Women's Manufacturing Workshop Series that Supports Inclusiveness and Skill Building in Undergraduate Engineering Education

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Abstract

During the past six years, pre-semester assessments of student skills have revealed a lack of hands-on experience by women students in the First-Year Engineering Projects course at the University of Colorado at Boulder. Moreover, instructors in this course have observed a pattern of female students choosing other activities within their teams rather than engaging in the hands-on construction aspect of product development. To address these concerns, a Women's Manufacturing Workshop (WMW) series was piloted during the 2002-03 academic year through a partnership between the Women in Engineering Program (WIEP) and the Integrated Teaching and Learning Laboratory (ITLL). Another aim was to provide women students a context for pursuing engineering through acquisition of knowledge and skills applicable to the design-build process in a low-risk setting. This paper discusses the effects of the WMW on the students, including an increase for women in their comfort with machining and other hands-on skills, and an increased likelihood that these women will remain in engineering.

Background

The Women in Engineering Program (WIEP) at the University of Colorado at Boulder (CU) identifies, expands and develops new learning opportunities for women engineering students. The WIEP fosters community among women by hosting departmental luncheons, speakers and events. These types of programs have been shown to improve retention in engineering. Recently, the WIEP and the Integrated Teaching and Learning (ITL) Program facilitated a successful, hands-on manufacturing center workshop series for women only. These workshops were formulated to counteract the observed patterns in the First-Year Engineering Projects course, and provide an environment that promotes community and engagement in engineering among the women.

The Stage: First-Year Engineering Projects Course

The Women's Manufacturing Workshop (WMW) series is set within the framework of the First-Year Engineering Projects course (FYEP).[1] Each year, approximately 350 first-year engineering students complete this hands-on, team-based projects course. The students learn the design process and build engineering projects in diverse topics such as assistive technology, Rube Goldberg contraptions and robots. The projects have real world relevance and are interesting to the students who work on them in small, multidisciplinary teams. Within teams, students are encouraged to learn new skills, such as computer-aided drawing, hands-on machining and assembly, engineering analysis, and communications skills, which will benefit them throughout their college experience. Another FYEP course goal is to provide a context for first-year engineering students to evaluate their decision to pursue engineering, as many students have been advised to become engineers without knowing what an engineer does, and about 30% of the first-year students have not declared a specific engineering major.

The course format — small student-to-teacher ratios, hands-on learning, team-based design project work, deadlines and deliverables — is also an effective way to learn, and one that mirrors how engineers work in industry. Another important course objective is to increase students' knowledge of, and comfort with using, hand tools and machining equipment. Course instructors encourage students to use the manufacturing resources in the ITL Laboratory, with equipment usage required to complete most design projects. Manufacturing capabilities exploited by students include professional quality milling machines, drill presses, bandsaws and lathes. Computer-numeric-controlled (CNC) laser cutters, and a rapid prototyping machine are also well used by students.

Gender Differences in First-Year Engineering Projects Course

The effectiveness of the FYEP course is documented by retention studies conducted on 2,581 students into their seventh semester of college.[2] The results for all students show a 19% increase in the likelihood of a student remaining in engineering into their senior year if they completed the FYEP course during one of their first two semesters in engineering. The retention results are even more impressive for women students. Women who take the FYEP course are 9% more likely to persevere in engineering into their sophomore year, and 27% more likely to remain in engineering into their senior year compared to their female counterparts who do not take the course.

The projects course has also been found to increase students' confidence in their own skill development.[3] Students rate their skills at the beginning and end of each semester, and self-report significant increases in communication, teamwork and design skills, as well as knowledge of engineering methodology and engineering careers. When analyzed by gender, these skill gains held up for males and females.

Even though the FYEP course builds engineering skills and promotes retention for women, important differences have been observed between how men and women behave in the course. Instructors have found that prior to enrolling in the course many women have not tinkered with tools, disassembled gadgets, or built toy models, as have many men students in their classes. Instructors have also observed a general pattern whereby women students assume team roles that include writing and presentation preparation, journaling, and team organization — and excel at these functions — while choosing not to perform roles requiring hands-on skills such as computer-aided drawing, machining and component assembly. In contrast, male students often choose to perform the technical, hands-on tasks with which they are comfortable, and do not opt to participate in tasks requiring communications and organizational skills. Even when instructors intervene, students are reluctant to give up tasks they perform well to learn new skills outside of their comfort zone, citing the benefit to the team and project.

For women students, dominance by male team members can further complicate the issue and lead to marginalized roles within the team. Many instructors of our CU design courses who incorporate quantitative peer evaluations into final course grades routinely report that male team members frequently rate their female counterparts lower if the women have not machined component parts — even when the women are viewed by their peers as highly valuable team contributors in other areas.

