AC 2007-701: LEARNING THROUGH THE DESIGN OF A FISH HATCHERY FOR A COMMUNITY ON THE CHEYENNE RIVER RESERVATION – AN EWB SERVICE-LEARNING PROJECT

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Learning through the Design of a Fish Hatchery for a community on the Cheyenne River Reservation – an EWB Service-Learning Project

Abstract

Engineering students, with faculty guidance, undertook a service-learning experience focused on the design of a fish hatchery on the Cheyenne River Indian Reservation in Red Scaffold, SD. The team developed a technical guide for implementation of a commercial fish facility producing 100,000 pounds of fish annually that utilizes water reuse technology and local natural resources. The project provided a knowledge base on the existing geothermal well and how it may be utilized to produce electricity. The design assisted the tribe in securing needed funding from the Bureau of Indian Affairs. The College of Engineering has integrated Engineers-Without-Borders (EWB) into its formal curriculum through its widely acclaimed Engineering Clinic sequence. Clinic is a required course (from the freshman through senior years) in which multidisciplinary teams of students carry out independent research projects over the course of one or more semesters. They are a vital part of the "hands-on, minds-on" curriculum where students apply engineering principles to projects sponsored by industry, government or individuals. EWB projects present opportunities for students to apply engineering theory to real life problems that are not only outside of the classroom, but also often outside of their country and culture. Properly addressing the problem required the students to appreciate the societal and cultural impact of any system they introduced. Students first prepared for this by researching the history of the tribe and its culture. This information was crucial for adequate preparation in the preliminary site assessment. This experience presented enormous opportunities for both the community at Cheyenne and for the university students and faculty.

The success of the project is due to the collaboration of the two communities. The people of the Reservation in Red Scaffold are getting ready to construct a fish hatchery which will provide a needed source of food and income. They are also learning basic engineering concepts, so that they will be able to maintain and expand the system when necessary. The university students are learning lessons that they would never get in a classroom, while applying their classroom education to genuine engineering problems. They also were exposed to the Native American culture and a way of life that most Americans never experience. A multidisciplinary team of five students from chemical, civil, mechanical and electrical engineering conducted analysis and design on a broad range of topics such as waste solids removal, ammonia-nitrogen control, heat loss analysis, and power calculations for available methane gas from the existing wells in Red Scaffold. The work of the students in the clinics was supplemented by volunteer help from the EWB student chapter members. EWB receives broad administrative support, promoting the value of service learning and inter-collegiate activity while providing oversight for curriculum standards. College seed money has been provided and EWB is an element of ongoing development campaigns for sustained funding. This paper presents the pedagogical techniques used to enhance student learning through this project and the process developed to integrate the EWB and other service learning projects into the junior and senior years of the Engineering Clinics.

Introduction

The College of Engineering's innovative curriculum provides a unique opportunity to integrate service learning activities that increase student awareness of social equity, global issues, and stakeholder concerns as they pertain to engineering practice. In many curricula, case studies are presented in specialized courses, or as segments of a design course, but identification of stakeholder needs and views are not effectively included in the design process itself; hence, societal or environmental effects are *reported* at the end of the project rather than *integrated* as part of design considerations. Additionally, many of the process or product design projects in which a fledgling engineer might play a role are parts of a larger whole and do not present an opportunity to interact directly with stakeholders outside the immediate community (manager, technicians, operators, etc.) in the plant or manufacturing facility. These engineering solution models raise significant ethical issues because the engineer is making critical decisions based on limited or biased information, which could lead to negative impacts and conflict. As educators, our goal is not only to train competent and creative engineers, but also to prepare citizens with technical training who can systematically assess the impacts of technology on local and global populations, cultures and environments and appropriately implement optimal engineering solutions which address these considerations. Service learning activities provide a window of opportunity for students to engage in civic duty while applying relevant engineering concepts.

The College of Engineering considers service learning to be an important vehicle in the internationalization of engineering education. Service learning connects students with critical societal issues that can be solved or alleviated through technology. It gives students an opportunity to witness firsthand how technology can be a powerful force in enhancing the quality of life worldwide, and how it can promote community prosperity and improve international relations. This paper presents the pedagogical techniques used to enhance student learning through this project and the process developed to integrate the Engineers-Without-Borders (EWB) and other service learning projects into the junior and senior years of the Engineering Clinics.

