Session 1308

Biological Engineering Student Design Projects With Real Clients

Ann D. Christy, Marybeth Lima
The Ohio State University / Louisiana State University

Abstract

This paper examines the use of student engineering design problems for real clients that require a multidisciplinary team approach to solve them. Design projects are described including animal habitats for a variety of wild animals, an inner-city playground, food-grade bacteriocin bioseparation apparatus, environmental control systems for a tiger habitat (in conjunction with the animal habitat student design team), and ozone disinfection of apples for cider production. Clients for these projects included university planning committees, local companies, zoning commissions, and researchers in food science and horticulture. Most of the student designs are now in the process of being built or implemented. The interactions between client and class are described and updates on the status of the projects are presented.

I. Introduction

Student design projects that are real and relevant and that can be conducted with the input from practicing professionals are desirable in engineering education.[12] The first two steps in the quality function deployment (QFD) design methodology, as described in Ullman[11], are to identify the customer and determine the customers' requirements. Direct interaction with the customer gives engineering students a more realistic experience of design, and better preparation for their professional careers. However, as Christianson and Rohrbach[1] point out, the customers' consideration may be subtle and may require ongoing dialogue and questioning between the student designers and the client/customer. Industry has been critical of engineering education that does not produce graduates who are sufficiently knowledgeable about how design is practiced in industry or who are able to deal with open-ended problems.[8] Interacting with real clients is a good way to enhance ties between industry and academia. Another method to enhance industrial ties is the use of student portfolios.[2, 5]

Much of the literature on linking industry with engineering design education focuses on capstone design courses.[4] Although the projects described in this paper were done as part of specific content related engineering courses and not as part of a capstone design experience, the literature on capstone courses can inform the practice of bringing real clients to engineering education at any level. Sources of student design projects include the instructor, the students themselves, other departments within the university, engineering societies, and industry.[4] A survey of 360 departments at 173 engineering schools reported that 64% involved some form of industry sponsorship in their capstone design courses.[10] Of these 33% had weekly contact between the students and the industry representative, 27% had monthly contact, 31% had contact at the start and finish of the project, and 17% used other patterns of contact. It was thought that local industry sponsorship was preferable because closer, more frequent contact between students and industry was possible.[10] Potential problems with using industry projects include the difficulty of matching the time restrictions of semesters or quarters with industry time schedules, confidentiality, patent rights disputes, and even finding industry projects that meet course objectives.[4] Nonetheless, students react favorably to industry related design projects because they are perceived to be real and instructors are viewed as resources not adversaries.[9] Hands-on design that takes the students through conceptual design to detailed design to actual construction of a completed product is even more effective in providing a compelling, powerful design experience.[3]

II. Case Studies

The authors developed student design projects having real clients for three courses at their two respective institutions, the Ohio State University (OSU) and Louisiana State University (LSU). In her senior level design courses at OSU, Dr. Christy strives to pose design problems that require a multidisciplinary approach to solve them. Food, Agricultural, and Biological Engineering students vary greatly in their interests depending on which specialization option they have chosen for their major, such as power and machinery, soil and water, environmental, biological, and food engineering, and it is a challenge to select projects that can engage all interests. Dr. Christy's design projects have included ozone disinfection of apples for cider, environmental control systems for a tiger zoo habitat, and food-grade bacteriocin bioseparation.

In her freshman level course at LSU, Dr. Lima introduces her students to biological engineering. This is accomplished through a semester long design project that emphasizes "big picture" concepts involved in design, including the engineering design method, methods of evaluating decisions, the importance of communication in the design process, and consideration of different perspectives and how they affect a design. Dr. Lima selected the design projects based on needs of the local community, relevance to biological engineering, potential interest in the project for students and instructor, and the willingness of clients to work with students. The design projects have included several animal habitat designs of local animal cages, and a playground. Following are individual descriptions of each of the design projects including, where applicable, updates on the progress of the designs after the classes completed them. The table below summarizes the courses and dates for each of the design projects:

