Service Learning as a Strategy for Engineering Education for the 21ST Century

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ABSTRACT

Service learning is an effective strategy to enable engineering schools to attain the objectives outlined in recent reports on reforming the undergraduate engineering curriculum for the 21st Century. service learning is a method under which students learn and develop through active participation in thoughtfully organized activities that are conducted in and meet the needs of a community. The objective of this paper is to introduce readers to the possibility of service learning as a viable pedagogic method in undergraduate engineering education. Courses from three different engineering curricula are described in this paper to illustrate how service learning can be integrated in a wide variety of courses in the engineering discipline. Service learning as a pedagogy can be used to enhance student learning while building university-community ties and addressing the many education, health and environmental needs in our community.

INTRODUCTION

Education that is grounded in experience as a basis for learning is not new, and community service by students in institutions of higher learning has a long history in the United States[1]. service learning is defined as a method by which students learn and develop through active participation in thoughtfully organized service activities that meet the needs of a community; is integrated into and enhances the academic curriculum of the students; and is coordinated with community organizations including K-12 schools and institutions of higher learning[2]. In service learning, community needs are defined by the community partners. Federal support for service learning originated from President George Bush's "A Thousand Points of Light" initiative, with the culmination of the U.S. Congress passing the National and Community Service Trust Act of 1990 and the creation of the Corporation for National Service (CNS).

This paper describes three examples of implementing service learning in engineering curricula that received direct and indirect funding support from CNS: 1) the Mechanical Engineering curriculum at the University of South Alabama, 2) the Electrical Engineering and Computing Science curriculum at George Washington University, and 3) the Civil and Environmental Engineering Department at University of Utah.

THREE CASE STUDIES OF SERVICE LEARNING IN ENGINEERING

Integrating Service Learning into a First-Year Mechanical Engineering Course

The faculty of the Mechanical Engineering (ME) Department at the University of South Alabama

(USA) began, in Fall 1993, a self-study to evaluate the undergraduate program to meet the challenge of educating engineering undergraduates for the 21st Century[3]. They came to the realization that "Introduction to Mechanical Engineering," which carried one-credit hour at the time, was insufficient to address the needs of current first-year students because of its present format (9 to 10 meetings per academic quarter for 50 minutes each). Beginning in the Fall Quarter, 1995, a new 4-credit hour "Introduction to Mechanical Engineering" was introduced as part of the curriculum revision. The course has many of the features of successful, first-year "Introduction to Engineering" courses described in recent ASEE journals[4,5,6,7], except that service learning provides the context for the design projects.

The service learning project is carried out with the partnership of the Mobile County School System and provides students enrolled in "Introduction to Mechanical Engineering" with real-life customers in their design projects -- a team of two middle-school teachers. The students are informed about a need in the community (the schools) for more resources to support hands-on of mathematics and science in middle-schools in Mobile County [8], and they are tasked with designing and producing manipulatives/instruction modules that satisfy the need of their teacher customers for implementing hands-on activities to teach mathematics and science.

To make the process "real-world" like, each student design team is given a budget of $50. In the process, engineering students will have opportunities to write a problem statement, develop criteria and constraints to judge design ideas, implement the project, write progress and final reports, and make oral presentations. Since the knowledge base for the design project is middle-school mathematics and science, the "analysis" part of the design process will be less of a burden to the first-year students and they can focus their energy on the "creativity" and "process" part of the design. (There are many everyday examples of engineering that are described by middle-school mathematics.) Interaction with middle-school teachers and students will provide the opportunity for first-year engineering students to appreciate diversity and practice their communication skills.

Method: Twenty (20) middle-school teachers were recruited in November, 1995 from the SECME (Southeastern Consortium for Minorities in Engineering) program of the Mobile County Public School System during the 1995-96 academic years. One application criterion was that only a teacher team consisting of a mathematics or science teacher and a language art or social studies teacher from the same school could apply. The teachers were provided with a small stipend from a grant from the Corporation for National Service for their involvement.

Orientation for all teacher participants took place in early December, 1995. At the orientation, a description of the service learning project and ME125 instructors' expectations of teacher participants were presented, both in the form of a one-page questions-and-answers information sheet as well as a short presentation and discussion session led by the authors of this paper. These expectations will include meeting with the design teams, implementing and evaluating the instructional modules in their classroom, attending final project presentation, and participating in an evaluation survey of the service learning project. Teacher participants' expectations of the project and ME students were surveyed at the conclusion of the orientation session.

