A Case Study Approach to Freshman Engineering Courses

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Introduction

The entry-level engineering course is an important element in the development of young engineers and in the retention of engineering students. The objectives of a typical entry-level engineering course are wide-ranging and may include (1) the development of an appreciation for engineering, (2) an introduction to the disciplines, (3) the development of competency with specific engineering topics (e.g., technical communications, engineering ethics, and computer skills), and (4) the building of relationships among students and between students and faculty. A useful tool to achieve these objectives is a set of integrated case studies.

In this paper, the experiences at the University at Buffalo with the use of case studies as the main pedagogical tool in a large (approx. 420 students) introductory engineering course will be discussed. The ideal characteristics of case studies and the goals of case study use will be presented. Techniques for reinforcing key concepts throughout all case studies will be discussed. The paper also will summarize experiences with the evaluation of student performance with limited resources in a large class.

Examples of the case studies will be presented. A set of case studies has been developed to cover the range of engineering disciplines and content (engineering analysis and design methods; engineering calculations; technical communications; ethics; and professional issues). To develop an appreciation of engineering, the case studies represent a mixture of historical engineering solutions, forensic analysis (what went wrong?), and the solution of current and emerging problems. To teach content, the case studies allow the students to identify the tools required to solve a problem.

Background

Many engineering curricula employ one or more freshman engineering courses to train and retain engineering students. The freshman engineering course may be discipline-specific, with different courses for each department or discipline. Some freshman engineering courses are very general and include an introduction to all engineering fields. General freshman engineering courses can be very large and comprise many recitation/lab sections.

The objectives of a typical entry-level engineering course are wide-ranging. Common objectives include:

- the development of an appreciation for engineering,
- an introduction to the discipline or to the major engineering disciplines,
- the development of competency with specific engineering topics, and
- the building of relationships among students and between students and faculty.

Common engineering topics to be mastered include problem-solving skills (especially analysis and design methodologies and engineering calculations), professional skills (e.g., technical communications and engineering ethics), and computer skills. Frequently, an appreciation for the engineering profession and professional interpersonal skills are developed through group work.

To assess the content and delivery of entry-level engineering courses, freshman engineering courses at all public AAU universities were surveyed. Twenty-nine of the 34 public AAU universities have ABET-accredited engineering programs in all the traditional engineering disciplines. Two schools do not require a freshman course. Of the remaining 27 schools, about 48% offer a centralized large course common to all departments, while 41% offered freshman courses by department. (Two schools, 7%, offered a centralized course with different sections for each department.) The most common skills taught in the freshman courses were: professional skills including ethics (18/27 schools), problem-solving (9/27), computing (9/27), technical communications (6/27), and design (5/27).

A useful tool to achieve the objectives of a typical entry-level engineering course is the case study. Case studies (or cases) are stories intended to educate.[1] Case studies offer several advantages over lecture-based instruction. First, case studies better develop both analytical and decision-making skills.[2] Second, case studies involve the student in a real-world problem or situation. Third, better case studies motive the student to learn.[3]

The list of uses of case studies in engineering is almost identical to the list of objectives in many freshman engineering courses. For example, Henderson *et al.*[4] note that case studies can be used to:

- introduce engineering and engineering disciplines,
- introduce the "real world",
- teach basic concepts,
- teach problem-solving skills, and
- strengthen student-faulty relationships y encouraging student-faculty interaction.

Why, then, are case studies not used more frequently in freshman engineering courses? Case studies in engineering have been encouraged since at least 1974.[5] A number of engineering case studies have been developed and are available in the literature[6,7] and on the web (see, for example, references 8-12). One barrier to the use of case studies in freshman engineering courses is the lack of a set of *integrated* case studies that cover the topics and disciplines of interest. The purpose of this paper is to describe a set of integrated case studies used to teach a large freshman engineering course at the University at Buffalo.

Target Course

The course for which the set of integrated case studies was developed is EAS 140: Engineering Solutions. EAS 140 is a three-credit, one-semester course taught in the fall. The course is required for majors in aerospace, chemical, civil, electrical, environmental, industrial, and mechanical engineering. Over the last five years, the course enrollment has averaged 423 students per year. Typical composition of the course is shown in Table 1.