Project	Institution	Course	Date
Disinfection for food safety using ozone	OSU	FABE 625: Modeling and design of biological systems	Winter 1998
Bacteriocin bioseparation	OSU	(same as above)	Autumn 1998
Wild animal habitats	LSU	BE 1252: Biology in engineering	Spring 1997, 1998
Elementary playground	LSU	(same as above)	Spring 1999
Tiger habitat HVAC	OSU	FABE 645: Environmental engineering of agricultural structures	Winter 1998

Disinfection for food safety using ozone

Outbreaks of food-borne and water-borne disease are matters of considerable public health significance. One student design project explored disinfection of cider-making apples by ozone. Recent documented cases of natural contamination of cider with *E. coli* O157:H7 has called the microbiological safety of fresh apple cider into question and placed the future of the cider industry in jeopardy. The students' clients for this project were faculty from the Department of Food Science and Technology and the Department of Horticulture and Crop Science. This OSU research team is currently evaluating ozone treatment as a way to maintain the safety of fresh apple cider products. The team needed a system to be designed which would allow them to investigate ozone delivery, determine the most effective parameters to decrease the microbial load on fresh apples, and assess the effects of ozone treatment on cider quality as compared with raw and pasteurized products.

The class was divided into four student teams to work on the ozone project: 1.) A machinery design team that worked on the apple conveyor and ozone contact chamber. 2.) An environmental team that worked on capturing and treating any stray ozone emissions for the safety of workers who would be operating the system. 3.) A fluid mechanics team that worked on optimizing the mixing regime and designing proper flow rates. 4.) A transport phenomena team that worked on optimizing the mass transport of ozone from the generator to the disinfection water to the apple surface, by designing the sparging system and specifying food grade surfactants that would overcome the apples' natural waxy surface barrier.

The four teams had to interact with each other, because each portion of the project relied on the other three. This provided a fairly realistic example of how such projects take place in industry. The final report was a combination of all four team reports. This particular design project was used as the basis for a research grant proposal, which was successfully funded. Research is in progress, with the development and construction of two bench- top ozone treatment chambers, based on the senior students' design project, being anticipated within a year. Small- and medium-scale cider producers in Ohio are excited about hearing the results of this research to help them evaluate the possibilities of using ozone instead of pasteurization to meet the more stringent food safety requirements. They have balked at pasteurization due to its perceived negative effect on cider quality and its cost. Commercial food processing equipment manufacturers have already expressed interest in scaling up OSU's bench-scale system to a larger, commercially viable system.

Bacteriocin bioseparation

As another example of multidisciplinary tasking, four student teams worked on a bioseparation project with a client from OSU's Department of Food Science and Technology. The teams had to interact with each other, because each portion of the project relied on the other three. The project was introduced by a memo to the class from the instructor as project leader, as follows:

MEMORANDUM

FROM: A.D. Christy, Senior Associate, FAB Engineering Associates, Inc.
TO: Engineering Staff, FABE 625
RE: Bacteriocin bioseparation system
DATE: October 27, 1998

Our firm has been asked to design an aseptic bacteriocin bioseparation system. Last week was spent gathering preliminary data. Today we'll share these preliminary reports. The work tasks were assigned as follows: * Bacteriocin properties. * Costs and vendor information for food grade materials. * Overall process conceptualization. * Sterilization and autoclaving requirements. Over the next four weeks, we will be designing the bacteriocin bioseparation system requested by our client, Ms. XXXX, of the Department of Food Science and Technology. The design can be separated into several distinct work tasks:

1. Cell separation design
2. Heat treatment design
3. Mixing design
4. Bacteriocin powder separation and drying design

Our design will not need to include the fermentation (pre-processing) or packaging (post-processing) steps. The client has agreed to handle those steps manually in her lab. We will assign design teams during our morning meeting. Teams will provide informal verbal progress reports on a weekly basis.

The deliverable to the client is a series of design report memos, one for each of the four design tasks. Therefore, submit a short memo summarizing your team's design recommendations with all supporting calculation sheets included as attachments. Use the standard business memorandum format (as illustrated here) and include your objectives, design criteria, any assumptions made, and your results / specifications / recommendations. Remember to cite all references. This type-written memo (two to four pages maximum) is due November 24, 1998.

Project reports were submitted in the format of business memos. The final report delivered to the client was a combination of all four team reports plus a summarizing cover memo from the instructor.

