A Project-Oriented Introduction to Engineering Course

Kenneth F. Reardon
Department of Chemical and Bioresource Engineering
Colorado State University

Abstract

This paper describes an introductory engineering course taught to first year students in chemical, environmental, and bioresource (agricultural) engineering at Colorado State University. In this lecture-laboratory course, a variety of "hard" (technical) and "soft" engineering subjects are put into practice in a group design project, with the overall goal of providing students with a sense of the engineering field while being both challenging and fun. Details of the lecture topics and design project (construction and testing of a solar water heater) are provided in this paper, as are comments on the outcomes of the course. Overall, this integrated lecture-laboratory course appears to meet all of our objectives for an introductory course in engineering, and student feedback on this course has been very positive.

1. Introduction

When asked their objectives for a first-semester introduction to engineering course, our students overwhelmingly list "learn about engineering as a career" as their top choice, with "learn about my major" typically the second-ranked objective. Unfortunately, they lack the technical, computational, and problem-solving skills needed to take the suite of courses that would allow them to truly understand either. In our experience, asking engineering students to wait until their second year to learn about their major can lead to frustration with difficult chemistry, math, and physics courses that seem to have no relevance to engineering.

Many students are also frustrated with introduction to engineering courses that avoid calculations and technical topics. While these courses can convey important topics such as creativity, problem-solving methods, the engineering design process, and/or technical communication skills, students usually do not perceive the connections between these topics and the foundation courses (e.g., physics) with which they may be struggling. Furthermore, they may not feel as compelled to work on assignments for such a "soft" class when faced with a heavy load of computational homework.

To provide first-year students with an overview of engineering that avoids some of these pitfalls, we have developed a lecture-laboratory course entitled "Strategies of Engineering Design" in which lecture topics on a variety of "hard" (technical) and "soft" engineering subjects are put into practice in a group design project. The overall goal was to present the students with a course that provides them with a sense of the engineering field while being both challenging and fun.

2. Course Overview

The semester-long course consisted of one lecture section and four laboratory sections, and was team-taught by two tenured faculty members. One professor acted as lead instructor, organizing the course and teaching 80% of the lectures. Each professor directed two of the laboratory sections, and four graduate teaching assistants aided with the laboratory sections and homework grading. Students enrolled in this course attended two 50-minute lectures each week and one 100-minute laboratory section. Since the laboratory sections had a maximum enrollment of 19, the course also provided students with substantial faculty contact. The laboratory portion of the course was devoted primarily to a design project, in which students work in groups to design, build, test, modify, and retest a device. Effort was made to connect lecture and laboratory so that students understood how engineering concepts could actually be put into practice.

Students in this course were those who had chosen chemical, environmental, or bioresource (agricultural) engineering as their major. In addition, some engineering "open option" students (undeclared engineering majors) also participated.

Ten objectives were established for this course (Table 1). These were met in the lecture, laboratory, or both. Homework and reading assignments were posted on the course website (www.engr.colostate.edu/CBCC192), as were most course handouts. The website also provided links to professional societies, university resources, and solar energy sites.

The grade for the course was determined equally by lecture and laboratory criteria. The lecture portion of the grade was composed of scores on weekly homework assignments, four quizzes (some unannounced), and a midterm exam. In the laboratory, scores on weekly lab notebook entries, progress reports (written and oral), final project report, and level of participation were used to compute the grade.

Table 1. Course objectives for "Strategies of Engineering Design"

Objective	***Achieved in:***
Introduce students to the engineering design process	Lab
Introduce students to engineering problem solving methods	Lab
Provide experience with measurements, including statistical analysis	Both
Introduce basic engineering calculations (material and energy balances, fluid mechanics, heat transfer)	Lecture
Introduce students to the engineering profession (especially the fields of Bioresource and Agricultural Engineering, Chemical Engineering, and Environmental Engineering) and professional ethics	Lecture
Provide experience working with computers and the Internet	Both
Develop students' teamwork skills and their ability to work with diverse colleagues	Lab
Develop students' communication skills	Lab
Develop good student skills, including time management	Both
Introduce students to campus resources for academic survival and success	Lecture

3. Lecture Topics

Lectures were devoted to both technical and nontechnical topics (Table 2). Technical lectures introduced students to material and energy balances, fluid mechanics, heat transfer, and statistics. These topics were covered at a very introductory level, with the goal of conveying to students the basic issues associated with each so that they had an understanding of what the topics were rather than any in-depth knowledge (since they will achieve that in later courses). Examples and connections to real-world phenomena were provided to make the topics more interesting to students. One way this was achieved in the Fall 2000 version of the course was by short lectures from visiting scientists on problems of salinity in local rivers and global warming.

