

PUTTING TOGETHER A HANDS-ON EXPERIMENTAL ENGINEERING COURSE

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Engineering 25(E 25) Introduction to Physical Devices and Systems, or "How Things Work," is a hands-on engineering course for lower division engineering students that has been offered at the University of California, Davis through the financial support of the National Science Foundation.¹ In order to offer this course it was necessary to develop course curriculum, organize personnel, procure lab materials and interact with the university. This paper focuses on the planning, organization, and curriculum of the Winter 1995 E 25 course from the perspective of the course coordinator.² The contents of the course curriculum packet are also described.³

Introduction

The goals of Engineering 25 included introducing students to hands-on technical projects and to engineering jargon in a non-threatening, collaborative manner in order to increase the retention of women in engineering. The engineering lab projects were devised to satisfy these goals. For the labs to run smoothly, materials such as tools and raw materials had to be obtained. The professors, teaching assistants(TA's), and undergraduate assistants had to be coordinated as to who did what with which lab. The duties of the organizer included overseeing these lab project preparations, obtaining necessary materials, coordinating the efforts of all personnel, and ensuring that the course progressed smoothly.

Course Structure

During Winter Quarter 1995, E 25 was a three-unit, quarter-long class with two one-hour discussions and one three-hour lab session. There were two sections, one all female and one coed.⁴ To relieve grade pressure and thus encourage learning, the course was graded pass/fail. An attempt was made to offer the course as a technical elective, but this was not successful. Another goal of E 25 was to increase retention so the class was designed for lower division students, rather than upper division students who were more

¹ NSF Grant No. DUE93-54539(I)

² Information from the 1992, 1993, and results from the 1995 offerings can be found in Mary Margaret Bland's paper elsewhere in these proceedings.

³ INTRODUCTION TO PHYSICAL DEVICES AND SYSTEMS A Hands-on Collaborative Laboratory Course on 'How Things Work', Center for Women in Engineering, University of California, Davis, CA 95616

⁴ See footnote no. 2

committed to their engineering major. The class size was also kept small (under 20 students) to ensure a comfortable atmosphere with plenty of student-instructor interaction.

Course Curriculum

In the past, the course emphasized mainly mechanical engineering, but this year civil, chemical and electrical engineering labs were included. The topics covered in labs were: car dissection, device dissection, design and build wood project and presentation, internal combustion engine disassembly and reassembly, multimeter construction, heterotrophic plate count, construction site field trip, and dissolved oxygen probe construction. During class, the professors made an effort to focus on discussion rather than lecture and on concepts and terms rather than formulas in order to promote a collaborative, non competitive environment. Discussion topics included introduction to lab topics, gender equity, tools, World Wide Web computer information, design, bicycles, mechanics of movement, strength of structures, and refrigeration. Two female professional engineers spoke to the class about their experiences balancing professional and personal issues. There was also a mini-field trip to the waste water treatment site on campus, and some practice with a computer simulation of a chemical processing plant. At the end of the quarter the students presented their large device dissection projects. The final was a questionnaire designed to provide feedback about the course.

Lab Projects

There were seven lab projects as shown in the table below:

<u>LAB PROJECT</u>	<u>AREA OF EMPHASIS</u>
Design and Build	Mechanical Design
Internal Combustion Engine	Mechanical
Hand Tools/ Car Dissection	Mechanical/ Hardware
Device Dissection	Mechanical/Electrical
Multimeter Construction	Electrical
Heterotrophic Plate Count	Environmental
Dissolved Oxygen Sensor	Chemical

The lab design focused on emphasizing the process rather than on a specific end result. This allowed the students to learn by doing. At the first lab, the professor showed the students an assortment of hand tools, explained the tool's official name and then demonstrated it's use. The students then used this knowledge to dissect a small car. They were told to take a piece off of the car using the tools that were just demonstrated. The students were timid at first, taking off only small items, but by the end of the lab the entire car had been dismantled.

To become more familiar with tools and engineering concepts, the next step was the Device Dissection which was done as a small project, a large project and homework assignments. Students picked a small project in pairs and a large project in groups of four to six. The devices for the small project included toasters, radios, tape machines, mixers, and VCRs and the larger devices included washing machines, transmissions, engines and refrigerators. The students dissected the devices and presented their findings to the class. The benefits of the dissection include hands-on experience with devices and tools, knowledge gained about how the devices worked, hearing about others' experiences with



their devices, and the opportunity to present an engineering concept to a "friendly" audience. An excellent reference for the device dissection, "The Way Things Work," was held on reserve at the Center for Women in Engineering for the students.⁵ While it appears simplistic, the explanations of engineering concepts are more technical than other how things work books.

The students' favorite projects were the Design and Build lab and the Engine lab. The Design and Build lab introduced students to the complete process of design concept to product manufacturing. They enjoyed being able to design an item of their choosing and then build it using the specified wood and drywall screws. The Internal Combustion Engine lab allowed students to explore the cycles of an engine by disassembling, reassembling, and testing a single cylinder, four-stroke engine.

For exposure to electrical engineering, students constructed a Multimeter which involved soldering together a Radio Shack kit. This introduced the students to electrical concepts, soldering and the use of a multimeter. The students were introduced to water quality with the Heterotrophic Plate Count as an introduction to environmental engineering. They plated samples of water and counted the colonies that grew. The Dissolved Oxygen Sensor included building and using a sensor in a chemical engineering laboratory.