These differences between men and women have been held up in student self-ratings of skill.[3] Even though both men and women demonstrate increased confidence in their engineering skills at the end of the course, men typically rate themselves higher than women at the beginning and end of the course in the technical skills of design and basic engineering methodology. Likewise, women rate themselves higher at the beginning and end of the course in the professionally oriented skills such as teamwork and productive work practices.

These differences have also been observed in the literature. At age 13, a gender gap begins to appear in science proficiency scores, with boys outperforming girls. This gap continues in high school, with boys scoring higher than girls on the SAT Mathematics and Science Achievement Tests, as well as on the Mathematics and Science Advanced Placement Examinations.[4,5] In the college environment, one study found that many women who embark on a computer science major have never taken apart or built computers, in dramatic contrast to their male classmates.[6]

One solution to this problem has been the formation of girls/women-only initiatives, such as after-school programs that encourage students to use computers and technical equipment.[7] In mixed gender settings, it was observed that boys chose the computer equipment first, around which they formed enthusiastic groups to interact with the computer program, seldom relinquishing their hold on the computer. In this scenario, the girls chose to observe the boys from the edges of the room. However, when girls-only days were implemented, the girls occupied the equipment in a manner similar to the boys. These programs now routinely offer girls-only days as a way to foster learning of technology by the girls. Another example of a women only initiative has been developed by Hampshire College who have developed the Women's Fabrication Workshop in the Lemelson Assistive Technology Development Center. This course is designed as a hands-on introduction to basic tools and machinery in the design center where students work on a variety of projects using metal and plastic.[8]

With this in mind, and inspired by drastically increased participation of women students in the product design initiative at Hampshire College following introduction of a women-only Manufacturing workshop series, [8] members of the WIEP and the ITL piloted a women-only manufacturing workshop series to expose women to hands-on machining with the hope of building greater technical skill, and positively affecting their desire to engage in and remain in engineering.

Pilot Women's Manufacturing Workshop Series

The Women's Manufacturing Workshop (WMW) series was designed to be informative and provide a safe environment for learning to use the various machine tools. Twenty-eight women students in the First-Year Engineering Projects course sections were invited to participate. Eleven women attended the sessions that took place for two hours one evening each week for five weeks (total of 10 hours). Two co-instructors taught the workshops, a female graduate student in mechanical engineering and the male manager of the ITLL Manufacturing Center. Two women undergraduate engineering teaching assistants also supported workshop participants. The ITLL Manufacturing Center was closed to other users during the WMW.

Each student in the WMW created a small fabrication project comprised of several materials, requiring use of the table saw, vertical band saw, milling machines, lathe and drill press. During each workshop session, students were instructed on the operation and safety aspects of a particular machine, followed by small teams of students using that equipment to create a component of their project. The instructors and teaching assistants provided mentoring and instruction, as needed. The students could also choose to work in the Manufacturing Center at times outside the WMW evening sessions. Female teaching assistants held office hours to support their use of the shop at other times.

Methodology

Ten of the eleven WMW participants completed a written post-workshop survey and participated in a focus group interview about their experience. In addition, all eleven participants completed a written post-semester survey several weeks after completion of the WMW, at the conclusion of the FYEP course.

Results and Discussion

Due to the small number of participants in the pilot workshops, statistical analysis of results is not possible. Therefore, only raw data and/or percentages are presented.

Reasons for Taking the Workshops

Survey results revealed that 80% of the WMW participants had no prior manufacturing experience. Most took the workshops to enhance their knowledge through the hands-on learning experience. Even though all students had previously completed a required two-hour manufacturing safety course, most did not feel confident to undertake machining. Many students wanted more in-depth knowledge of specific machines for manufacturing.

Skill Development

Post-workshop surveys and a focus group discussion revealed that the women engineering students acquired a new level of self-confidence and capability about the Manufacturing Center resources, reporting an average skills gain of 137% across all machines. The actual gains in skills depended on the amount of usage. For the machines that were primarily used to construct their fabrication project — the vertical band saw, milling machines and lathe — the women reported hat their skill level more than doubled.

Workshop Content

The perception of the adequacy of the MWM content level varied according to the participant, as shown in the frequency distribution in Figure 1. Participants reported the workshop content material bordered on "too much" as well as "not enough." Some wanted the pace to move more quickly, yet others appreciated the slower pace, while many recognized that additional content and knowledge could be learned.

