptions we considered and investigated were:

- lack of self-confidence in one's ability to perform engineering and technical tasks, particularly spatial and mechanical tasks [19];
- decrease of confidence levels during their college careers, a decrease that is unrelated to actual decreases in their ability or achievements [20];
- perception of engineering and some science disciplines as male professions, a concern that is exacerbated by primarily male portrayals of engineers and scientists [21];
- tendency to attribute success to external factors and to attribute failure to personal lack of ability, while the reverse is true for men [22];
- perception that women who are confident in science and engineering classrooms often elicit negative responses from their male peers [7]; and,
- tendency to hide academic abilities to avoid alienation and ensure social success [23].

To respond to these challenges, we considered a model course and teaching method directed toward women in engineering that would enhance career and academic beliefs in the following areas:

- awareness of and respect for one's particular learning style and technique with a recognition that different students learn in different ways;
- awareness of interpersonal and intellectual skills that allow them to challenge and change their own and societal attitudes toward women in engineering;
- opportunities to become role models for each other and to encourage and support each other; and,
- opportunities to develop convictions that they have the capacity to complete their engineering degree program.

In summary, the considered methodology is intended to replace the perceived 'odds' against the women engineering students with perceptions and beliefs designed to motivate them and increase the likelihood that they will continue in the engineering program using the sources of self-efficacy.

Computers: 'thinking inside the box'

Admittedly, the recognition and replacement of such perceptions presents an ambitious agenda. However, the anomalous nature and associated mystique of computers provides a unique instructional opportunity. Therefore, as a model, we chose to offer a 2-credit computer repair and

diagnostics course designed specifically for women in engineering. We specifically chose the area of computers for the following reasons beyond transferring knowledge about computer skills:

- *Information technology*: Information technology is perceived as 'gender-neutral.' That is, unlike most scientific fields, little or no social stigma is attached to computer expertise. If you are an expert in the computer field, you are a 'guru,' not a 'geek' [24].
- *Task specific*: The computer repair class, being designed as 'hands-on' can focus on task performance. Self-efficacy theory suggests that self-efficacy judgments are relatively task specific [25].
- *Relevant experience and training*: In computer repair, the initial 'learning curve' is small. Distinct from other sciences, one can quickly gain a respectable level of expertise that sets one apart from other computer users whose level of knowledge in computer repair appears to be drastically lower. Relevant training (i.e. how to work effectively with computers) contributes information about personal accomplishments. For example, studies have shown training to be an important source of information and experience for changing self-beliefs [26].
- *Laboratory experience*: Consistent with the previous example, the student's experience and training with the computers that are available for use in the laboratory is likely to influence self-efficacy assessments. Thus, being familiar with 'hands-on' technology in a laboratory where they become familiar with current equipment boosts self-confidence. This confidence in a laboratory setting increases involvement in traditional engineering laboratories where men commonly dominate the work.
- *Modeling*: Use of effective computer repair technologies by the student's professors are vicarious sources of self-efficacy information. Again, as opposed to the lecture-oriented courses, the 'hands-on' nature of this class allows for modeling opportunities which can boost efficiency by teaching effective ways of dealing with challenging situations [11].
- *Environmental factors*: Positive environmental factors will positively impact an individual's performance belief [27]. With few, if any, male counterparts in the course, the women students are required to assume the leadership role of investigator and are actively encouraged to experiment with technology. This is an important cue to individuals in determining their beliefs that they can accomplish certain tasks.
- *Supportive environment*: Researchers have indicated that deficiencies from being in an environment that questions one's presence are important predictors of persistence [28]. The course engenders situations where the students receive respect and gratitude.

- *Interaction with peers*: The course allows the women to become role models themselves as they develop positive beliefs in their scientific ability and become examples to change the attitudes of their female peers, as well as their male counterparts.

Specific elements of the course

The course, directed towards female engineering students, was specifically designed to allow the participants to explore their own self-perceptions and their relationship to engineering and technology. Consequently, the sources of efficacy information (Fig. 1) were considered in establishing the teaching curriculum. Performance accomplishments, vicarious learning or modeling, freedom from anxiety with respect to behavior and verbal persuasion and support from others were all integrated into the curriculum. The class begins with an interactive discussion about why the students chose to participate in the course and what they expect. Through this directed discussion, the instructors provide an opportunity for the students to present their experiences with computers through ratings of 'users only, some diagnostic/repair experience, or significant experience'. In the six offerings of this course, (with a total of 93 participants and 85 being female), only 3 women claimed to have significant experience. The vast majority of the participants were in the first category of 'users only' even though they expressed a longstanding interest in computer diagnostics/repair. When queried as to why they had not pursued their interest, the most common responses were:

- fear of repercussion (if something went wrong) from authority figures—parents, teachers, spouses, or even their brothers;
- fear of breaking something; and,
- belief that special training is necessary just to *learn* how to fix a computer.

