"Thinking ~~Outside~~ Inside of the Box:" Retention of Women in Engineering.

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Abstract *- This paper describes a current effort at Penn State Altoona to address the issue of low retention of women in science and engineering. This effort also is designed to contribute to the long-term advancement of women in these fields throughout their careers. The approach taken is to challenge women students to recognize their beliefs and self-perceptions regarding their relationship with engineering and thus provide them with the opportunity for positive change. As a consequence, their actions have potential to change stereotypical attitudes towards women in the sciences. The particular method we chose to accomplish these goals is to design and teach a course to educate women in the area of computer problem diagnosis and repair. The course includes diagnosing and troubleshooting software and hardware problems, and upgrading and maintaining the systems as well as an introduction to component functionality and integration. Demonstration of the proficiency attained by the women in computer technology distinguishes them among colleagues. This distinction results from the well-recognized prestige associated with this level of knowledge of computer technology.*

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 20% of the total number of students studying in engineering undergraduate programs nationwide. At The Pennsylvania State University (Penn State) main campus, the number of women enrolled and earning undergraduate degrees closely approaches that figure. However, at the Penn State Altoona campus, the percentage of female engineering students is significantly below the national average at approximately 13%. 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 southcentral Pennsylvania [3]. The predominate demography of southcentral 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, we do know that "environmental" influences contribute significantly [2]. Isolation, exclusion from networks and lack of role models constitute a major source of deterrence for women in engineering. The dearth of senior women engineers and role models in Penn State Altoona's service area (rural southcentral Pennsylvania) is particularly striking. Further, widespread acceptance in the community of a stereotyping of engineers as stolidly male means that women engineers have few role models with whom to identify, few female mentors to encourage them and they are ill-prepared to deal with the perceived social stigma of entering a male-dominated profession.

A further result of the environmental influences is the lack of self-confidence often found in women aspiring to be engineers [4]. In the Penn State Altoona service area, school counselors and teachers are often ill prepared to provide girls in the *primary and secondary* schools with the encouragement they need to pursue their interest in science and math. 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."[5]

Consequently, retention of women who do enroll in the engineering programs presents a challenge that must be addressed. To address this challenge, engineering pedagogy as a whole is being examined [6]. Educational processes that focus on which methods best work for educating women are being considered. This work describes our current efforts to develop a mechanism to empower women both 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

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engineering degrees.

OUR METHODOLOGY

In developing our model to affect a change in self-perception and societal beliefs regarding the role of women in an engineering program, we considered how to address the particular concerns that dissuade women from the engineering field of study. As mentioned above, in the Penn State Altoona service area, the primary perceptions we considered and investigated were:

- Self-confidence in one's ability to perform engineering and technical tasks;
- Opportunity to interact with role models;
- Surrounding social climate and criticism of their career choices; and,
- Challenges related to learning styles that may conflict with institutional environments and university instructional practices.

To respond to these challenges, we considered a model course that would influence improvement in the students' abilities in the following areas:

- Awareness of and *respect* for one's particular learning style and technique;
- 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.

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 (not just the use – the actual appeal to the masses of the technological aspects) provides a unique instructional opportunity. Therefore, 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:

- Computer 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."
- 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.
- Additionally, the "hands-on" pragmatic nature of computer repair allows the women – in a female-friendly environment – to experiment with how they approach laboratory style problems.
- Leadership abilities are fostered as the computer course provides an atmosphere where women are actively encouraged to experiment with technology. In fact, as there are few, if any, male counterparts in the course, the women are required to assume the leadership role of investigator. This further encourages development of self-confidence as a researcher and leader.
- In computer repair, the initial "learning curve" is small. Distinct from other sciences, one can quickly attain a *respectable* level of expertise that sets them apart from other computer users whose level of knowledge in computer repair appears to be drastically lower.
- The course engenders situations where the students receive respect and gratitude. That is, the ability to diagnosis and repair computers is generally accepted as a respected skill, regardless of gender, age or occupation. Consider the situation where a teenager is able to solve the computer problems in an adult's machine. The belief of the adult is one of awe and gratitude regarding the abilities of the teenager.
- 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 was specifically designed to allow the participants to explore their own self-perceptions and their relationship to engineering and technology. 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.[3] The vast

[3]. Perhaps if one had significant computer knowledge, one would feel no need to take the course. However, of the many men expressing desire to attend the course, most claimed to

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.