Five two-person teams were assigned to serve as design customers for engineering students enrolled in "Introduction to Mechanical Engineering" in Winter and Spring Quarter, 1996, respectively. The teacher participants met with the engineering student team for an initial interview to gain background information, and they hosted a visit by the design team to their school. The teacher participants also met with the design teams to provide feedback throughout the design process

To prepare the engineering students for their design project, a series of five presentations and activities on designing for instruction were led by a faculty from the College of Education whose expertise is on instructional design and K-12 science education. This portion of instruction includes:

(1) an overview on what motivates middle-school students and participate in activities on motivation;

(2) the essential components and techniques to implement cooperative learning;

(3) an overview of learning styles and self-analysis scales;

(4) the different levels of cognitive development and elements of objective classification.

To overcome the difficulty of scheduling, provisions were made so that at least two students from each 4-person design team were present to meet with the two teacher-participants, with bonus points awarded when an additional student or the entire team is able to meet with the design customers. Students filled out a meeting log after each meeting, which was then returned to the instructors. In the first year, on the average, three to six meetings were held between the teams and their design customers.

To complete the design project, each engineering-student team presented to the teacher customers a three-ring notebook containing the instructional modules consisting of five days worth of introductory, developmental and culminating activities together with the physical manipulatives, and make an oral presentation attended by all the teacher participants. A similar three-ring notebook was submitted to the instructor. The design project constituted 50 percent of the course grade -- 25% for the report and 25% for the final project presentation.

Results of the Service Learning Experience: From the standpoint of establishing university-K12 partnership, the service learning project met its goal. Ten instructional modules and supporting manipulatives were designed and produced in the first year. A survey of the teachers at the end of the project showed that 100 percent of the teachers were happy with the instructional modules and 67 percent had implemented them in their classrooms. All teachers who actually used the modules said in their qualitative responses that they found the module very useful. All of the respondents said they would use the module again in the future. One teacher participant made a presentation at a state K-12 service learning workshop on the modules produced for her class, and another three teacher participants were slated to make presentation at a national K-12 conference. After the project's conclusion, 87.5 percent of the teachers from winter quarter and 66.7 percent of the spring quarter reported they were satisfied with the process of the project, with the rest citing time and scheduling conflicts as a reason for their dissatisfaction.

Student assessment included collecting data in the form of a pre- and post survey on efficacy in class work, engineering as major, and working with middle school teachers; attitudes toward school, engineering, Learn and Serve, and community service; abilities related to problem solving, computer skills, interpersonal interactions, and cooperative learning activities. Results of the student survey were mixed and often statistically insignificant because of the small student population (a total of 41 students in Year One) and the lack of a control group, so they must be interpreted with caution.

Concerning student attitudes toward the community and civil responsibility, attitudes were somewhat more negative during the winter quarter, but student attitudes became more positive during the spring quarter. Both findings were statistically significant. It should be noted that one student in the winter quarter objected (he disagreed with any type of learning other than drill and practice during the lectures on learning style presented by the faculty from the College of Education), and motivated some of the other students in the class to disagree with the service-learning approach. No problems of this sort occurred during the spring quarter.

In the open-ended responses, winter and spring quarter students listed benefiting society as a definition of engineering, along with apply knowledge, problem solving, and designing. Benefiting society was either most or second most important according to the engineering students both quarters. Student perception of their ability to do design increased in winter quarter but decreased in spring quarter. The winter quarter finding was statistically significant but the spring quarter finding was not.

Positive student attitudes toward engineering increased slightly both quarters, but neither finding was statistically significant. Their self-confidence in studying engineering as measured by a series of items increased both winter and spring quarters, and both findings were statistically significant. Confidence that the students could complete their degree showed little or no change. Concerning interpersonal interactions, student confidence in talking with faculty members in the department and talking with a person already employed in the field increased both quarters. Both findings were statistically significant.