Background

Service Learning (SL)

Research on service learning spanning the last three decades has revealed that service learning facilitates the development of leadership skills, self-esteem, teamwork, communication skills and acceptance of cultural diversity[1,4,8,10]. It has also been shown to increase the development of intellectual and cognitive abilities and improve academic performance[7]. From a pedagogical point of view, service learning is one form of experiential learning, in contrast to the "information-assimilation" model that typifies classroom instruction [2,3]. Both methods have their advantages and disadvantages. The "information-assimilation" model emphasizes a "top-down" approach to learning, in which principles and facts are presented symbolically (e.g. through books, lectures, or videotapes), and specific application of principles are learned primarily through deductive reasoning or "thought" experiments rather than through direct experience with real world situations. The advantages of the "information-assimilation" method are that it can transmit large volumes of information within a short time span and that it emphasizes logical, cognitive organization of that information within a short time-span. The method's weakness is that student's actual acquisition and long-term retention of information are problematical.

Utilizing Service Learning to Incite a Passion for Learning

Certainly, student experience tells us that traditional lecturing (the traditional strategy with the lowest retention rate) is not the method to use in order to spark student passion. While there is no question that reading and certain audio-visual materials can lead to student learning, experiential learning stirs more enthusiasm in students. Once the enthusiasm and desire for learning a topic is there, the possibilities of learning breakthroughs are limitless. Service-learning (SL) allows students to put their learning into practice. Once the student sees that the service experience will have a real impact on people's lives; the "ownership" of the project and the desire to learn increase dramatically[11].

The typical retention rate for various teaching styles is shown in Table 1. A study of instruction between control group and students with SL experience showed that the students in SL group scored significantly higher in retention[5]. Approximately 74% of the control-group students perceived the work load as being excessively high. However, in the SL group, although a majority of students had logistical problems (pertaining to transportation), completion of requisite work within deadlines was not reported as an issue.

Table 1 Retention Rates versus Teaching Method[5]

Teaching Method	Average Retention rate
Lecture	5
Reading	10
Audio-visual	20
Demonstration	30
Discussion group	50
Practice by doing	70
Immediate use of learning	90

Engineering Clinics at the University

The Engineering Clinics are a required eight-course sequence that emphasizes engineering practice and professionalism in a multidisciplinary setting (Table 2). There is a required clinic in every semester of study though the emphasis of each clinic is different. A two-semester Freshman Clinic sequence introduces all freshmen engineering students to engineering at the university. In Freshman Clinic, the students are introduced to a hands-on, active learning environment through a 3-hour weekly lab and a 1-hour weekly class meeting schedule. The first semester of the course focuses on multidisciplinary engineering experiments using engineering measurements as a common thread. The theme of the second semester is reverse engineering of a commercial product or process. Sophomore Clinic I combines a 1-credit multidisciplinary engineering laboratory with the 3-credit college composition and rhetoric requirement and is co-taught by engineering and writing arts faculty. The 3-hour laboratory for the course is a semester-long multidisciplinary design project. Sophomore Clinic II follows the same structure as Sophomore Clinic I, with public speaking as the 3 credits of required technical communications[9]. By this fourth clinic experience students are involved in solving open-ended engineering problems, and considering the merits of numerous solutions. Students enrolled in the Junior/Senior Engineering Clinic work in teams to carry out independent research projects. The Junior/Senior Engineering Clinic, a 4-semester required course, is an integral part of the engineering curriculum in which students apply engineering principles to emerging technologies. Students work on service related projects or research grants funded by industry or government in multidisciplinary teams[6]. The makeup of the teams is driven by the requirements of the project. Teams of students are organized based on their particular skills, interests and background, and matched to a particular project. The service-related projects offered through the junior and senior clinics are not meant to be a volunteer extracurricular activity. The projects usually have regional, national or international impact. Examples of SL projects offered through the engineering clinics will be presented later.

