A key element for success on each local campus was the project leadership's ability to get faculty working together in a focused effort to create change. The ability of the campus coordinator to generate enthusiasm and obtain commitment from department chairs and faculty leaders was crucial. When leaders were unable to elicit this action, very little progress occurred. Halfway through the project it became evident that strong leadership influence had a major impact on project outcomes. Consequently, some basic leadership training was introduced in the final national conference.

If a significant core of faculty is willing to tackle changing the reward system at research-oriented universities, it is possible to make significant inroads into the reward process as is evidenced by above average progress at the University of Idaho, North Dakota State University, Rutgers University, Texas A&M University and Texas Tech University. These universities completed the largest amount of teaching reward plans.

Finally, after 12 years of leading change in 28 institutions, the door for changing the reward system for teaching is opening. However, the door to change also closes quickly in those institutions where leadership does not focus on the teaching mission. The lure of research grants can easily turn back any progress that was made on these campuses.

## Recommendations

1. University administrators and faculty benefit from learning how to influence change using collaborative and transformational leadership strategies before attempting to change reward cultures. Strategies such as creating a common vision and empowerment of faculty with authority, should be introduced at the beginning of any change project.

2. Plan for a meeting or conference where participants learn strategies on how to change the reward process. National conferences focusing exclusively on reward systems change can be an effective catalyst to begin cultural change.

3. Institutional climate for change should be assessed before awarding a grant. Some university cultures are such that change in the reward system will not happen in one generation. Funding such cultures is questionable.

4. Sustained commitment by funding agencies is critical to keeping the focus on teaching reward systems. The work has just begun. There are many years of tradition to be overcome.

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# Implementing Real-World Problem Solving Projects in a Team Setting


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## Abstract

Hands-on experience is an important educational component of agricultural and technical disciplines, and substantial effort and innovation in this area is being realized. This paper examines the use of real-world student design problems for actual clients that require a multidisciplinary team approach to solve them. The projects described were used in courses throughout biological and agricultural engineering curricula, and diverse methodologies were used to



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implement the projects via an interactive, group approach. Student projects included design of environmental controls, waste management systems, environmental impact plans, natural habitats for wild animals, a playground, and food-grade bioseparation and sterilization equipment. Clients for these projects included university administrators, local companies and consulting firms, zoning commissions, members of the local community, and researchers in food science and horticulture. Methodologies for implementing these projects are discussed, the impact of these projects on student learning is detailed, and recommendations for using this approach are presented.

## Introduction

Student projects that are real, relevant, and can be conducted with input from practicing professionals are desirable in education, particularly in engineering (Wankat and Oreovicz, 1993). Direct interaction with the customer/client gives students a more realistic experience of design and better preparation for their professional careers. Industry has been critical of universities producing graduates who are deficient concerning design practices in industry and cannot deal with open-ended problems (McMasters and Ford, 1990). Lack of communication skills is also a frequent industry complaint. Interacting with real clients is an effective way to improve the education of our students, to address the concerns of industries, and to enhance ties between industry and academia. This is true of all agricultural and technical disciplines, not just engineering.

Problem solving at all levels, including K-12th grade, usually starts at an arbitrary midpoint. Typically, text book problems are not open ended, do not require investigation and interpretation, and rarely incorporate the front-end work, such as identifying knowledge and information needs, that is associated with solving real world problems. Furthermore, in the United States, educators often use short answer or multiple choice assessment techniques which place the focus on students obtaining a specific answer rather then assessing how they obtained the answer. Real-world problems rarely have a single answer, and the processes used to develop a set of recommendations or a design are key elements.

Some instructors have incorporated real-world design projects into the classroom. Khan (1994) required students to complete soil fertility evaluations for private farm owners as part of an agronomy course and reported that the project improved students' teamwork, leadership, problem solution, and public relations skills. Davis (1999) had horticulture student groups team with Habitat for Humanity to design and install a landscape for a local family. The latter project was conducted as a service-learning exercise, in which learning objectives were accomplished by completing a set of activities within the community, with the final goal of serving that community. This educational reform movement is receiving increasing attention as an important means of imparting technical, social, ethical, and civic responsibility dimensions into education (Davis, 1999; Schneider, 1998).