Each class contained 2 to 6 female participants (24 out of the 85 total or ~28%) who claimed to possess "some" to "significant" working knowledge of computers. (The level of "some knowledge" was defined as the ability to install RAM.) However, of these participants, approximately 85% stated that they had a brother who routinely worked on computers and through their influence, they developed a level of comfort with computer repair. Of the 24 female participants with experience, *none* of them claimed to have learned their computer skills themselves. Second, *none* of them claimed to have learned their skills from other female peers. The remaining 15% (3 students) learned computer repair through some formal training in either high school or between high school and college. Additionally, 22 of the 24 participants in this category still claimed some trepidation in simply opening the computer case and modifying the RAM. Consequently, the initial classes were devoted to replacing the students' fear-based caution with appropriate application-based caution that stems from an analysis of the problem and not from institutionalized stereotypes.

Dispelling the Fear

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 notion (belief) that "damaging the equipment was intolerable." During class discussions, Dr. Shull tells the story of his dissertation advisor (Dr. J. W. Wagner) who proudly kept photographs of equipment destroyed by his graduate students – very expensive optical equipment. Ironically, most of the equipment was destroyed during the students' attempt to "diagnose and repair" the faulty device. Dr. Wagner, currently dean of engineering at Case Western University, proclaimed, "If equipment is destroyed through honest investigation, this is a good thing." Or, as Edward John Phelps noted, "The [wo]man who makes no mistake does not usually make anything [7]."

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. How could they further damage a non-working computer? Nevertheless, their trepidation is obvious. To break their bondage to the fear belief, 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. Within this two-hour laboratory period, the students' transformation is clear and is exemplified by many groups' requests for a second machine to work on.

As a result, 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 dissemble and reassemble the entire computer. (Figure 1 shows a student in this process.) 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. They express an acute sense of self when they are able to successfully reboot their machine. 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, the instructors reinforce the participants' newly developed perceptions and confidence. However, the confidence issues, at this point, tend *to be associated less with fear* than with the frustration that they are incapable of understanding the machines.

As the final tier towards developing an application-based caution, the teams are 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 idea that the students can actually do it all, we

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have extensive computer repair knowledge.

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.

*Figure 1 Student working **inside** the box.*

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. However, this exercise reinforces their newly acquired confidences in their technical skills and diagnostic expertise.

At this juncture, the course is at its midpoint chronologically in the semester and in computer topics. Technologically, the first half of the course dealt primarily with hardware components. The second half introduced 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 primary focus of dispelling the fear-based belief and altering the attitudes towards technology has been completed.

CONCLUSIONS

The success of this course is measured in its ability to achieve the primary goals of changing the participants' beliefs and in the potential to change the beliefs/attitudes of society 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 that creates their relationship with this entity called the computer. It is through this understanding and awareness of their beliefs and *not* what someone else believes about them that will allow them the opportunity to change their beliefs in positive ways. This method also allows the student to honor their own learning style while challenging them to grow and expand their abilities within their learning style.

If we believe in the unique attribute of computer technology as gender neutral and that knowledge of it commands respect, then there is clear evidence in its ability to change attitudes of people external to the course. During the semester, over 60% of the class reported working on computer problems of others. Approximately 15% (12) of the female participants humorously reported some annoyance with people constantly asking them for assistance in fixing or upgrading their computers.

This computer-based approach is an initial step in removing the barriers that inhibit the full participation of women in the engineering workforce. Using the basic concepts of this approach, we can do more to facilitate key transition points in engineering education.

REFERENCES

1 National Science Foundation (NSF). 1999. "Women, Minorities, and Persons with Disabilities in Science and Engineering:" 1998 (NSF 99-338). Arlington, Va.: NSF.

2 Takahira, Sayuri, Goodings, Deborah, and Byrnes, James, "Retention and Performance of Male and Female Engineering Students: An Examination of Academic and Environmental Variables." *Journal of Engineering Education*, 87(3), 1998, pp. 297-304.

3 The Penn State Altoona Admissions Office, Internal Memorandum, 1999.

4 Hackett, G. & Betz, N.E., "Self-efficacy Perceptions and Career-related Choices of College Students." In D.H. Schuck & J.L. Meese (Eds.) *Student Perceptions in the Classroom*, pp. 229-240, Hillsdale, NJ: Earlbaum, 1992.

5 Plucker, J.A. "Secondary Science and Mathematics Teachers and Gender Equity: Attitudes and Attempted Interventions." *Journal of Research in Science and Technology,* 33(7), 1996, 737-751.

6 Barr, R. & Tagg. "From teaching to learning: A new paradigm for undergraduate education." *Change*, November/December, 1995, pp. 12-25.

7 Speech at Mansion House, 24 Jan. 1899.