Table 2. Overview of general technical topics in the eight-semester Engineering Clinic sequence

Year	Engineering Clinic Theme (Fall)	Engineering Clinic Theme (Spring)
First Year	Engineering Measurements	Competitive Assessment Laboratory
Sophomore	Multidisciplinary Design Modules	16-Week Multidisciplinary Design Project
Junior	Product Development	Process Development
Senior	Multidisciplinary Capstone Design/Research Project	Multidisciplinary Capstone Design/Research Project

EWB –Service Learning Projects

The majority of the SL-related projects that our students have worked on have been through Engineers Without Borders™-USA. The US affiliate of EWB has as its mission "to help disadvantaged communities improve their quality of life through implementation of environmentally and economically sustainable engineering projects, while developing internationally responsible engineering students." EWB projects have provided students with an opportunity to use what they learn in the classroom to solve important community problems like water supply and wastewater treatment by adapting technology to the needs and resources of the host community. The project teams are usually multidisciplinary and ethnically diverse, which include a significant number of women. Students are involved in all aspects of the projects including site reconnaissance, design, project build-out, and fund raising. A significant challenge faced by the teams is that the design and equipment must be consistent with the host community's abilities to maintain them and that materials should be locally available. In addition, the design must be done in consultation with the host community.

Design of a Fish Hatchery on the Cheyenne River Indian Reservation

The EWB project focused on fish production commercialization in Red Scaffold, SD on the Cheyenne River Indian Reservation. Seeking to capitalize on the natural resource of their geothermal wells and develop a business that would provide sustainable economic benefits, the people of Red Scaffold utilized the Engineering Clinics. A multidisciplinary team of five students from chemical, civil, mechanical, electrical and computer engineering was assembled and worked on the project throughout the semester. The work of the students in the clinics was also supplemented by volunteer help from the EWB student chapter members. The team reviewed and analyzed a broad range of applicable topics, including waste solids removal, ammonia-nitrogen control, heat loss, and potential electric power generation from available methane gas from the existing geothermal wells.

The student team identified appropriate available technologies that could usefully extract the available thermal energy within the geothermal resources at the site to assure that a fish hatchery could be sustained through the long, cold winters in the region. They used previously collected engineering study data, manufacturers[1] equipment design information and specifications, theoretical models they had learned in the classroom, and consulted with professional engineers both on campus and off campus to determine the most attractive project elements and develop design recommendations. Consultation with the senior members of the Cheyenne Tribe on available, cost-effective and maintainable technologies led to the tribe[1]s selection of the final technologies for which funding would be sought. The engineering Clinic team developed a technical guide for the implementation of a commercial fish production facility utilizing water reuse technology that local natural resources that could produce 100,000 pounds of fish annually.

This process was fruitful not only for the tribe, but also for the students. They were able to learn firsthand how project design and selection is far more complex than what can be described by illustration in the classroom. The degree of personal growth that students experience on these SL projects cannot be easily measured, but student feedback resoundingly supports that these activities are some of their most memorable, instructive and profitable of their college experience.

The Impact of Service Learning

The EWB design was a foundation element in the tribe's application for funding from the Bureau of Indian Affairs (BIA). The BIA has provided support and the people of Red Scaffold are getting ready to construct a fish hatchery that will provide a needed source of food and income. They are also learning basic engineering concepts so that they will be able to maintain and expand the system when necessary.

In the U.S., most students have not experienced a federally managed reservation system, nor have they been in communities where the citizens must be responsible for maintaining cooperative systems and fixing them when they fail. This project offered a significantly different experience for the team, requiring that they consider the users and the constraints for sustainable maintenance and operation, the availability of materials, and the ease diagnosing or remedying a malfunction. The team had to constantly re-evaluate their ideas from the perspective of the host community, recognizing that it was not enough to devise a solution that works; they must devise a solution that works for the people of the Cheyenne Tribe. The families of Cheyenne tribe are depending on the efforts of the students to improve their lives. This type of experiential education is one of the basic definitions of service learning, transforming this project into much more than just an academic exercise.

This project challenges students to apply their engineering theory to a real world problem. A water distribution system required the students to reference engineering courses such as fluid mechanics, solid mechanics, surveying, and structures. The system cannot be too complex or else it will be too difficult for the host community to maintain and too expensive to fund. This projects were somewhat unique and all the more educational, because these factors must be considered by the team.