**The objectives of this paper are to describe methodologies for implementing real-world problem solving projects for industrial and service sectors and to evaluate the success of these methods. Instructor reflections and recommendations are also included.**

## Methods

Real-world, client-centered student design projects were introduced in senior and freshman- level courses at The Ohio State University (OSU) and Louisiana State University (LSU), respectively. Each course employed principles of active learning, and all used student teams to perform project work. Instructor and clients worked together to present the problem to be solved and to choose the appropriate approach for obtaining solutions. Each project was unique and was selected based on course learning objectives and student rank. Assessment methods included student portfolios (Christy and Lima, 1998; Lima et al., 1999), instructor observation and reflection, and client satisfaction. Specifics on how these issues were handled are detailed in the following paragraphs, which describe the individual projects.

**Senior-level biological engineering design projects.**

*Disinfection for food safety using ozone.* Recent documented cases of natural contamination with *E. coli* O157:H7 have called the microbiological safety of fresh apple cider into question and have placed the future of the cider industry in jeopardy. The students' clients for this project were faculty from OSU's Department of Food Science and Technology, and the Department of Horticulture and Crop Science, who needed a system to be designed that 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.

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 stray ozone emissions. 3.) A fluid mechanics team that optimized the mixing regime and designed proper flow rates. 4.) A transport phenomena team that optimized the mass transport of ozone from the generator to the disinfection water, and to the apple surface. The four teams had to interact with each other because each team's portion of the project relied on the other three. This provided a realistic example of how such projects take place in industry. The final project report was a combination of all four team reports.

*Bacteriocin bioseparation.* Four student teams worked on a bioseparation project with another client from OSU's Department of Food Science and Technology. The teams worked on a different aspect of the overall project design: fermentation and filtration, heat treatment, mixing, and final separation. The teams had to interact with each other because each team's portion of the project relied on the other three. The project was introduced by an executive business memo to the class from the instructor as project leader. Student project reports were submitted in the format of business memos. The final report delivered to the client was a combination of the team reports plus a summarizing cover memo from the instructor.

**Senior-level soil and water management design projects.**

In this course, students "work" for FAB Engineering (a fictitious consulting company) in teams of three to four people to develop design solutions for real-world problems that are presented by external clients. After a problem has been presented, the teams identify and define the problem to be solved, determine methods that might be used to solve it, and establish their information needs and knowledge deficiencies. Based on this analysis, they request lectures and/or laboratory activities that will address their knowledge deficiencies and will facilitate developing a solution to the problem. There is no required text, and the students often work with design manuals and materials which are used in industry. Also, the students are not assigned textbook style homework problems. This approach has improved student learning and interest because students come to class to learn something they have a "felt need" to learn and can directly apply their newly acquired knowledge to solving a real-world problem. A written technical report that involves engineering judgment and an evaluation of the economic, social, political, and/or environmental impacts is required for each project.

*Land use impacts on watershed hydrology.* The county engineer's office presented a problem related to the design of a new culvert to replace an existing undersized culvert in disrepair. Construction for the culvert was underway and students had the opportunity to visit the site and conduct a reconnaissance of the watershed. Students evaluated the adequacy of the new design and evaluated land use changes. The students studied several decades of land use and projected future changes affecting this watershed, which has seen rapid urbanization. Flooding, scour, and impacts upstream and downstream of the culvert were evaluated.

On another occasion, the students worked with the Nature Conservancy and the U.S. Geological Survey to evaluate the impacts of urbanization and discharges on aquatic biota in a tributary of the Darby Creek. Urbanization is increasing stream flows and adversely impacting water quality and the diversity of the ecosystem. Students conducted a reconnaissance of the watershed and surveyed the channel profiles in the areas most affected by urbanization. Current and projected land use changes were used to evaluate flooding and scour impacts. An assessment was made of alternate measures that would reduce adverse hydrologic impacts while sustaining or enhancing the aquatic ecosystem.