Table 1: Course Composition (Fall 2002 data)

Discipline	%	Class	%
Aerospace engineering	13	Freshman	88
Chemical engineering	9	Sophomore	7
Civil engineering	14	Junior	2
Computer engineering	<1	Senior	1
Electrical engineering	14	Other	2
Environmental engineering	2		
Industrial engineering	2		
Mechanical engineering	24		
Other engineering	15		
Other	7		

The course meets twice per week in large lecture sections (typically, 100-130 students/section) and once per week in 17-19 lab sections of about 20-22 students each. The lecture sections are taught by faculty and the lab sections by graduate teaching assistants. The course objectives are to:

- develop an appreciation for the breadth and elegance of the engineering profession;
- help freshman become successful engineering students;
- convey fundamental concepts in engineering analysis, design, communications, and ethics through engineering case studies;
- provide information for the engineering disciplines offered at the University at Buffalo, and
- serve as a beginning point of contact between freshmen and the School of Engineering and Applied Sciences faculty and staff.

Development of Integrated Case Studies

In the past, the course was taught using content-rich lectures in the lecture sections and hands-on teaching of computer skills in the labs. Starting four years ago, case studies were introduced to better achieve the course objectives. Although a number of case studies have been developed, typically 4 or 5 case studies are used in the one-semester course.

A list of case studies used recently is presented in Table 2. The characteristics of the case studies are shown in Table 3. The Millennium Bridge case study concerns swaying problems encountered with the opening of the Millennium Bridge across the Thames River in 2000. This case study is used to introduce students to the case study concept and to demonstrate how work can be distributed within a group to address engineering problems.

Table 2: Representative Case Studies

Case Study	Description
Millennium Bridge	Diagnosis and repair of the swaying Millennium Bridge in London
Workstation Design	Analysis of existing computer workstations and design of new workstations
Pill Coating	Students measure the rate of dissolution of a lollipop (a model for a pill) and evaluate a mass-transfer model
Power Transmission	Transmission of electrical power
Hyatt-Regency	Collapse of the Kansas City Hyatt-Regency walkways
Trebuchets	Analysis and design of medieval weapons
Computer Interfaces	comparison of the accuracy of a pencil and a computer mouse
Bridges/Walkways	constrained construction of a model bridge or walkway

The Workstation Design case study uses computer workstations on campus as a vehicle to teach analysis and design. Students are introduced to basic human factors concepts, which are applied to the analysis of existing workstations on campus and the design of a new workstation. Modifications of the case study have included the design for wheelchair-bound users and minimizing workstation costs.

The Pill Coating case study is a modification of the lollipop dissolution experiment describe by Fraser[13]. Students evaluate a new sucrose-based coating for a pill using a lollipop as a physical model. Students measure the lollipop diameter over time under different temperature and stirring conditions. In their reports, students must evaluate the appropriateness of a simple mass-transfer model which predicts that the lollipop diameter decreases linearly with time. In a large class, sufficient temperature conditions can be studied so that the effects of temperature can be evaluated (through, for example, the Arrhenius model).

In the Power Transmission case study, students investigate Ohm's Law and power loss equations by looking at line losses in a long (2500 ft) extension cord. The data collected by demonstration in lecture can be applied to numerous real-world situations. Example applications used in the course include consumer electronics and the transmission of power from Niagara Falls to Buffalo at the turn of the century.

The Hyatt-Regency case study allows the student to quantitatively investigate the catastrophic collapse of the walkways over the Kansas City Hyatt-Regency lobby in 1981. In addition to highlighting basic structural engineering principles, the case study probes engineering ethics and professional behavior.

In the Trebuchets case study, students build and analyze catapult-like medieval weapons called trebuchets. Analysis is conducted through canned computer programs and verified through experiments.

The Computer Interfaces case study concerns the controllability of the human-pencil interaction compared to the human-computer mouse interaction. Students gather data on the accuracy and speed of drawing a line between concentric circles using both a pencil and a mouse. Simple industrial engineering theory[14] is used to translate experimental data into a controllability index.

