Evaluation of "How Things Work": A Hands-On Experimental Engineering Course

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Background

Engineering 25, "How Things Work," was an experimental, hands-on course originally offered to lower-division female engineering students at the University of California, Davis. E25 was designed and developed primarily to lower the attrition rate of women engineering students by providing them with a classroom environment and experiences that increased their confidence in working with mechanical and electrical devices. The original course also specifically addressed some of the factors identified as barriers to women who are pursuing a degree in engineering, such as feeling isolated in classes and labs due to the low numbers of women taking engineering courses, failing to see the relevance of their coursework to engineering, having negative experiences in laboratory classes, and having little exposure to female role models in engineering.

Funded by NSF[1], E25 was originally offered at UC Davis in 1992 and in 1993, during Winter quarter. Eighteen first- and second-year students participated in the course in 1992 and seventeen participated in 1993. Course components included a number of hands-on engineering-related activities including introduction to hand tools, dissection and exploration of common household devices and appliances, disassembly and reassembly of one-cylinder, four-stroke engines, and a truss building project. Other activities included guest speakers, project presentations, device dissection homework, and classroom discussions of gender-related issues.

Evaluation results obtained from these first two years were used to modify the course, and in addition successful components of the course were used to develop a series of hands-on workshops for K-12 teachers.[2] After using evaluation results from years one and two to obtain additional funding from NSF, two sections of E25 were offered during Winter quarter 1995.[3] One section, like the first two offerings, was composed only of female engineering students, and the other had both male and female participants.

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[2]"A Model Project to Improve the Climate for Women in Engineering," funded by FIPSE, grant no. P116B1164.
[3]NSF grant no. DUE93-54539(I).

This paper will focus on E25 from the perspective of its evaluation. E25 goals are presented, along with the design and methodology chosen to address those goals. Results from years one and two are linked to changes implemented in 1995. Finally, results from year three are summarized and presented along with conclusions and recommendations.

Goals

To address the attrition of women engineering students at UC Davis and counteract these barriers, Engineering 25 was developed with the following goals:

* Provide a hands-on, non-threatening laboratory and classroom experience.
* Provide a collaborative, instead of a competitive, classroom environment.
* Introduce women to, and familiarize them with, the technical engineering jargon.
* Provide opportunities for networking among students, and with TA's and professor(s).
* Offer students access to female engineering role models.
* Implement successful hands-on E25 components in workshops for K-12 teachers.

In addition, the following goals were set forth for the 1995 sections:

* Offer and compare an all-female and a mixed-gender section.
* Institutionalize E25 at UC Davis.
* Disseminate information about E25 to other institutions and interested parties.

Evaluation Design and Methodology

A case study design, incorporating both qualitative and quantitative measures, was used to evaluate all three years of E25. This design was selected for several reasons: the course was new and innovative, descriptive information was needed about the course, and because it was not possible to randomly select and assign course participants. The following measures were used to evaluate the course all three years:

Prequestionnaires - These were given to students prior to signing up for the course. This prequestionnaire was revised slightly in years two and three. The prequestionnaires asked students for their age, year in school, and major, and also asked them why they wanted to take the class, about prior experience with mechanical and electrical devices, their comfort level in taking devices apart, whether they had ever considered changing their major, and what engineering classes they had taken prior to E25.

Journals - Students were given a notebook to use for lab notes, vocabulary, and to provide feedback about the course and its effects. The first year, very general questions were asked about the course and activities, and several concrete themes emerged. Specific weekly questions were then developed from these themes and given to students to answer in years two and three.

Final Exams - Students were given a "final exam" that primarily asked for final course feedback such as the labs and activities they liked the most and least and any suggestions for improvements to the course. In 1993 and 1995, the final exam asked students again if they were still considering changing their major. In 1995, students rated specific course activities from most to least enjoyable.

Interviews - Group and individual interviews were conducted with each TA and professor(s) after the conclusion of each course offering. Professors and TA's were asked for their observations and feedback about what worked about the course and suggestions for modifications. The 1995 group interview became a brainstorming session regarding course institutionalization at UC Davis.

Focus Groups - Focus groups were held in 1993 and 1994, one year after students completed E25. Approximately half of each class participated in a focus group. Students were asked whether they were still pursuing an engineering major, if E25 had any lasting effects, and to discuss whether the class should be opened to males.

In 1995, the following were added:

Weekly planning/feedback meetings - A project team of professors, TA's, evaluator, and the director of the Center for Women in Engineering met weekly to make ongoing modifications to the course and provide one another with feedback and insights.

Observation - All E25 labs and lectures were observed during Winter quarter 1995 by both the project evaluator (the author) and the Director of WIE, and were then compared for validity.

Results: Year One (1992) and Year Two (1993)

Student journals were the largest and most useful sources of data about E25. In years one and two, students wrote specifically that their participation in E25 and its hands-on activities increased their confidence and self-esteem, and in turn increased their desire to remain within engineering. They also wrote that having female TA's and female professional engineers as speakers provided them with valuable role models, that they recognized the benefits of networking and working in collaborative groups, and that being in a non-threatening, all-female educational environment helped them safely discuss their feelings in addition to feeling comfortable exploring mechanical devices. Useful feedback about specific course and lab activities was generated (and was used to modify the course after each offering). Finally, students felt overwhelmingly that, although excluding them seemed unfair, men should not be allowed to take the course: having even one male involved would significantly alter their experience. Information obtained from other evaluation methods confirmed all of these findings.