Concerning teaming, student attitudes showed a slight negative change both quarters but neither finding was statistically significant. When students were asked to list three skills obtained from the design project, teaming was mentioned approximately twice as often as any of eleven other skills. Teaming skills mentioned included cooperative learning, working with others, sharing ideas and working in a group, designing a project to suit others, the importance of total group involvement, the ability to communicate with team members, and the recognition of roles within the group.

Concerning the objective that engineering students will learn to team effectively with middle-school teachers, they became more bothered on a series of items measuring teaming during the winter quarter and less bothered during the spring quarter. The spring quarter improvement was statistically significant.

Integrating Service Learning into an Electrical Engineering and Computer Science Curriculum

As part of new curriculum guidelines to incorporate social and ethical implications of computer technology into the required curriculum, a Technology and Society course has been developed by the Electrical Engineering and Computer Science Department for second and third year computer science, electrical engineering, computer engineering, civil engineering and mechanical engineering students in the School of Applied Science and Engineering at George Washington University in Washington, DC. The course presents topics on ethics and social impact related to computer technology to teach the learning objectives proposed by the ImpactCS Project at

George Washington University[9,10]. These objectives are:

(1) responsibility of the computer and engineering professional;
(2) basic elements of ethical analysis;
(3) basic skills of ethical analysis;
(4) basic elements of social analysis; and
(5) basic skills of social analysis.

These objectives are taught by providing students with the opportunity to identify stakeholders and ethical issues in concrete situations. They are shown that technology does not simply "impact" society in a one-way causal chain, but society also influences the shape and development of technology, and the social or organizational setting in which a technology is used influences the way it is used. They are made aware that social relationships have implicit and explicit considerations of power and that those power relationships may shift as a result of the new technology. Another important idea is that the situations in which a technology will be used, the people who will use that technology, and the uses to which it will be put, are all more varied and diverse than one might first expect.

To assess these implications, students are expected to systematically collect and analyze empirical data gathered in a social context. These goals can be accomplished by requiring students to participate as a team to do a Social Impact Analysis (SIA). First proposed by Shneiderman in 1990, the SIA has shown to be a very effective vehicle to enable students to gain experience in assessing the impact of a particular computer implementation in a real-world setting with real stakeholders[11,12].

Method: Prior to spring, 1996, students were sent to administrative offices around the campus to conduct their SIA's. However, during the spring of 1966 the instructor of the course teamed with a representative from the Community Services Office at GW funded under an AmeriCorps grant to identify 17 sites that were off-campus community service organizations. These sites included agencies that provided after school day-care, services to the homeless, senior citizen centers, an AIDS clinic, several public schools, and public health clinics. Students were provided with an on-campus liaison to the off-campus site and given the following statement of purpose:

> "The purpose of this project is to give you the experience of working as a team with a real client to produce an analysis of the operation of a computer system in the real world. The clients you will be working with are all involved in providing social services to the local community. They are often over-worked, under-staffed, and working with very limited or primitive computer resources. Your job is to analyze how they are using the computer to help provide the service. What impact is the computer having in their organization, who is using the computer, how is it being used, is it viewed as a positive or negative asset in the organization, are there ways that it could be used differently, is the delivery of service being helped by the computer? If the client is using the computer to access a database, you will want to ask how the data is verified for accuracy, how the data is protected for privacy, who can access the data, and how it is being used. You need to be aware that some of the data you see or collect could be confidential, so you must assure the client that your final report will be given only to them and to your professor." [13]

Students were told that the goals of the analysis would be for them to 1) determine how the system works, the actual vs. idealized practice; 2) provide them and their client with a venue for thinking about the social and ethical aspects of computer systems; and 3) provide their client with a document that will be useful in future modifications of the system. In particular, they were urged to provide recommendations to their client to help them to improve the use of their computer systems to be more reliable, secure and efficient. Students were urged to practice the skills of a social analyst that included thoughtfulness and imagination in constructing their data collection interview questions, in identifying places to observe, in dealing with a variety of stakeholders, and in finding hidden assumptions in the technology. They were urged to give attention to detail in data collection and in thoroughness of analysis. They were also given the caveat to be very respectful of people who might have fewer technical skills then they did. Because they would be going off-campus to visit their clients at some sites that were in questionable areas in the city, they were required to travel in teams of least two people to any site.