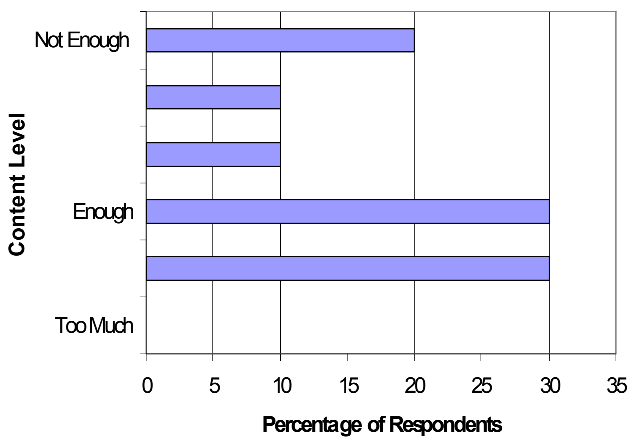

Figure 1. Adequacy of content level in the workshop series.

When the women evaluated their preparedness to work safely with the equipment following the workshop series, most felt either somewhat prepared or prepared, although most recognized they would still need some help to use the machines. These results are shown in Figure 2.

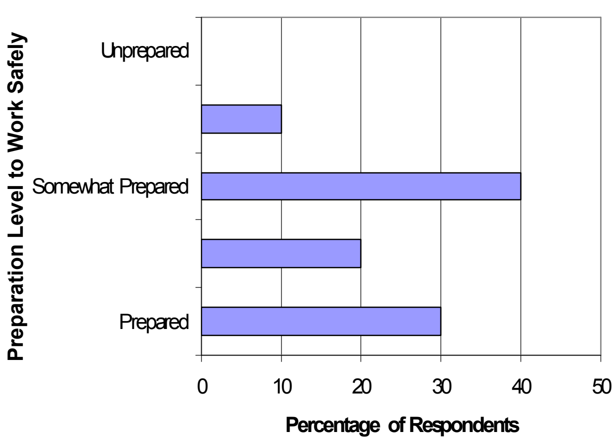

Figure 2. Levels of how prepared were participants to work safely on the machines.

Workshop Outcomes

The participants were surveyed at the end of the semester to evaluate the effects that taking the WMW had on their performance during the semester within their FYEP course design teams. All but one of the women reported a higher level of self-confidence when working with the machines after taking the workshops. As one student noted: " I gained the confidence to… go into the machine shop… rather than rely on another team member who said he would do it but hasn't yet." Many reported that the machines they used in the projects course were the same ones they had used in the workshop series, making the women more confident about their use. The results are shown as a frequency distribution in Figure 3.

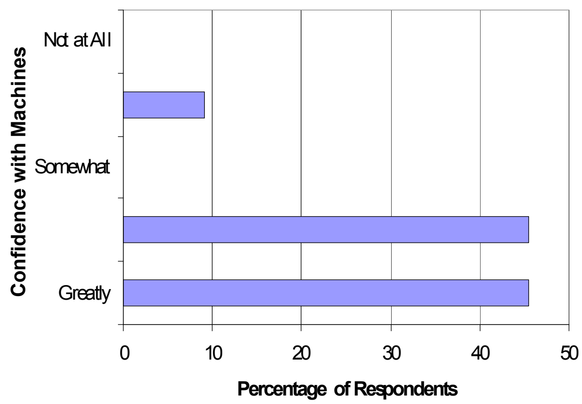

Figure 3. Confidence levels with machine usage.

The participants also noted an increase in their own performance level within their FYEP course design teams. Some reported that they were the ones "to go to the machine shop," while others noted they were more willing to "help with the hands-on work." These results are shown in Figure 4.

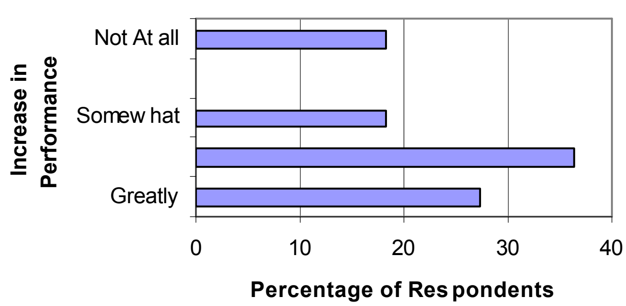

Figure 4. Increased student performance level.

The level of satisfaction indicated by the participants with their choice of engineering as a major also was evaluated. These results are shown in Figure 5. Ten percent (one) of the participants reported she chose to leave engineering, but "not as a result of the workshop." Four participants were highly satisfied with engineering as a result of the workshop series. If the pilot workshop's reduced rate of leaving engineering holds true with the participants in future workshops, retention has the potential to be improved by almost 10%, when compared to our average for women of 18% leaving by their sophomore year.

