For Presentation at the Air & Waste Management Association's 90th Annual Meeting & Exhibition, June 8-13, 1997, Toronto, Ontario, Canada

97-WA91.06

Environmental Engineering Design

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ABSTRACT

This paper outlines the capstone environmental engineering design course that has been used effectively at California Polytechnic State University. Senior level students work in teams on a multi-media industrial problem. The experience involves literature review, problem formulation, proposal writing, time management, technical and economic analysis and an oral and written presentation of the results. Feedback from alumni and employers has been positive.

INTRODUCTION

Design has been a strong component of Cal Poly's undergraduate program in Environmental Engineering since the program was established in 1968. The specifics have evolved over the years and now consist of a two course sequence. This paper will discuss the components of environmental engineering design, the capstone design class at Cal Poly and the background needed by students to take these classes. The classes have received favorable feedback from alumni and employers.

Design is a key element to all engineering programs. ABET [The Accreditation Board for Engineering Technology] defines engineering design as the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often integrative), in which the basic sciences and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Engineering Criteria 2000, ABET's proposed basis for accrediting Engineering Programs beginning in 2001 places more emphasis on design.

At a minimum engineering design must meet department goals, satisfy ABET requirements, and motivate students [1]. It is our belief that the design experience is critical for every environmental engineering student.

DEPARTMENT MISSION

Cal Poly's mission is to prepare students to practice engineering. This means developing the skills needed to prepare them to work in heavy industry, consulting, sales, governmental regulatory agencies and graduate school. The College of Engineering had 3,809 undergraduate students in 1995. The Environmental Engineering program had over 300 undergraduate students. Employers expect Cal Poly students to have a strong background in engineering fundamentals. In addition, they expect graduates to be able to work independently in the lab and field, to have good written and oral communication skills, to be able to pass the EIT, and to be able to go to graduate school. Environmental Engineering at Cal Poly started with a concentration in air pollution control and has evolved to into a multi-media program. It has elements of chemical, mechanical and civil engineering reflecting the background of the faculty.

ENGINEERING CRITERIA 2000

ABET has proposed that Engineering programs must demonstrate that their graduates have the abilities given in Table 1.

In addition, the professional component of ABET's requirements call for one and a half years of engineering topics including engineering science and engineering design. The curriculum must prepare students for engineering practice culminating in a major design experience based on knowledge and skills acquired in earlier coursework, and incorporating engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturing, ethical, health, and safety, social and political. [2].

CAPSTONE DESIGN AT CAL POLY

Prerequisites To Capstone Design

The senior design sequence consists of a four unit class in industrial ventilation and a 3 unit capstone environmental engineering design course. Cal Poly is currently on the quarter system. A strong background in the engineering sciences and chemistry is key in environmental engineering. In addition to one year of basic engineering chemistry, organic chemistry, quantitative analysis and physical chemistry are recommended. A strong background in Math, Physics, and Microbiology is also required. Senior students already have taken, or are concurrently taking the environmental engineering courses listed in Table 2.

Industrial Ventilation Design

The first design course in the senior year is Industrial Ventilation Principles and Design. Individual and team project work including computer simulation are used in learning the fundamentals of industrial ventilation. A laboratory is used to measure and establish the characteristics of fans. A design problem involving a multi-port exhaust system is undertaken for a local manufacturer. After visiting the plant, students work as teams developing designs for the specific problem. Flow rates are determined, ducts sized, fans are selected, power estimated and total costs determined. The results are written up and submitted to the company in proposal format. As an example, the project selected in 1995 was for Blue Lion Musical Instruments, a small manufacturer of custom guitars in Santa Margarita, California. On review of the students' work, the manufacturer commented on the fact they learned several things that were extremely useful in upgrading their shop and improving the work environment.

Examples of other industries that are interested in participating as partners include those with paint spray booths and clean rooms.

Capstone Design

The three unit capstone design course consists of 7 contact hours a week as outlined in Table 3. The Capstone design course at Cal Poly is Team taught. Faculty with CE, ENVE and ChE backgrounds all participate in the experience. In addition most of the instructional team are Registered Professional

Engineers.

We will describe each of the elements, some of which are done in parallel. The **predesign theory** part of the course is given by lecture. The students are introduced to new information on process design including concepts of process design, flow diagrams, computer aided design, economics, project management, and ethics. Peters' Process Design for Chemical Engineers[3] has been used as a required text. About 25% of the course is lecture.

Students are introduced to environmental safety regulations and industrial hygiene concepts by allowing them to form teams to research topics and make oral presentations to the class. This is done in seminar format using one hour of class time per week. Occupational & Environmental Safety by Kazianian & Wentz has been used as the starting point for students[4]. This time has also been used to work on Environmental Impact Analysis related to the Design Problem. The instructional staff provides background and perspective.

During the fourth week, after some initial short design assignments, the students are given the scope of the **final design problem**. Problems dealing with industrial process design that give the student a chance to apply engineering fundamentals and air and waste management technology are chosen by the faculty. In addition to applying concepts previously learned, the student must bring in concerns like pollution prevention, safety and industrial hygiene and consider the effect on the community. Economics are a key element addressed in this class. Students are expected to use the latest information retrieval methods available. In addition, students learn to work in teams and make written and oral presentations related to their design.

After initial research, teams must formulate a tentative solution and alternatives and submit these as proposals. At the same time each team submits a management time and resource management plan. These are evaluated by the faculty and returned during the fifth week.

The students then must complete a preliminary process design that is multimedia. They must consider feasibility, alternatives, and capital and annual costs related to the project and as well as return on investment with minimum impact on the environment. In addition, the design must meet current and future environmental and safety regulations.

