First Year Engineering Projects:
An Interdisciplinary, Hands-on Introduction to Engineering

University of Colorado at Boulder

Introduction
The University of Colorado at Boulder is embarking on an ambitious plan to revitalize undergraduate education by creating a new, innovative laboratory facility designed to encourage experiential, hands-on learning across all engineering disciplines in a setting that strengthens the creative problem-solving skills of students in multidisciplinary teams.

The Integrated Teaching and Learning Laboratory (ITL) is being planned as a central college laboratory facility devoted to undergraduate education. Currently in the design stage, the 32,000 sq. ft. building is projected to be ready for its first students in 1997. In the meantime, we are beginning to pilot various curricular components, including a new course, First Year Engineering Projects, a hands-on introduction to engineering.

Relationship to Other First Year Courses
A range of first-year experiences exists. Some schools, such as the University of Maryland, have student teams design and construct large projects (e.g., windmills or human-powered pumps) over an entire semester. However, such projects can be resource-intensive. Other universities (e.g., Arizona State) believe that the end result of an engineering design process for first-year students should be a paper design, rather than the artifact. While potentially less resource intensive, students do not experience firsthand the real world challenges which characterize engineering design from concept to completed device.

Some universities provide introduction to engineering experiences. At Cornell, for example, students can choose from one of 15 introductory courses that might focus on the study of civil engineering through a case study approach to bridge design. This is supplemented by a design experience constructing an actual model bridge. This type of course provides an in-depth look at one field of engineering rather than a broad overview of all disciplines.

A few institutions take an ambitious approach which integrates the entire first-year curriculum in mathematics, science and engineering, including Rose-Hulman Institute of Technology and Drexel. This type of curriculum has definite appeal, but the majority of those attending a 1993 NSF workshop on “The First Year Engineering Experience” did not consider this approach “practical for most colleges of engineering” due to the difficulty in achieving cooperation among the various departments, typically inside and outside of the engineering college.

There is much that can be learned about engineering design by carefully studying how contemporary artifacts are designed. This is the basis of a “mechanical dissection” course developed at Stanford University. Applying the concept of reverse engineering, students methodically disassemble and reassemble an artifact of their choosing, diagramming it, analyzing it and preparing a presentation on how it works.

Our approach at the University of Colorado has been to develop a course for first-year engineering students that combines many of the best features of other courses across the country. The new course consists of a series of smaller elements which are mixed together into a course which meets the needs and interests of the individual faculty member responsible for the course and the students enrolled.

Details of Projects Course
Course Goals
The purpose of this course is to provide an introduction to engineering through a series of projects done in interdisciplinary teams. Specific course objectives include:

- Introduction to engineering as a career
- Interdisciplinary teamwork
- Open-ended, hands-on design experiences e.g., design projects, reverse engineering
- Communication skills (oral and written)
- Experience in journaling
- Introduction to engineering methodology e.g., CAD, spreadsheets, modeling software, engineering measurements
- Mentoring opportunities for upper class TAs
Course History
At the time of this writing, the course has been offered twice. The first two pilot sections were offered in the Spring 1994 semester to 32 students. Each section had a distinctly different format and focus. Following final evaluations of both sections, we consolidated the elements and format of the course prior to offering three sections to 80 students in the fall of 1994. Following the example of our colleagues at Maryland, section sizes are limited to 30 students.

The first sections were taught in makeshift space throughout the Engineering Center. Subsequently, we renovated 1200 sq. ft. of storage space to create a student-centered learning environment for the three fall 1994 sections. Our experiences teaching in this space provided valuable insight at a crucial time of the schematic design process for the new IITL building, which will contain two 1200 sq. ft. classrooms dedicated to this course.

Course Elements
The course was broken down into a series of elements as shown in Fig. 1.

Team dynamics and communications workshops.
Team dynamics exercises were conducted to break down communication barriers and to demonstrate, in a safe environment, the synergistic power of group problem solving. Project teams were formed during these exercises to provide the team a first experience where they could creatively solve problems and get to know each other.

Communications exercises demonstrated the connection between effective communications and productive teamwork through active learning exercises, followed by group discussions. Cooperation puzzle games and team communication exercises demonstrated communication basics such as positive mannerisms, resolving conflict, breaking old habits, yielding in a group situation and creative invention. Teams developed "contracts" delineating how team members would commit to each other regarding expectations for team behavior and meeting rules.

Mystery artifact challenge. This is an introductory two-week "ice-breaker" project to allow students to work with their team for the first time on a challenging problem: to deduce the function of six unusual artifacts. Each team writes a summary analysis of each artifact and an in-depth report and oral presentation on one device of their choosing. This is a good introductory project because it is challenging and also has a high probability of success; the worst students can do is to guess incorrectly, but they know that most faculty cannot get them all right either. Students are evaluated on their process and presentation, not the correctness of their deductions. One example consists of a flat circular plate mounted on a shaft connected with a spring and pointer, mounted inside a tube with a vane at one end, used to measure maximum air velocity near rocket engines.

Short design and manufacturing project ("Bodiometer"). This is a short, three-phase exercise developed at Stanford utilizing Lego™ components that experimentally demonstrates the traditional "wall" between design and manufacturing. In Phase I, students have 75 minutes to design, build and document a device to measure two body dimensions: circumference of the instructor's wrist and "wingspan" - the fingertip to fingertip distance of the instructor's outstretched arms. They then disassemble their design and every team switches tables. In Phase II, each team must build another team's design, using the design drawings prepared in Phase I, and write usage instructions. In Phase III, each team acts the role of the user and takes the required measurements with the device constructed by another team in Phase II. Data are compared with the "exact" value as measured by a tape measure and issues such as accuracy, precision, etc. are discussed.