Wild animal habitats

The first year, students re-designed LSU mascot Mike the Tiger's on-campus cage into an interactive habitat. The final goal as explained to them on the first day of class was to present their design to the university administration for implementation. Tiger biology and behavior, and habitat design were studied through research, lecture, case study, and seminars and field trips in which students interacted directly with experts in these disciplines. Six groups of five students each worked together for the majority of the semester; groups were merged into two final groups that presented their designs (drawn in AutoCAD), a written proposal, and an oral proposal to an expert panel including LSU administrators. A formal proposal was submitted to the University in August 1997. See Lima[6, 7] for more specific information regarding this project.

The second year, students were assigned in groups of three to five students to work on one of three projects in the local area: (1) the re-design of a jaguar cage at Southern University, (2) the re-design of a multi-room cage for several tigers at a gas station, and (3) a chimpanzee cage at a carnival area. The methods of study were the same as for the previous year's class, however, a unit on working together in groups was added. Also, groups were not merged toward the end of the semester, thus, several re-designs of each enclosure were presented to the expert panels, and clients (the owners of the enclosures) were asked to choose which re-designs they liked best.

Tiger habitat HVAC

The co-authors collaborated in a project linking courses at the two universities, in which senior OSU students designed the heating, ventilation, and air conditioning (HVAC) system for the tiger enclosure design that freshman LSU students were completing. The main part of the proposed new habitat is open air; an environmental control system was needed for the enclosed off-exhibit area. This off-exhibit area is closed to the public, and is comprised of loading dock, office, keeper area, two loading/feeding dens, and the room in between the loading/feeding dens. Except for the loading dock, these areas all needed to be air conditioned in the summer. In addition, the office needed to be heated during the winter for human comfort. The students were to design the appropriate ventilation rates and area of inlets for winter and summer seasons. Assume outside conditions using 99% and 1% climatic design values (wet and dry bulb values). Design the supplemental heat requirements for winter conditions. Design the supplemental cooling requirements for summer conditions. Do the preliminary conceptual design of the control systems for fans, ducts, inlets, heaters, and air conditioners specifying temperature set points and appropriate widths of inlets during winter and summer design conditions. Sketch the off-exhibit area layout showing where all fans, inlets, and other equipment should be located. Locate vendor's information and price quotes to obtain a preliminary cost estimate for the environmental control system. Students worked in teams of two to four. Each team submitted a different design approach, based on that team's set of engineering assumptions. A conference call was held between OSU and LSU during class period to discuss design considerations and clarify objectives. Each team submitted a short memo summarizing the design recommendations with all supporting calculation sheets included as attachments. The students' different HVAC designs were given to Dr. Lima at LSU to incorporate in the overall tiger habitat design

Elementary playground design

Students will be assigned in small groups not only with their classmates, but also with Southern University students, with the objective to help K-6 students design a playground for those students, elementary school. The approach for learning about playground design will be the same as for the prior two years, with an emphasis placed understanding playground design from both adult and child perspectives. Student groups will make several visits to the elementary school to find out what the K-6 students want, to present those designs, and to facilitate the process of determining a finished product. Students will present their final design to the elementary school, and will present a proposal for implementation to local business and the local parks commission.

III. Reflections and Suggestions

We have compiled the following information based on experience, reflection, and interaction with students. These ideas can provide tips for instructors who choose to use client-based design projects.

A. Interactive teaching. Real life design projects are an interactive teaching method that will probably require instructors to learn material while they are teaching it, especially if instructors choose different design projects for each class. This approach departs from the "omniscient teacher" paradigm and may be initially uncomfortable for some; however, in so doing, instructors will model the life-long learning process that is critical for our students' future success.

B. Open ended problems. Because of the "real life" nature of the design problems used, final solutions may not be achieved in one academic term. We suggest that instructors set rigorous but reasonable goals for students in this regard. While this approach once again departs from traditional "canned" problem-solving exercises, the students have a much better sense of engineering practice, and can still master all objectives required for a "canned" exercise.

C. Instructor workload. These design projects take more work than traditional teaching and learning approaches, but the increased student motivation and learning more than offsets the extra time input. Suggestions in this regard involve making contact with potential clients before starting class, and setting up procedures for meeting and communicating that are presented to students at the beginning of the project. A teaching assistant is ideal for scheduling meetings and mediating communication.