The Bridges/Walkways case study is the classic engineering project involving the construction of a bridge or walkway to achieve a technical specification (usually, allowable load) using limited materials (usually, a limited number of popsicle sticks).

It should be noted that the Trebuchets and Bridges/Walkways case studies can be used as the basis of entertaining competition between groups. Students typically compete for moderate prizes in a number of technical and non-technical categories. In the fall of 2002, the following case studies were used: Millennium Bridge, Workstation Design, Pill Coating, Power Transmission, and Hyatt-Regency.

Table 3: Case Study Characteristics

Case Study	Type	Engineering Content	Discipline
Millennium Bridge	Analysis (historical)	Introduction to case studies and group work	Civil
Workstation Design	Dilemma	Analysis and design	Industrial
Pill Coating	analysis (contemporary)	Data collection and modeling	Chemical
Power Transmission	Analysis (historical or contemporary)	Engineering feasibility	Electrical
Hyatt-Regency	Analysis (historical)	Ethics and analysis	Civil
Trebuchets	Dilemma	Analysis and design	Mechanical
Computer Interfaces	Analysis (contemporary)	Data collection and modeling	Industrial

Delivery of the Case Studies

Each case study is delivered over a period of two weeks in four one-hour lectures and one two-hour lab. The case study is introduced in the first lecture of the set. In the second lecture, the content is introduced (third column of Table 3), using the case study as a springboard. Thus, all content is introduced through a problem to be solved. The third lecture is devoted to the discipline highlighted in the case study (fourth column of Table 3). In the last lecture, any remaining case study material is presented, along with instructions for the preparation of the deliverable. During the set of four lectures, students meet in lab to learn appropriate computer skills, gather any needed data, or work on the deliverable.

Students work in groups of about four. Group assignments are made by the instructor. Groups generally share lecture and lab sections, but are expected to meet as a group outside of class hours. Each group submits one report for each case study. Case study reports are graded by the faculty lecturers. Group work is used to teach group dynamics and to minimize grading.

Assessment

The value of the case studies was assessed each year through end-of-the-semester surveys conducted by the School of Engineering and Applied Sciences. These surveys tend to measure the popularity of the teaching methods. In a typical year, about equal numbers of students list the case studies or group work as one of the three best aspects of the course or one of the three worst aspects of the course (see Table 4 for data from Fall 2001). Students rating the case studies high point to being engaged by the real-world problems. Students rating the case studies low frequently cite the difficulties of group work (e.g., arranging meeting times and dealing with recalcitrant members). It is clear from student feedback over the last five years that challenges with group work diminish the value of the case studies for a significant portion of the class.

Table 4: Number of Responses in End-of-Semester Survey in Fall 2001[1]

Mentions of Case Studies		Mentions of Group Work		Total Mentions of Case Studies or Group Work	
Liked best[2]	Disliked most[3]	Liked best[2]	Disliked most[3]	Liked best[2]	Disliked most[3]
30	12	10	18	40	30

Note: 1. 87 respondents out of 126 in one lecture section (69% response rate)
2. Question asked: "The three aspects of the course that I liked the best were:"
3. Question asked: "The three aspects of the course that I disliked the most were:"

In spite of the reported problems with group work, 67% of all the students in 2001 reported positive experiences in establishing peer connections. This represents an increase over the 56% of the students reporting positive experiences in establishing peer connections in 1999, when fewer case studies were employed in the course.

It was hoped that the midterm, final, and case study reports could be used to assess whether students learned more through the use of case studies. However, the nature of the examinations changed when case studies were introduced. It was decided to use "mini-case studies" in the midterm and final to mimic the way that the students had been taught. In addition, the requirements in the deliverables have been made more challenging each year, minimizing the value of comparing case study reports from year to year. Anecdotal evidence from conversations with students suggests that case studies aided in student involvement and interest level.

Conclusions

An integrated set of case studies allows for meeting the objectives of many freshman engineering courses. By using case studies to deliver all content, students are exposed to a consistent and engaging teaching approach. Examinations also were changed to a mini-case study format.

Changes in assessment vehicles decreased the ability to quantify the effects of the case studies on learning. Conversations with students revealed that case studies improved student involvement and interest.

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