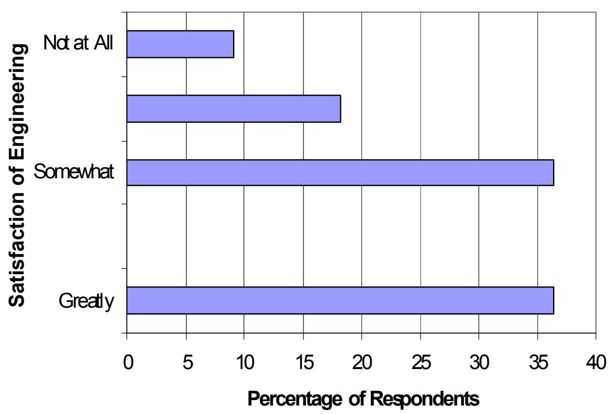

Figure 5. Satisfaction with choosing engineering as a major.

Improvements Warranted

Suggestions for workshop improvement were solicited. The WMW instructors and students noted that the fabrication project undertaken by the women was too complex for the time provided. Also, many participants indicated there were times of low productivity during the workshop when they were waiting for a specific machine to become available. Many students pointed out how crowded it became around the few focus machines. And, some students wanted fewer participants in the workshops. Most of these suggestions for improvement can be met by using a scaled-down student project that requires less time at each machine and is easier to assemble. Also, the participants will be asked to first develop a more detailed machining plan. Having the plan before starting to machine will help participants to better understand the sequence of steps to be accomplished and lead to less time waiting for instruction.

Some women who were invited to participate had schedule conflicts, noting that the times or days for the WMW overlapped with courses and other commitments. To meet the needs of more students, future plans include offering two-four workshop sessions each semester at a variety of times. Also, future participants will have more choice in scheduling workshop times either in the evening or during the daytime.

Workshop Highlights

All students valued the teaching styles of the two instructors and the helpfulness of the teaching assistants. This overwhelming praise for the instruction emphasizes the importance of effective teaching style for this audience. The women noted that the clarity of instruction, the emphasis on understanding the terminology and directions, the emphasis on safety, and the high level of professionalism contributed to a positive outcome. While this teaching model was successful, it is difficult to find two instructors every semester, especially with the possibility of additional workshops in future semesters. A modified teaching model to be implemented for future sessions of the WMW incorporates an advanced student teaching assistant with one primary instructor. One or two additional teaching assistants will also provide support. This new model has at least one advantage over the previous teaching model. It helps establish a vertical integration of knowledge and skills between upper division students and first-year students that can carry on each year.

During the five-week WMW, participants did use the Manufacturing Center to work on their fabrication project at times outside of the evening workshops. They said this was made easier by their familiarity with the shop and established relationships with the staff. Participants also reported that they enjoyed themselves in the WMW learning environment, reporting that the workshops were fun and helped them feel a part of the engineering community.

Summary

Results from the pilot WMW series support our hypothesis that providing a risk-free, single-gender manufacturing setting for women students helps them to gain manufacturing skills while enhancing their confidence that they can hold their own within male-dominated design/build teams.

Clearly, the results indicate that the workshop series promoted self-confidence and increased the likelihood that the women participants would choose more hands-on team roles. Participants subsequently reported increased comfort working within their male dominated teams, and some reported they helped other team members with machining tasks, bragging that they were the ones to machine parts to construct their projects.

The Women's Manufacturing Workshop participants became competent in those technical skills most valued by their male team members, helping them gain entrance into the male-dominated engineering "clubhouse," and hopefully increasing their confidence in their ability to persevere and pursue a future in engineering. The impact of this inclusiveness on long-term retention will be followed.

Bibliography

1. Carlson, L. E. & Sullivan, J. F. "Hands-on Engineering: Learning by Doing in the Integrated Teaching and Learning Program," *International Journal of Engineering Education,* Vol. 15, 1999, pp. 20-31.
2. Knight, D. W., Carlson, L. E., and Sullivan, J. F. "Staying in Engineering: Impact of a Hands-On, Team-Based First-Year Projects Course on Student Retention," Proceedings of the ASEE Annual Conference, Nashville, TN 2003 (submitted).

3. Knight, D. W., Sullivan, J. F., Poole, S. J., and Carlson, L. E. "Skills Assessment in Hands-On Learning and Implications for Gender Differences in Engineering Education, Proceedings of the ASEE Annual Conference, Montreal, Canada 2002, Session 2430.
4. Macoby, E. E., and Jacklin, C. N. *The Psychology of Sex Differences,* Stanford, CA, Stanford University Press, 1974.
5. Benbow, C., and Stanley, J. S. "Sex Differences in Mathematical Ability: Fact or Artifact?" *Science,* vol.222, 1983, pp. 1262-1264.
6. Margolis, J. and Fisher, A. *Unlocking the Clubhouse: Women in Computing,* Cambridge, MA, The MIT Press, 2002.
7. Mead, M. "Does Gender Really Matter?" The Women's Foundation of Colorado Forum, Denver, CO, www.wfco.org, May 21, 2002.
8. MacEwan, R. "Women's Fabrication Workshop" Hampshire College, http://lemelson.hampshire.edu/Courses.html

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