The components used were restricted by their availability to the community. Anything used in the design must be purchased in the host community. These parts must also be priced reasonably enough, so that the people can actually afford to buy them. This ensured that the community can replace any part that breaks.

This experience is full of opportunities for both the host and the university communities. The people of the Cheyenne River Indian Reservation will be constructing a fish hatchery soon. They are also learning some basic engineering concepts, so that they can maintain and expand the system when necessary. The College of Engineering students are learning lessons that they would never get in the classroom, while applying their classroom education to actual engineering problems. They also get exposure to another culture and a way of life that most Americans never experience.

Diversity: A Multifaceted and Multicultural Experience

We seek diversity in our educational exposure, but this project presented in many types of diversity in genuine scenarios. Diversity began with the University students and faculty, and the various ethnic origins they brought to the team. We found that recognizing the cultural differences of the team members enabled them to draw from their own differences when approaching the project tasks. This helped when later appreciating the local culture on the reservation and it was particularly beneficial to have team members who grew up outside of the United States and in less developed communities. These people were able to empathize with the plight of the Native Americans that the team was trying to help, so they provided unique insight into the solution process.

The group is also diverse in that four different disciplines (chemical, civil, mechanical, and electrical/computer) of engineering were represented. As a result of these four disciplines working together, the analysis brings a more diverse perspective into consideration and impacted the resulting system components. The team had to deal with conflicts that arose from the differing views, but the process lead to a more comprehensive design. project This project actually leads to the team members learning more about each other's cultures as well as the Cheyenne community culture.

The cultural difference between those at the university and on the Indian Reservation was significant. Through this experience, the students were exposed to the Native American culture and a way of life that most Americans never experience. One of the most obvious differences was the hierarchy within the community and the organizational structure.

Another significant difference between the two cultures was economic. College students from predominantly middle class backgrounds in the United States represent the demography at the university; however, the people on the reservation are not as privilege. It was a humbling experience for the university students to experience the lifestyle of the community. The students were also amazed that while these communities may be economically impoverished, they were also very generous and culturally rich. An engineer could only realize this lesson from an engineering project of this nature. While these insights are not technical, they are some of the most profound lessons anyone can learn.

Administrative Support

College seed money has been provided and EWB is an element of ongoing development campaigns for sustained funding. The College supports EWB for many reasons, including the fact that EWB projects are a good fit for our hallmark Engineering Clinics. The project teams are usually multidisciplinary and ethnically diverse. They also include a significant number of women. As we work to provide the technical education desired by students, we must also provide the cultural development and the ability to assess the impact of engineering in the broader community. EWB projects have the potential to address these traits which have been identified as critical components of successful engineers in the future.

Conclusion

Projects and service based learning provide an increased breadth and depth to the educational experience and engineering pedagogy of a university that is not available to classroom based learning alone. SL projects also expose students to the culture and language of the host community through technical projects that benefit the host and give students experience and exposure to the diverse peoples and practices. By applying what they learn in the classroom to a project that may be essential for the well being of a community, students learn that the most important calling of the engineering profession is to improve the quality of life for humankind. Students are often surprised to learn during their experiences that there are far more similarities than differences among the people of the world. The need for basic services, often taken for granted by students in the United States, is universal as is the need for respect and understanding. Students become better engineers when they learn to work closely with their customers, weaving and adapting appropriate technology to the needs and resources of the community to assure its sustainability into the future. This alternative is superior to forcing an assumed optimal technical solution that may not be at all appropriate for a local application. By learning to value and respect other cultures, the students gain a better appreciation for all that they have, and the role that engineering and technology can play in the development of the global community.

The junior/senior clinics provide students with valuable experiences that give them advantages when applying for internships, scholarships, graduate school, and jobs after graduation. Often, the undergraduate students can point to conference or journal publications, engineering reports, design and fabrication experience or field work as evidence of their exceptional preparation for the real world. This is supported by anecdotal evidence and internship surveys from employers. The engineering clinic sequence is an excellent platform for integrating service learning into the engineering curriculum.

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