Although intrigued by computer repair, the students were overwhelmingly fearful of doing something 'wrong' or damaging the equipment. Our course model was specifically designed to rout the belief that 'damaging the equipment was intolerable'. Or, as Edward John Phelps noted, 'The [wo]man who makes no mistake does not usually make anything' [29].

To this end the students are paired together and are presented with the assignment of completely dismantling a non-working computer and then reassembling it. Initially, the students typically proceed with undue caution. We would wonder how could they further damage a non-working computer? Nevertheless, their trepidation is obvious. The instructors demonstrate opening the box (a difficult task on most IBM-brand machines) with total disregard for the equipment or the 'correct' way; thereby encouraging the participants to become 'physical' with the machines. As the students disassemble the machines, the instructors

introduce the basic components and structure of the personal computer.

As a result of these exercises, the students now believe that entering the box can not only be fun but holds no negative consequences—at least within this *safe* environment. Now, we attempt to replace the fear-based, undue caution with a sense of appropriate, application-based caution. This process is completed in two steps. First, a two-hour laboratory presents the participants with a challenge similar to the previous one. However, the stakes are raised by presenting the teams with bootable (but otherwise nonfunctioning or outdated) computers. The students are informed that this assignment is not graded based on the final condition of the computer. Instead, the teams are graded on the quality of their notes as the machines are disassembled and the use of their notes as the machines are reassembled.

As before, the task is to completely disassemble and reassemble the entire computer. However, the goal is now to restore the computer to bootable condition. Still, the participants remain well aware that damaging the components of these machines holds no consequences. In the few cases where components are damaged, the teams are directed to similar machines to salvage replacement parts. Here, the instructors play a significant role in both outlining the organized approach to the task, detailing the function of the computer components (e.g., expansion cards, cabling, and types of memory and their required configurations), and component safety issues such as static electricity. More importantly, through verbal persuasion, the instructors reinforce the participants' newly developed perceptions and confidence.

The teams are then presented with new fully functional machines. (At the time of this writing,

Pentium II machines are being used in this segment.) The assignment has two components. First, and now familiar, the students are to remove all the computer components, reassemble, and boot the computer to Windows. Second, the hard drive is to be reformatted and an operating system is to be installed. To present the concept that the students can actually do it all, we introduce this assignment as 'making a computer from scratch'. As such, building a new computer from its constituent components, installing the operating system, and booting to Windows instills significant student confidence.

The Pentium II machine has another creative instructional advantage. The look of the components of the machine is significantly different from the 486- and Pentium I-based computers used in the previous two laboratory assignments. Armed with three weeks of working with the basic components of a personal computer, the distinctive look and format of the Pentium II computer challenges the participants with the idea that the fundamentals are the same; only the details change—a common engineering education construct.

As a final step in working with the hardware, the participants must diagnose and repair intentional bugs introduced in the machines (loose cables, improperly seated expansion cards, defective RAM and faulty power supplies, etc.). Generally, the participants have little difficulty in the detection and repair of these bugs. In fact, they have encountered most of them in their work building the computers in the previous laboratory assignments.

At this juncture, the course is at its midpoint chronologically in the semester and in computer topics. Technologically, the first half of the course

Table 1. Sample survey

Participant Questionnaire: Computer Repair and Diagnoses				
Rate your level of agreement to the statements below. Use the numbered rating scale provided.				
1	2	3	4	5
Strongly Agree	Moderately Agree	Neither Agree nor Disagree	Moderately Disagree	Strongly Disagree
				Agreement (1 –5)
1	I feel apprehensive about using computers.			_____
2	It scares me to think that I could cause the computer to destroy a large amount of information by hitting the wrong key.			_____
3	I hesitate to fix a computer for fear of making mistakes I cannot correct.			_____
4	Computers are intimidating to me.			_____
5	I received adequate training to perform minor maintenance on my computer			_____
6	I am confident that I can perform minor maintenance on my computer.			_____
7	I received adequate training on computer software and computer function.			_____
8	I am confident that I can successfully perform hands-on computer repair work.			_____
9	I am confident that I can solve most engineering problems, if I invest the necessary effort.			_____
10	Thanks to my resourcefulness, I know how to handle difficult engineering laboratory assignments.			_____
11	It is easy for me to stick to my aims and accomplish my goals in solving laboratory problems.			_____