After preliminary site visits, each team then had to organize their research plan to include such data collections techniques as structured interviews, surveys, observations, and content analysis of historical documents. During the course of the semester the teams were required to present a written and oral progress report and then a final oral presentation and written report with their findings and recommendations.

Results of the Service Learning Experience: When comparing the reports of students from this cohort to students in previous years, it became apparent that doing a project with a community service component provided a much more powerful learning experience for the students. In previous years, students had focused on the technology more than the people at the sites, because most of the on-campus sites were doing fairly traditional office work. In spring of 1996, the students became much more interested in the human aspects and much more tuned into the social, rather than technical, implications of the technology being used to the sites.

Several teams were quite disturbed when they found that the computer equipment at their sites was made up of obsolete technology dumped there, often without any manuals or with key pieces missing, by corporations that were upgrading their own technology and desiring a tax deduction for making a contribution to a non-profit organization. One team talked about a site with a closet full of old computers where the staff was feeling very guilty about not using them. When the students looked at the equipment, they immediately were able to make the assessment that it was useless and obsolete, thus relieving a deeply felt concern.

Most of the teams were able to provide useful advice and even technical assistance to their sites in the process of doing their analysis. Each site received a copy of the team report with recommendations. Two of the sites used the report to acquire more funds for new computers from their governing boards. A number of the students became so interested in the community service aspect of their project that they expressed the desire to go back to their sites to work as volunteers.

Overall, the addition of a community service aspect to the SIA assignment greatly enhanced the learning experience and raised the consciousness of students about many of the social issues that had been previously discussed in class. A topic like the privacy and security of databases became a real issue at the AIDS clinic. The lack of equity of opportunity for poor children was brought home when students saw the obsolete computer equipment they had in their schools and daycare centers. The importance of a good recordkeeping capability became apparent at the public health clinics. Students left the course with a first-hand understanding of the ethical and social implications of computer technology and with a greater sense of responsibility for creating future technologies.

Integrating Service Learning into a Junior-Level Civil Engineering Course

"Hydrology: Civil and Environmental Engineering" is a junior-level course in the taken by all Civil Engineering students at University of Utah. Its content is predominantly the study of design and analysis skills for natural and engineered surfaces and ground water systems. Students enrolled in the course are required to undertake a design project, which constitutes ten percent of the course grade. Class enrollment is usually between 60 to 85 students. Beginning 1996, service learning became an option for the students to engage in design, where they will apply their classroom learning of hydrology and water resources to provide a needed service in the community.

Method: Clients for the design include the Utah Department of Transportation, which manages polluted water runoff from highways, and the State Department of Environmental Quality, which monitors and manages water quality in the state of Utah. In 1996, as a part of an overall study to create an urban trail, students enrolled in CE 452 performed water quality analysis on a spring that flows through a lake-filled valley in the Salt Lake City area and hydrological analysis of siting pedestrian bridges. An objective of the service learning project was that students develop a client-engineer relationship through the interaction with the service recipients. The clients were involved in the evaluation of the service learning project and participate in evaluating the effectiveness of the students.

Through the service learning project, students had an opportunity to work in teams to apply the design and analysis skills for natural and engineered surface and groundwater systems that they learned in CE 452 to provide a needed service to their community. The service opportunities were aimed at the development of the civil education of students. Activities in the class provided a method for students to think about what they learned through the service experience and how these learning related to the curriculum. This included in-class reflection and assignments of topics for discussions that were led by a Teacher Assistant provided by the university's Office of Community Service. As part of the service reflection, students had to discuss why it was important for all citizens to be involved in their communities in a democracy.

Results of the Service Learning Experience: Students submitted reports and made presentations to their engineering clients, and their reports have been incorporated in a proposal that will be submitted to the Shoreline Trail Trust to seek federal support for the urban trail in Salt Lake City. Future work will include hydrological analysis of siting a tunnel in the trail and other environmental impact studies.

CONCLUSION

The three projects described in this paper all illustrate how a service learning component can greatly enrich engineering education. The students involved in these projects learned to work together in teams and were highly engaged and motivated by their interaction with "real" people in the various service agencies. In most cases, students were enthusiastic about the experience.

Similarly, the client agencies were very satisfied with their participation in the collaboration and valued the expertise that the students provided to them. Most importantly, however, the students came to understand at a deeper level the social responsibility that comes with being a member of the engineering profession.

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