Changes to the 1995 course offering

At the conclusion of the first two years of E25, several modifications were made to the course structure and curriculum, as shown in Table 1 below. Although the students benefited from the primarily mechanical approach, it was felt that future students could benefit more fully from a broader technical base. To address this, a teaching team was formed and a group of five female TA's and five female undergraduate assistants were selected to bring to the course a broader range of engineering majors. The two additional professors were female engineering professors, one in civil/environmental and one in chemical engineering, and they also acted as additional role models for students. Several of the undergraduate assistants were former E25 students. Additional labs were created to add hands-on activities in both civil/environmental and chemical engineering, along with an improved design/build wood project. The course was expanded from two to three units to provide much-needed additional lecture and discussion time, and grading was changed to pass/fail in order to further add to the low-stress environment. Finally, to determine whether it was necessary for women students to participate in an all-female course in order to derive its benefits, a co-ed section was added as a non-equivalent comparison group.

Table 1: Comparison of Course Elements: Years One and Two vs. Year Three

Course Elements 1992-1993 (Years 1 and 2)	**Course Elements 1995 (Year 3)**
2 units, graded	3 units, pass/fail grading
1 all-female section each year	2 sections: 1 all-female, 1 co-ed
Taught by 1 male mechanical engineering professor	Team-taught: 1 male mechanical, 1 female civil/environmental, 1 female chemical engineering professor
Curriculum focused primarily on mechanical engineering[4]	Curriculum focused on multiple engineering disciplines[5]
4-5 female graduate TA's, mostly from mechanical engineering	5 female graduate TA's and 5 undergraduate female TA's, from multiple engineering disciplines
Participants self-selected	Participants self-selected; females assigned based on course schedule availability, not randomly assigned

[4]Curricular details from the first two years of the course are described within the following article: Henderson, Jerald M., Desrochers, Debra A., McDonald, Karen A. and Mary Margaret Bland. "Building the Confidence of Women in Engineering Students With a New Course to Increase Understanding of Physical Devices." Journal of Engineering Education, October 1994, pp. 337-342.

[5]Curricular details about Year 3 are described by Angelica E. Folson, elsewhere in these 1995 WEPAN conference proceedings.

There were also several course elements that remained common to all three years:

* Focus on lower division students
* Female TA's (and female undergraduate assistants in 1995)
* Female professional engineers as speakers
* Focus on gender issues in the classroom

Results: Year Three (1995)

As in years one and two, students from both sections in year three reported in their journals and on their final exams that they felt their confidence increased while participating in E25, and that group collaboration and exposure to female engineers, TA's and professors as role models was beneficial. None of the males, however, felt that it was essential to have females as role models; instead, they viewed them as general role models and felt they could have been of either gender. All students valued the interaction and networking among themselves and with TA's and professors, and many felt that they had identified a professor whom they could seek out as they continued on in engineering. In addition, the professors valued getting to know students on an in-depth basis early in their major. Students also again provided feedback on specific labs and course activities. Students overwhelmingly preferred activities that allowed them not only to take apart a device and explore how it worked, but also to put something back together, build, or design a device.

There were a number of new findings from year three:

* Exposure to various E25 labs and activities allowed students to either verify their choice of engineering major, or choose an engineering major they enjoyed more.

* Students were observed making direct links between concrete and abstract science and engineering concepts during their class and lab project presentations.

* A comparison of the all-female and the co-ed sections revealed that students in general felt that having an all-female section was beneficial, but not essential for deriving benefit from the class. Several female students in both sections felt that an all-female class was most desirable, but several females in both sections also thought a co-ed version of E25 was beneficial. None of the men felt that having an all-female section was essential, and a few were offended by the idea.

* Several differences were observed between the two sections. Females in the co-ed section were generally more outspoken, assertive and competitive than those in the all-female class. Although the TA's and guest speakers seemed to behave almost identically with each section, all three professors were observed to teach the two sections differently; for example, professors tended to reveal more personal

information to the all-female class and provide them with more help and assistance. Also, there was much less discussion of gender issues in the classroom (i.e. females feeling isolated in engineering classrooms, differences in gender communication, etc.) in year three than in years one and two, and the least amount of discussion occurred in the co-ed section.

Conclusions and Recommendations

Based on evaluation results, several course aspects have been identified as valuable in considering future offerings of E25, either at UC Davis[6] or for those at other institutions interested in offering a similar hands-on course:

* Provide students with hands-on projects, including projects that allow students to take apart, reconstruct, or design and build devices.
* Keep the size of the class and lab groups small.
* Provide opportunities for interaction and networking among students, TA's and professors.
* Provide students with speakers as engineering role models.
* Offer activities that highlight links between concrete and abstract concepts.
* Offer labs and activities that provide a cross-disciplinary approach.
* Target lower division students to increase their retention in engineering.

Finally, although it could not be proven that an all-female class is essential for retention of female engineering students, evaluation evidence from all three years strongly indicates that offering an all-female course may encourage at least some women to remain in engineering.

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[6]Details about plans for the institutionalization of this course at UC Davis are discussed by Angelica E. Folson, elsewhere in these 1995 WEPAN conference proceedings.