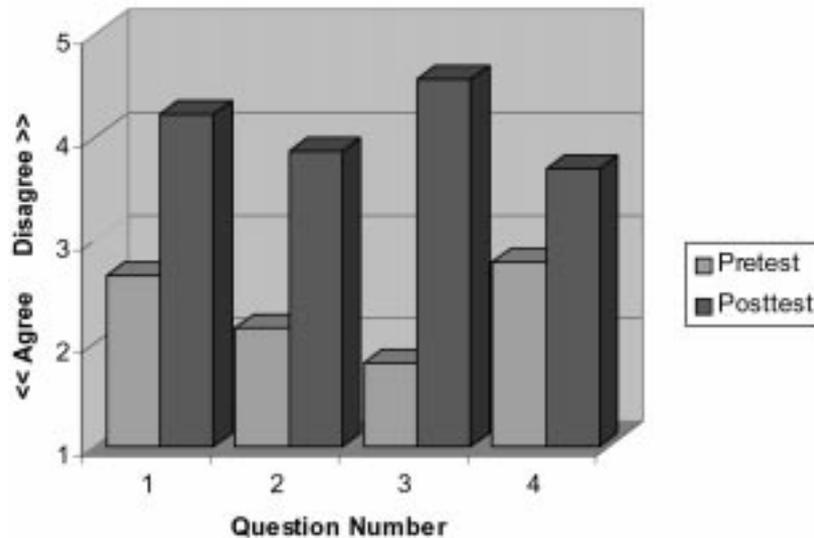


Fig. 2. Response to questions: concerning student computer anxiety.

deals primarily with hardware components. The second half introduces software issues such as installation of operating systems, program installation, updating drivers, virus protection, software maintenance of the hard drive, and introduction to the control panel. While these topics are important in achieving the goals of the course, the foundation of the sources of efficacy information has been laid and then used through the course.

DISCUSSION

We examined the students' beliefs and perceptions at two stages of the course. Initially, we developed an 11-question instrument; four of the questions focus on the students' beliefs about their computer ability; four of the questions focus on the students' beliefs of their experience in information technology; and the remaining questions focus on generalized engineering self-efficacy. A sample instrument of these eleven questions is included in Table 1. A 5-point Likert scale was used. Due to the size of the student sample, no precise statistical significance can be attached to the findings. However, the results provide implications for future directions in teaching endeavors.

The survey was provided to the students at two stages—the inception and the completion of the class. At both times, the survey was interspersed with preliminary questions, not mentioned here, to provide other computer background information. Preliminary instructions were given prior to each student survey to establish the appropriate judgmental set. The students were asked to judge their current operative capabilities, not their potential capabilities or their expected future capabilities. Only female responses were considered due to the low number of male participants in the classes.

Figure 2 provides a comparison for the different stages for Questions 1, 2, 3 and 4, dealing with

computer anxiety. Initially, these questions reflected how many students possessed a high level of anxiety relating to the workings of a computer. Our hypothesis was that there should be, based upon the 'hands-on' experience received, a significant decrease in that belief. The results validate the hypothesis as the comparison of the students' initial and concluding beliefs reflect.

Questions 5, 6, 7 and 8 are focused on students' experiences and training. The questions were designed to ascertain the perceived effects of training on the students' self-efficacy beliefs. The hypothesis was that there would be a significant positive correlation between previous and current student training and computer self-efficacy beliefs to perform certain tasks. Thus, the responses for questions 5 and 7 should be similar to those for questions 6 and 8. A comparison of the topics for those four questions at both stages showed mixed results. Looking at the four questions, Fig. 3 shows the expected increase in confidence (response numbers are lower) at the conclusion of the class. However, the responses showed a lower confidence level in their ability to perform the actual task than their confidence in the training and receiving experience.