A successful lab from previous years was one where students took apart a bicycle. This year, however, the lab was done as a discussion. The students were introduced to the different parts of a bicycle, along with the part's relevance to engineering, and how to take them apart and put them back together. As a discussion, the disassembly was done for the students and as a lab, they brought their own bikes to work on. Their homework assignment was to take apart and put back together a piece of their own bike. Gears, bearings, lubrication, strength, and drives were introduced to the students. A helpful reference book with clearly labeled pictures of bicycle parts and the associated tools was "Richards' Bicycle Repair Book."⁶

A curriculum packet is currently being prepared and will describe in more detail the course curriculum including labs, discussions, field trips, and speakers. This will be available for a limited time after August 1995 from the Center for Women in Engineering at the University of California, Davis.⁷

Personnel

Engineering 25 was approached with a team effort. This year the class was team taught by a male mechanical, a female chemical, and a female civil engineering professor. The rest of the team included an evaluator, five female graduate teaching assistants, the director of the Center for Women in Engineering and five female undergraduate assistants.⁸ A mechanical professor was an appropriate choice for the course considering the mechanical emphasis of the curriculum. He was also the professor for the first two offerings of the course. The other professors and teaching assistants were female to provide positive role models for the students. Having many instructors often led to

⁵ Macauley, David, "The Way Things Work," Dorling Kindersley Inc., 1988.

⁶ Ballantine, Richard and Grant, Richard, "Richards' Bicycle Repair Book," Dorling Kindersley Inc., 1988.

⁷ See footnote no. 3

⁸ Hereafter when referring to all of the professors, teaching assistants, and undergraduate assistants, the term instructors will be used.

confusion and an excess of personnel during the actual labs. The general consensus following the course was that two professors and two teaching assistants would have been appropriate for the small class size of twenty students. At a weekly meeting all of the available instructors discussed the previous and upcoming weeks labs and events. It was a good idea to discuss the dynamics of team teaching so that all understood their role in the course. The attitudes of the professors and teaching assistants were also important. The instructors had an understanding of classroom dynamics and gender equitable instruction and attempted to teach accordingly. To maximize the benefit for the students, the class utilized a discussion format rather than a lecture format.

Much of the impact of this course was the relationships formed between the students and instructors. This emerged due to the small class size and discussion format. The students and instructors used name tags throughout the course so that everyone could be on a name basis. The students were also invited to the mechanical professor's house for dinner to encourage interaction. As a homework assignment, the students were asked to talk to one of the professors in office hours for ten minutes. This was to encourage the students to feel comfortable interacting with professors in the office setting.

Materials and Lab Space

The organizer was in charge of obtaining materials and lab space. The necessary materials included a full set of common tools, jewelers screwdrivers, soldering irons, bicycle tools, broken or used devices, and containers to store these items. The E25 tools and soldering irons were purchased with grant money from NSF.⁹ Additional tools were borrowed from the engineering shop and engineering tool check-out rooms.

The devices were obtained in the summer before the offering of the course. They were all donations, but this was a time-intensive process that may not be feasible for a long-term course. Advertisements were placed in local newspapers, faculty mailboxes, and at apartment complexes. Making the wording of the ad very specific would have helped save time as would arranging a full day of pick-ups. Small devices were obtained through the ads including bread makers, toasters, mixers, tape players and even larger devices such as washing and dish washing machines. Apartment complexes were also a good source of refrigerators, dishwashers, and washing machines. The cars were donated to the College of Engineering for E 25. These devices and cars needed to be stored. The ideal location would have been a lab dedicated solely to the class so the devices would not be disturbed or ransacked for parts by other eager engineering students. Instead they were stored in several different locations. The ideal lab room would also have had large tables or desks, access to multiple electrical sockets and adequate ventilation for the engine and sensor labs. However, the E 25 labs this year were held in different rooms, each possessing at least one of these qualities.

Limitations

This type of course is difficult to duplicate without a large amount of funding. The materials including tools and raw materials can be prohibitively expensive. If grant money is not available, these items can be borrowed, received as donations, or covered by a lab fee. If cars are not donated, they could be retrieved from a junk yard at a minimal cost.

⁹ NSF Grant No. HRD9053903

The large number of TA's is also expensive. It would be more cost and time efficient to do the class with only one TA per 10 students. The small class size may also be difficult for a university to justify for lower division students. The large number of personnel also made coordination difficult but a class with a smaller number of instructors would solve that problem. This year the course was run with simultaneous labs for the two sections. This led to many difficulties that can be avoided by running the labs at different times. There are also limitations stemming from people's attitudes. E25 did not get full recognition because many professors and departments dismissed the class as "remedial," "not academic," and "unimportant." For this course to be institutionalized, it is advantageous to have a few influential supporters of the idea.

Future at UC Davis

The current plan at UC Davis is for the course to be organized and taught at the department level. Each department will submit proposals to teach the course as an introduction to their field. These courses will include the important aspects of the course including hands-on labs, field trips, speakers, discussions of personal vs. professional issues and relation of concrete to abstract engineering concepts.

Other forms for the course suggested during brainstorming discussions include a seminar series that could be developed based on past E 25 experience. Each quarter could have a different emphasis, for example, a specific field of engineering or activity such as hands-on labs, discussions, speakers, etc. The important elements could also be focused into workshops held before school or during quarter breaks. Regardless of form, the challenge is to balance available resources with the important hands-on, hardware intensive activities.