Significant open-ended design project. Several schools have demonstrated the benefit of extensive hands-on design projects, most notably the University of Maryland. Our approach was to scale back the scope of projects to allow room in the semester for other projects but still retain the benefits of exploration of a significant open-ended problem. This approach has an additional benefit of having the intense deadline of the project fall in the middle of the term instead of at the end. Each section spends seven weeks on a different design project, reflecting the personality and/or expertise of the individual faculty member. Projects piloted in the fall 1994 sections are:

Section 1: Design a voice control system and then test and evaluate its performance with a microphone/voice-controlled model car. The design of the vocabulary involves learning about speech signals and voice recognition techniques, and then developing a set of foreign language words that can be distinguished using prewritten computer software.

Section 2: Two concurrent design problems are assigned, which adds the interesting task of management of parallel projects:

a. Design, construct and test a craft suspended on water and also propelled by surface tension, with a competitive run-off.

b. Design, simulate (using Working Model software), build and test a Rube Goldberg device of each team's choosing which will perform a useful function through a surprising combination of sequential actions. For example, an aluminum can be dropped through a chute which triggers a bobbing bird which releases a spring, activating a switch turning on a motor which drives a gear train to rotate the can under a bowling ball which is released, crushing the can.

Section 3: A design, build and test in a face-off with other teams a robotic manipulator using a combination of Lego Ducta components and custom fabricated parts which can move a steel ball from a tee into a can located at an arbitrary...
spot in the workspace. The manipulators are computer-controlled, and students use Working Model software to model and predict the behavior of the manipulator and compare it to the actual performance.

Reverse Engineering Project. In the five-week Reverse Engineering Project, students learn about how engineering products are designed and manufactured by “dissecting” a product which they select. Each team analyzes a different product and presents the results during a poster session. In the first pilot section, a lawn mower engine (initially nasty and non-functional) and a prosthetic elbow were selected.

Guest Design Lectures. Guest Design Lectures distributed throughout the course are given by faculty members from different engineering departments. They describe a current project to give a flavor of the various engineering disciplines. Each student writes a one-page summary of each lecture.

Logistics
Like our colleagues at Maryland, we have found regular planning meetings among faculty and TAs to be very valuable. Initially, we intended to meet biweekly, but issues inevitably arose and we found weekly meetings more appropriate. In addition, we held intensive sessions at the end of the semester to evaluate and redesign the course.

Evaluation
Methods Used
Two methods were used to evaluate the course: the usual end-of-term Faculty Course Questionnaire (FCQ) required of all courses at the University, and the more in-depth Student Group Interview Feedback process at mid-term and the end of the semester. The FCQ asks a series of questions, then compiles an overall course and instructor letter grade. The latter uses a group process to both elicit the questions that are germane to each section of the course and tabulate student responses to those questions.

In addition to contemporaneous evaluation of the course, students will be tracked longitudinally as they progress through their academic careers through periodic questionnaires and phone interviews. Our goal is to determine what impact, if any, taking the course had on such issues as retention, comprehension of subsequent material, choice of major, career attitude, etc.

Results
Evaluation by both methods was positive. FCQ ratings for the Spring 1994 course averaged B+ for the course and A- for the two instructors. The interview process yielded more specific comments and data, such as:

- Provides more of a sense of what engineering is (100% agreed)
- I will return to engineering in the fall (91% agreed)
- Would recommend the course to other students (91% agreed)
- Iterative learning process was beneficial (100% agreed)

In general, students in both semesters were enthusiastic and positive about their experiences in the course. They cited working in groups on hands-on projects as being especially beneficial. Specific comments generated during the evaluation of the first pilot offering were taken into account in designing the second offering for the fall. One additional piece of significant data is that the course had the lowest drop rate of any lower division engineering course in Fall 1994.

Challenges and Future Plans
Two sections of the course were offered in the Spring 1995 semester, using a mix of experienced and new faculty. The intent of this strategy is to combine continuity with the infusion of new talent and ideas.

Many challenges exist in introducing significant change to well-established curricula, and departmental reaction to this course has been mixed. Five of the six departments in the College have accommodated this course into their curricula on an ad-hoc basis, while one department will not at present accept the course for credit. The Department of Aerospace Engineering Sciences, after an intensive year-long curriculum study and revision, has formally adopted the course into their required curriculum, effective next fall. As a result, four sections will be offered in the Fall 1995 semester.

Generating faculty enthusiasm for new ventures is also challenging. Many of our faculty have taught this course on an overload basis, but long term implementation will require consistent accounting as part of a regular teaching load. The fact that section sizes are limited to 30 students implies that more faculty will be needed, as opposed to large lecture classes. And, changing the teaching mode of lectures, homework and examinations to one of active, hands-on learning can be difficult for some faculty at first.

The success of this course and the planning for the new ITL facility has spurred an interest in curricular innovation, prompting the new dean to form a College-wide Education Committee. This group’s charge is to examine opportunities for curricular improvement, including sponsoring an intensive retreat, developing options for a common, or “no-fault” first year and proposing ways for various disciplines to utilize the new facility when it comes on-line in 1997.

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References

The time spent on each project is proportional to the height of each block.

Figure 1. Course Elements of First Year Engineering Projects.

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Al Bedard received a B.S. in physics from Boston College in 1957. He received his M.S. and Ph.D degrees from the University of Colorado in 1976 and 1982, respectively, in the Aerospace Engineering Sciences department. He is a physicist and project leader with the Wave Propagation Laboratory at the National Oceanic and Atmospheric Administration (NOAA), coordinating or directing seven major field experiments ranging from wind shear detection to atmospheric acoustic gravity waves.

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