In addition to these subjects, important nontechnical engineering topics such as technical communication and ethics were introduced in lectures. Other presentations on campus resources for academic problems, conflict resolution, library use, and study abroad were also included. Although presentations of this type were required since this course is one of Colorado State's First-Year Seminars, those topics were reasonable to include in as part of a first-semester course.

For the past two years, the textbook used for this course has been *Engineering Your Future* (Great Lakes Press)[1]. We chose this textbook because it covered the nontechnical topics well, provided a good description of the engineering design process, and was particularly thorough in its introduction to the various engineering majors, careers, and job functions. While this book also included coverage of basic technical topics such as dimensions and units, it did not cover material balances or any of the other technical engineering topics.

4. Laboratory Activities

A schedule of the laboratory topics is presented in Table 3. Early laboratory sessions focused on creativity and team development. These normally included an activity followed by a mini-lecture to solidify the main points conveyed in the activity. Since group work and development of team skills is an important element of this course, a teamwork game, "Swamped!"[2] was the feature activity of the second laboratory. The game sets the scenario that each group has been caught in a storm while on a canoe trip. Their canoes have been swamped, and only a few items recovered. Their task is to rank the importance of the 10 recovered items, both individually and as a group. This game introduces the idea of team synergy, and the students were asked to assess their design group's synergy at both the midpoint and end of the course.

The next few laboratory sessions focused on the engineering design process. The *Engineering Your Future* text presents a ten-step design sequence, but any similar sequence could have been used. Laboratory sessions 3 through 6 consisted of a mini-lecture to explain the design steps (defining the problem through implementation) followed by time for the student groups to work on those aspects of their design projects. After the lecture on implementation, there were no more lectures in the laboratory sessions and activities focused exclusively on building and testing.

Table 2. Lecture topics in "Strategies of Engineering Design" (Fall 2000)

Week	***Lecture topic(s)***
1	Introduction; systems of units, conversions; significant figures
2	Introduction to systems and processes; introduction to engineering; Career Center presentation
3	Material balances
4	Material balances; guest presentation by alumna at biotechnology company
5	Energy balances
6	Energy balances
7	Technical writing; guest presentation from University Writing Center; oral presentations
8	Measurements; Statistics
9	Statistics; midterm exam
10	Introduction to chemical, environmental, or bioresource engineering (guest presentations); ethics
11	Fluid mechanics; heat transfer (conduction)
12	Heat transfer (convection)
13	Heat transfer (radiation); review of efficiency; problem solving skills
14	Campus resources: guest presentations from library and HELP/Success Center; International aspects of engineering careers; guest presentation from Study Abroad Office; campus resources: guest presentation from Ombudsman’s office
15	Case studies of material and energy balances: guest presentations on river salinity and global warming; course summary and evaluation

Recently, the design project has been a solar water heater. This has proven to be an ideal project since it incorporates all of the technical topics and also connects with the sense of environmental responsibility of many students. To construct their water heaters, teams must purchase or otherwise (legally) acquire the necessary materials. They are reimbursed up to $25 per team for these costs (paid by a small course fee) and are given the suggestion that they not exceed $50 for the project. Nearly all teams spend less than $50, and some are able to construct their water heaters for less than $25.

Testing is done with a portable setup that features a pump, rotameter, hot and cold water reservoirs, thermocouples on the inlet and outlet lines, and a radiometer. Each group must calibrate the rotameter before testing their heaters in the sun, and this provides the students with an opportunity to perform statistical analysis (linear regression, standard estimate of the error) on data that are relevant to them. Following their initial water heater test, each team must modify their water heater and retest.

An important element of the laboratory sessions is technical communication, in the form of two written progress reports, two oral progress reports, and a final written project report. In addition to information on their design and testing results, the teams are required to include Gantt charts and budgets in their reports. Their budgets include not only materials costs but also labor and overhead, which invariably leads to discussions of how their simple water heater could "cost" thousands of dollars. These exercises in technical communication are always marked by a substantial improvement in quality over the semester. In particular, students' comfort and skill with oral presentations increases dramatically.

Table 3. Schedule of laboratory activities in "Strategies of Engineering Design". Actual activity for each group in Weeks 8-14 depended on their rate of progress.