Some examples of design problems that have been used in the past include the location and environmental controls needed for: the hazardous waste incineration of liquid wastes, a Kraft paper mill, a coal gasification plant, and the production of liquid fuel from coal. Most of these problems were developed from the literature with the assistance of the authors. We have found that some of the AIChE Annual Student Problems could be modified and expanded and work well as a multimedia environmental process design problem. Some that we have used include: Wastewater treatment from a nitroglycerin plant, germanium recovery from a fiber optics waste stream, and refinery waste water treatment.

The students are divided into teams to work on the entire problem. The faculty continue to present material related to successful design to the class as a whole Although the faculty do not answer questions on how the problem should be solved, they do encourage the students to submit questions in writing. If necessary, questions are answered by the faculty and distributed to all students. A definite time limit is imposed to produce a solution. In most cases the final design is due in 30 days.

During the last week of class each student team participates in an **oral presentation** of its design. This is done in front of a panel of faculty and outside industrial representatives, as well as all the students assembled. Each team is asked questions by the panel on its design. At the conclusion of all the design presentations, the faculty discusses the strong points and weak point of the presentation. This assessment addresses what the students should know and be able to do. The presentations are video taped for the students to individually later review.

The students also submit a written **final report** detailing their design. This report is graded on the technical merit of the work, documentation, and presentation. An individual memo is written to each design team by the faculty evaluating the submitted written report.

Alternate Approach

During Fall Quarter 1996 an alternative approach to the capstone design course was tried. Actual industrial problems were used for the design project instead of the more formal defined problem. The class was divided into teams or companies. Each company worked independently. Each Section of the class worked on different problems.

Lab Section A prepared a feasibility study on alternatives for the disposal or recycling of automotive paint sludge at the New United Motors Manufacturing Inc. (NUMMI) assembly plant in Fremont, California. NUMMI builds over 350,000 Toyota Corolla, and Geo Prizm automobiles and Toyota Tacoma trucks. A Cal Poly student on a CO-OP work assignment served as liaison between NUMMI and the class. An all day field trip at NUMMI conducted by plant staff provided basic data for the problem. Additional data requests were funneled though the CO-OP student.

The final oral presentations were conducted via a three-way video teleconference between Cal Poly, NUMMI, and an equipment vendor in Illinois. All four teams submitted very credible designs, and one is being evaluated by NUMMI for future adoption.

Lab Section B investigated waste minimization options at a food processing plant, Frito-Lay, in Bakersfield, California. Obtaining data from the plant was not as smooth as with NUMMI, since we did not have an in-place CO-OP student. In spite of this, the design projects were successfully completed. The entire Lab Section has been invited to the plant to give presentations to management staff.

This alternative approach, using the real world industrial problems, requires a lot of up front work by both faculty and the industrial partner during the previous quarter. Both NUMMI and Frito-Lay provided us with exceptional cooperation.

DISCUSSION

The senior design sequence is Cal Poly's approach to providing the student with an experience very similar to the real world. The importance of providing a relevant and realistic design experience at this level, and providing an environment to use engineering science learned in a simulated design is recognized [1,5]. Dixon has pointed out that to get started in a design role in industry, students need to know that the knowledge they have is correct and useful, that it is acceptable not to know everything, and that they have the background and ability to learn new facts, methods, processes, and principles as needed [6].

One challenge to the Design Instructor is the evaluation of team projects especially in large classes with many teams. Evaluation of the design competence of students in the Cal Poly capstone course is based on several things. Their basic understanding of fundamentals is graded based on homework and quizzes and their oral presentations. The quality of their design experience is based on comparing their proposal and final design report, along with their management plan, and their ability to answer questions during their oral presentation. The team participation is graded based on their management plan, faculty observation during class, level of participation in the seminar presentation, and peer evaluations. The literature suggests other ways of tracking progress including team member logs, exit interviews and final oral examinations. The amount of learning by each team member must be considered and some recent ideas on measuring this are presented in the literature [7].

Bieniawski [8] suggests that not enough emphasis is placed on engineering design in the undergraduate and graduate courses for engineers in most engineering disciplines in the USA. One reason for this is it is not as valued as research by the academic community for promotion. It often lacks the support it needs. With industrial participation in the design process this could change.

CONCLUSIONS

The capstone design course has been an important part of the Cal Poly undergraduate curriculum. The experience re-enforces academic learning, exposes student to real world design experience, demonstrates advantages of team approach ,and gives experience in oral and written communication. Industry support in design in terms of time and resources is critical.

Feedback from graduates indicates that it was one of most valuable courses since it has prepared them for work with consulting firms, industry, and graduate research.

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Table 1. Expected ability of engineering graduates.

a] apply knowledge of mathematics and science and engineering

b] design and conduct experiments as well as analyze and interpret data

c] design a system, component or process to meet desired needs

d] function on multi-disciplinary teams

e] identify, formulate and solve engineering problems

f] understand professional and ethical responsibility

g] communicate effectively

h] understand the impact of engineering solutions in a global/societal context

i] recognize the need for and have the ability to engage in life-long learning

j] have knowledge of contemporary issues

k] use the techniques, skills, and modern engineering tools necessary for engineering practice

Table 2. Capstone design course prerequisites.

air pollution and water pollution control

air pollution and water quality measurement labs
chemical engineering thermodynamics
mass transfer
solid and hazardous waste management
industrial ventilation
groundwater hydrology
geotechnical engineering
noise control

Table 3. Elements of capstone design course

Predesign Theory
Seminar
Design Problem
Section of Teams and Project Managers
Project Proposals
Management Plan
Oral Presentation of Design
Formal Design Report

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