*Waste management systems.* Several projects relating to this topic have been presented. One year, students evaluated a leachate collection and disposal system for a landfill. A local environmental consultant and alumnus served as the external client. In another project, an extension specialist presented a cattle feed lot design problem that included evaluating the feasibility of irrigating manure onto nearby fields. Students spent several laboratory periods surveying the area and conducting a reconnaissance of the watershed. Much of the focus of the study was on designing the feed lot, evaluating how many cattle could be located on the lot, and evaluating the viability of pumping manure from a storage lagoon and using it for agricultural production purposes. In a third project, the state Environmental Protection Agency commissioned the class to examine the feasibility of applying municipal wastewater from a small city to an agricultural field. Students assessed whether additional land was needed, determined the extent of nutrient uptake by crops, and made predictions regarding contamination of a nearby creek.

**Freshman-level biological engineering design projects.**

In this course, students are introduced to biological engineering 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. Community-based, service-learning projects were chosen to develop civic responsibility and to address social issues involved in engineering design.

Design projects were selected 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 instructor assigned groups of three to four students based on individual interest in the project and group learning techniques (Davis, 1993). Special consideration was given to developing communication skills (written, oral, and team/leadership); thus, these skills were taught as part of the course. Table 1 summarizes the projects used.

Table 1. Design projects used for biological engineering freshman level design course

| Project | Client | Product | Assessment |
|---|---|---|---|
| re-design of live tiger mascot cage (on-campus) | university administration | design drawings and specifications, enrichment plan, cost estimate, fundraising plan · | instructor, expert panel (zookeepers, professional engineer), architects, clients |
| re-design of local animal cages | local business owners | design drawings and specifications, enrichment plan, cost estimate | instructor, expert panel (zookeepers, professional engineers), clients |
| design of elementary school playground | elementary school children | design drawings and specifications, cost estimate | instructor, expert panel (playground inspector, playground specialist), clients |

The projects were introduced to students during the first week of the course; the first half of the semester was spent with instruction on the specific design project and other information gathering exercises such as field trips, library and Internet searches, and speaking with experts and clients. The second half of the semester was spent developing and evaluating designs with the input of the client, then preparing computer aided design drawings and specifications, including cost estimates. At the end of the semester, designs were evaluated by expert review panels and the clients. Multiple solutions were presented because merging numerous student designs proved cumbersome. Clients were then able to choose which aspects of each design they most desired, thereby creating a consolidated design.

**Combined senior and freshman-level biological engineering design project.**

Senior students designed the heating, ventilation, and air conditioning system for the campus mascot enclosure that freshman students were designing. The new habitat was open air; an environmental control system was needed for the enclosed off-exhibit area that included an office, storage area, and two animal dens. Each student team submitted a different design approach, based on that team's set of engineering assumptions. A conference call was held during the seniors' class period to discuss design considerations and to clarify objectives. Each team submitted a short memo summarizing the design recommendations with all supporting calculations. These were incorporated into the freshmen students' tiger mascot habitat design.

## Results and Discussion

The authors have concluded that real-world design projects enhance student learning, address concerns that industry has regarding graduates, and encourages industrial ties. These conclusions are based on assessment instruments, comments from students and clients, and instructor observation and reflection.

### Assessment

Student portfolios were used to assess student learning, see Christy and Lima (1998) for methodology, and Lima et al. (1999) for portfolios that are geared specifically toward enhancing industrial ties. Most students reported that working on these projects enhanced their mastery of the subject matter, improved their understanding of problem-solving and the industrial sphere, and helped their communication skills. These feelings were supported quantitatively by student performance on assessment instruments including exams, quizzes, and homework assignments that contained open-ended exercises.

Student feedback collected from standard university assessment instruments has been mixed. A few students think that the design projects are too open-ended and that the instructors need to assist the students more. The authors found that student ratings improved as they became more proficient and comfortable using real-world projects in the classroom. Interviews with students, written feedback, and alumni surveys have generally provided positive commentary on these courses.Client and student comments.