Finally, the questionnaire contained three questions dealing with a generalized sense of self-efficacy aimed at questioning the students' scale of personal competence with a variety of situations. Figure 4 provides a comparison of the general perceived self-efficacy results at the inception and conclusion of the class. Our hypothesis was that there should be a correspondence of the results of these questions to the students' increase in confidence in specific task-related computer situations. A comparison of the topics show mixed results. For example, in question 9, there was no significant difference between the self-perceptions at the inception and conclusion of the class. However, looking at questions 10 and

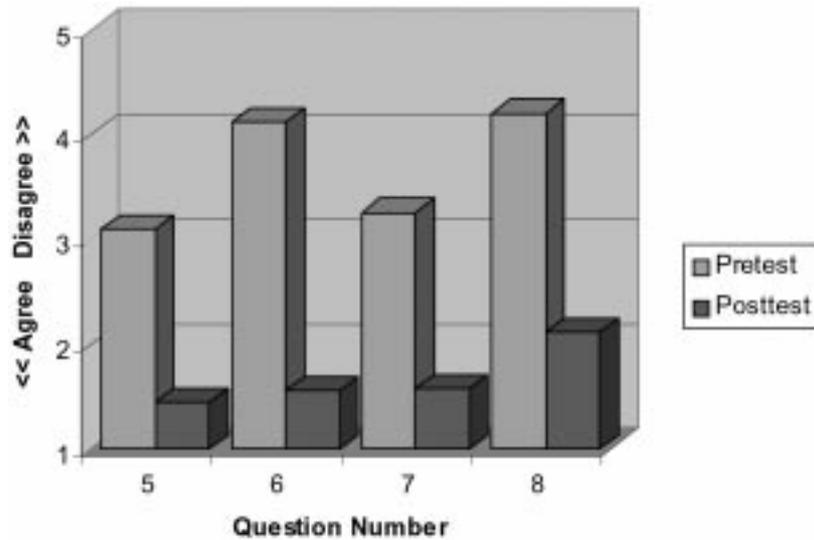


Fig. 3. Responses to questions on students perceived effects of training on their self-efficacy beliefs.

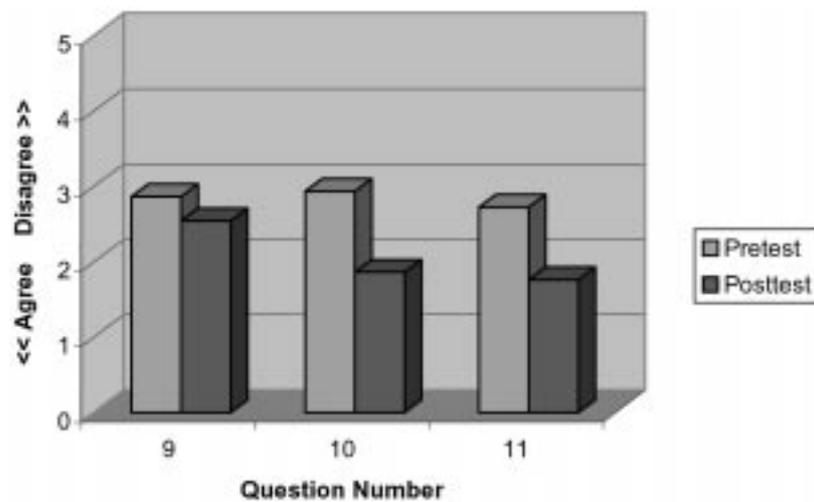


Fig. 4. Response to questions on students' self-rating of competence in a variety of engineering education situations.

11, there is the expected higher response in general perceived self-efficacy.

Overall, the results from this initiative were encouraging and suggest that teaching initiatives can be designed to maximize the development of self-efficacy beliefs.

CONCLUSION

This construct of self-efficacy is an idea that has a pervasive influence on human endeavors, including those in achievement in education. Overall, the results obtained herein indicated that women students' self-efficacy assessments can be enhanced. The current study provides a basis for further research in that area. This work is part of a larger NSF funded project that addresses these issues. The success of this course is measured in its ability to achieve the primary goals of changing the participants' beliefs regarding women's role

and abilities as engineers. The course's experiential method of learning allows the participants to discover their own belief structure about themselves.

This computer-based approach is an initial step in removing the barriers that inhibit the full participation of women in the engineering workforce. Students with high self-efficacy will approach difficult tasks as challenges to be mastered rather than dangers to be avoided, have greater intrinsic interest in activities, set challenging goals and maintain a strong commitment to them, heighten their efforts in the face of failure and more easily recover confidences after setbacks. Using the basic concepts of this approach, we can do more to facilitate key transition points in engineering education.

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