Week	***Activities***
1	Introduction; creativity/teamwork exercises
2	Teamwork game
3	Overview of design process; distribute project descriptions; Work on Design Stages 1-3 (define problem)
4	Design Stage 4 (generate solutions)
5	Design Stages 5-8 (decide on a solution)
6	Design Stage 9 (implement/build solution)
7	Implement
8	Implement; written progress report
9	Cost analysis; Design Stage 10 (evaluate solution, including calibrate flow meter)
10	Oral progress reports; evaluate; rebuild and re-evaluate
11	Evaluate/rebuild
12	Evaluate/rebuild; written progress reports
13	Rebuild/evaluate
14	Oral progress reports/evaluate
15	Final project reports (written)

5. Lecture-Lab Integration

A key feature of the course is that nearly all of the lecture topics are used in the laboratory, either directly or indirectly. Material and energy balances are used directly, since students must calculate the efficiency of their water heaters. Concepts and equations from the lectures on statistics are also used directly to perform linear regression and propagation of error analysis. And the lecture presentations on technical communication contained tips that were used by the students in their laboratory progress and final reports.

Other lecture topics, although less directly incorporated, nonetheless related to the laboratory activities. These topics include problem-solving skills, fluid mechanics, and heat transfer. Even a basic knowledge of fluid mechanics and heat transfer allowed the students to understand better the phenomena occurring in their water heaters and to make improvements during the "modify" stage. Since the students brainstorm solutions and make their selections during the early part of the course, but learn the basics of energy balances and heat transfer later, they become aware that good designs require both creativity *and* technical knowledge.

6. Positive Outcomes and Problems

This integrated lecture-laboratory course appears to meet all of our objectives for an introductory course in engineering. For most students, having a design-oriented engineering course in their first semester helped give them a sense of their major as well as the opportunity to develop teamwork and communication skills. Student feedback on this course has been very positive, with many commenting that the course had been demanding but enjoyable, and that they felt they had learned something about engineering. Comments from end-of-semester evaluations have included:

- "The class did a great job introducing many aspects of engineering without becoming overwhelming."
- "… material covered was relevant. It was challenging to a degree, however was also a good introduction."
- "This was a good class -- well balanced between lectures and hands on working"
- "It was also nice to work hands-on on the projects instead of just with theories."
- "The project was super and fun. I feel it helped a lot with creativity and should always be done in the future."
- "I felt this class met all objectives. I got a good overview on what ChemE is all about."
- "Covered all areas that freshmen want to hear about, i.e. where to find help, how to write technical papers, material balances."
- "I got to understand my major more clearly."
- "We took what we learned in class and were able to incorporate this into the water heater which made it more relevant than if we used hypothetical situations."
- "I learned a tremendous amount in this class, about the material presented, and what it is to be an engineer."

However, two problem areas have been noted. The first is that the course textbook did not contain sections on the technical topics (material and energy balances, fluid mechanics, heat transfer, and statistics). Although the lectures were supplemented by handouts and consisted mainly of working through examples, most students expressed a strong desire to have a book for reference while doing homework problems. Although no such book has yet been located, this may change as new volumes are added to the introductory engineering textbook series presented by some of the major publishers (e.g., McGraw-Hill and Prentice Hall).

The other problem is student retention, both in the course and in engineering. The course itself has a drop/withdraw rate of 10-15%, and an estimated 10% of those remaining in the course state their intention to change to a non-engineering major. To a large extent, this may not be a problem at all, as these are students who have simply found out sooner than later that engineering is not right for them. However, the instructors have noted some cases in which insufficient background (e.g., difficulties with algebra) and poor study skills have convinced some students to drop the course. This course currently has no pre- or co-requisites, and a possible solution to this problem is to require that physics or calculus be taken at least co-currently.

In summary, this project-oriented introduction to engineering course has proven to be a highly successful way to teach students about their majors by providing a multifaceted, hands-on, technical experience.

7. Acknowledgements

The author is grateful for the valuable contributions to the development of this course that were provided by Profs. Jim C. Loftis and Terrence H. Podmore, who assisted in teaching the course for two and one years, respectively. Valuable laboratory assistance has been provided by Mr. Timothy Gonzales and several graduate students. Finally, many guest lecturers from different offices and departments at Colorado State University also enhanced the quality of the course.

Bibliography

1. Oakes, W.C., Leone, L.L., Gunn, C.J., Dilworth, J.B., Potter, M.C., Young, M.F., Diefes, H.A., and Flori, R.E., *Engineering Your Future*, 2nd ed., Great Lakes Press, Wildwood, MO, 560 pp. (2000).
2. Glaser, R. and Roadcap, J., *Swamped! A Team Adventure*, Organization Design and Development, Inc. (1992).

KENNETH F. REARDON
Kenneth F. Reardon is an Associate Professor of Chemical Engineering at Colorado State University. In addition to teaching this first-year course, he has taught sophomore-, junior-, and graduate-level chemical engineering and biotechnology courses. His research interests are in the areas of biochemical and environmental engineering. Dr. Reardon received a B.S. degree from the University of Pennsylvania and M.S. and Ph.D. degrees from Caltech.