D. Group learning. Deliberate instruction on how to learn and work in a group setting is beneficial, as students had much more success working in groups when this instruction was provided than when it was not. While there is a wealth of literature on this subject, readers are encouraged to consult Wankat and Oreovicz[12] to start, and to share this information with their students.

IV. Conclusions

There are a number of benefits for students, instructors, and clients. The first benefit is student enthusiasm. Working on real world problems is an excellent way to obtain student buy-in and generate excitement in the classroom. A second benefit is the exposure the students receive to professionalism and the use of standard business practices, including interacting with clients, preparing presentations, writing business memos, participating in conference calls, working within teams, and coordinating between different teams. A third benefit is that useful and useable designs can result from posing real problems to an engineering class. This is good for students to see their work implemented, good for clients to build stronger ties between the university and industry, and good for faculty in enhancing their own growth and credibility with their students and in the professional arena.

Acknowledgements
This work was partly funded by the W.K. Kellogg Foundation, through Ohio Project Reinvent, a program at the Ohio State University to explore new approaches to teaching and learning. Dr. Lima gratefully acknowledges Louisiana State University for two Incentive Grants for Teaching Innovation (1997-98, 1998-99), and a grant from the Louisiana Collaborative for Excellence in the Preparation of Teachers (LaCEPT) that allowed these projects to be completed. Dr. Christy also acknowledges the support of the Ohio Agricultural Research and Development Center.

Bibliography

1. Christianson, L.L., and R.P. Rohrbach. 1986. *Design in Agricultural Engineering.* American Society of Agricultural Engineers, St. Joseph, MI.
2. Christy, A.D. and M. Lima. 1998. The use of student portfolios to encourage industrial ties in undergraduate engineering education. 1998 ASEE Annual Conference Proceedings, Seattle, WA.
3. Durfee, W.K. 1994. Engineering education gets real. *Technology Review* 97(2): 42-51.
4. Dutson, A.J., R.H. Todd, S.P. Magleby, and C.D. Sorensen. 1997. A review of literature on teaching engineering design through project-oriented capstone courses. *Journal of Engineering Education* 86(1): 17-28.
5. Lima, M., A.D. Christy, M. Owens, and J.C. Papritan. 1999. The use of student portfolios to enhance learning and encourage industrial ties in undergraduate education. *NACTA Journal.* (in press).
6. Lima, M. 1998. A Tiger's Tale: Students get hands-on experience in designing a wildlife habitat. *Resource* 5(1): 11-12.
7. Lima, M. 1998. Principles of living systems and engineering design for freshmen level students in biological engineering: design of a tiger habitat. 1998 ASEE Proceedings, Seattle, WA.
8. McMasters, J.H., and S.D. Ford. 1990. An industry view of enhancing design education. *Engineering Education* July/August, pp. 526-529.

9. Sloan, E.D. 1982. An experiential design course in groups. *Chemical Engineering Education* 16(1): 38-41.
10. Todd, R.H., S.P. Magleby, C.D. Sorensen, B.R. Swan, and D.K. Anthony. 1995. A survey of capstone engineering courses in North America. *Journal of Engineering Education* 84(2): 165--174.
11. Ullman, D.G. 1997. *The Mechanical Design Process.* 2nd edn. McGraw Hill, New York, NY.
12. Wankat, P.C. and F.S. Oreovicz, 1993. *Teaching Engineering*, McGraw Hill, New York, NY.

ANN D. CHRISTY, P.E.
Ann D. Christy is an Assistant Professor in the Department of Food, Agricultural, and Biological Engineering at the Ohio State University. She earned both her B.S. in agricultural engineering and M.S. in biomedical engineering at the Ohio State University, and her Ph.D. in environmental systems engineering at Clemson University. Before joining the faculty, she worked for an environmental engineering consulting firm on the east coast.

MARYBETH LIMA
Marybeth Lima is an Assistant Professor in Biological and Agricultural Engineering at Louisiana State University, and an Adjunct Assistant Professor in the Department of Food Science. She received her Ph.D. in Food, Agricultural and Biological Engineering from The Ohio State University in 1996.