Both clients and students reported that student communication skills were enhanced by completing these projects. The first two steps in the quality function deployment design (Ullman, 1997) are to identify the customer and to determine the customers' requirements. However, as Christianson and Rohrbach (1986) pointed out, the customers' consideration may be subtle and may require on-going dialogue and questioning between the student designers and the client/customer. Design projects requiring communication with real clients provides the opportunity for students to struggle with this issue. The following student quote demonstrates this point: " I learned that a large part of the success of a design is knowing how to get the best description of what the client desires. We had to be creative in getting the children at Beechwood to express their wants through their drawings, friendly conversation, and observation of which equipment they played on most. It took a great deal of listening and observing to get the overall needs of the clients."

Clients were also successful in securing usable designs from many of these projects. The ozone disinfection system has been fabricated and tested; the Darby Creek project is on-going; the live mascot cage design is currently being considered for implementation by the university administration; and fundraising is currently underway to build the playground.

## Recommendations

The authors have compiled the following recommendations based on experience and reflection; they are intended to provide tips for instructors who choose to use client-based design projects.

**A. Selecting the client and project.** Selection of client and project is key to the success of this approach and will depend on the learning objectives specific to the course. Instructors should strive to balance technical content and social, environmental, economic, and legal constraints inherent to any real world problem. While it is not necessary that the client be an industrial representative, the project should include enough business content to provide students with a realistic experience. This can be a particular challenge when using academic researchers as clients. Frequent contact between client and students is important for final project quality. Service-learning is an extremely useful way to encourage community outreach and civic responsibility and to showcase one's profession by integrating it into the community.

**B. Open ended problems.** Real-life design projects are an interactive teaching method that may require instructors to learn material while they are teaching it, especially if instructors choose different design projects for each class. Flexibility on the part of the instructor is also essential, as students may need instruction in areas that were not initially anticipated. Because of the 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 departs from traditional "canned" problem-solving exercises, the students have a much better sense of professional practice and can still master all the objectives required for a "canned" exercise. Introducing and starting the project early in the term, giving students the bulk of the term to complete the project and having it due one to two weeks before the end of the term works well. Teaching students for consecutive terms can help with solving longer open-ended problems.

**C. Instructor workload**. These design projects take more work than traditional lecture approaches, but the increased student motivation and learning more than offsets the extra time input. Make contact and establish meeting/communication procedures with clients and experts before starting class. The instructor can advise students of these procedures at the beginning of the term. Finding clients who are willing to work with students and willing to work with technical and communication "blunders" along the way is essential. A teaching assistant is ideal for scheduling meetings, mediating communication, and helping to grade assignments. Bringing experts into the classroom as guest lecturers can also alleviate instructor workload.

**D. Group learning.** Deliberate instruction on how to learn and work in a team setting is beneficial, as students had much more success working in teams when this instruction was provided than when it was not. Consult the following references for team and group learning instructional material: Davis, 1993; Jalajas and Sutton, 1985; Covey, 1989. Personality tests such as the Myers-Briggs Type Indicator (Myers and McCaulley, 1985) and how one's personality type affects team work and conflict resolution have also proved useful. These references are invaluable for addressing conflicts that will inevitably arise among students in teams.

## Conclusions

Using real-world problem solving projects yields a number of benefits. The first 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 teams. The designs can be used by industrial and community clients; thus, students can see their work implemented, stronger ties can be built between the university and industry, and faculty can enhance their own growth and credibility with their student and professional counterparts. Another benefit is that engineering and science students discover that communication and investigation skills are important in their respective professions. Throughout their education they have probably gained the impression that they will spend most of their time making calculations and developing design solutions. In actuality, they will spend a considerable amount of time communicating with clients, defining problem-solving objectives, and obtaining the information needed to develop solutions. Also, many of the issues that will drive the final outcome will be legal, economic, social, and/or political. Using real-world projects and student design teams is an excellent way to enhance education and prepare students for their future as working professionals.

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