Developing Technical Competency and Enhancing the Soft Skills of Undergraduate Mechanical Engineering Students through Service-Learning

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Abstract:

New ABET requirements have encouraged engineering faculty to help students develop "soft skills." Among these soft skills includes the ability to work in teams and communicate effectively, appreciation of different cultures and business practices, understanding the global nature of business and engineering and understanding the societal, economic and environmental impact of engineering. Inclusion of these soft skills into an already packed engineering curriculum can be difficult. One approach that appears to be effective at helping students develop the soft skills without compromising the acquisition of technical knowledge is service-learning. Service-learning is a form of project based experiential learning where the students are engaged in an activity that meets the specific needs of a community or nonprofit organization. When correctly implemented, both the service and educational objectives are met. Service-learning has been incorporated with varying degrees of success into many courses and/or curriculum in many universities across the United States since the late 1980's .[1-3] However, only a small fraction of the service-learning activity has been in the engineering disciplines. [1, 4] This is very unfortunate since many of the problems that exist in the world require engineering intervention.

During the fall semester of 2002, the Introduction to Materials Laboratory Class from the Mechanical and Aerospace Engineering Department at the University of Dayton was involved with a service learning project through ETHOS (Engineers in Technical Humanitarian Opportunities of Service-Learning). This project supported the work of the service organization, Aprovecho. The overall technical objective of the project was to improve the efficiency of a wood burning cook stove or "eco-stoves" by proper selection of the insulative brick materials used to make the stoves. In the Materials Laboratory, students manufactured three formulations of insulative bricks and assessed their properties by conducting various mechanical and physical tests. The educational goals of this project were to provide the students with a hands-on, service-learning experience to enhance their technical, program management, computer and communication skills. Another educational goal of this program was to expose the students to ideas of appropriate technology, environmental responsibility and ethics, cultural diversity and cultural sensitivity. This paper will focus on the educational objectives and outcomes associated with this service-learning project. Details of the project including student responsibilities, reflection and methods of assessing student performance will be addressed.

Introduction:

Industry and academia have identified the need for engineering students to develop soft skills in addition to technical skills. Examples of some of the soft skills are oral and written communication, project management, the ability to work well on a team, leadership, an appreciation of different cultures and business practices, engineering ethics and understanding

the societal, economic and environmental impacts of engineering decisions. [1,2, 5, 6] Experiential learning can provide an opportunity for students to develop both soft and technical skills. Additionally, it has been shown that students engaged in experiential learning have better retention of technical knowledge and are better able to apply what they have learned in college courses to real life situations after graduation. [1, 5, 7]

One form of experiential learning is service-learning. In service-learning, students become involved in a project that meets specific educational objectives while providing a needed service to the community. A critical component of service-learning is structured reflection. Structured reflection provides the students with the opportunity to think about the larger social issues associated with their work. From this it is hoped that the students will develop an awareness of the impact that professional decisions can have on society and the environment and have the opportunity to think about concepts of ethics and sound professional practice.[5] Service-learning has a fairly long history of formal and successful implementation in the social sciences and in disciplines in which clinical experiences are required.[1, 2, 3] Although it is not uncommon for engineering courses to provide opportunities for some form of experiential learning, service-learning is not implemented as frequently in engineering courses as it is in courses offered through other disciplines. This is unfortunate since engineering is by definition a "service" profession. [1, 4]

Project Description:

During the fall semester of 2002, three sections of the Introduction to Materials Laboratory in the Mechanical and Aerospace Engineering Department at the University of Dayton participated in a service-learning project with the service organization, Aprovecho. The three sections of this course were taught by two different instructors where one instructor taught one section and the other instructor taught two sections. The service-learning project chosen for this semester was a continuation of laboratory course work done during the 2001-2002 school year. The overall technical objective of this project was to generate meaningful physical and mechanical test data on prototype insulative brick materials. The data generated from this on-going work is being used to help stove designers make intelligent material selection choices so that they can design and build culturally appropriate, economical cook stoves with enhanced durability and fuel efficiency in developing countries. The specific technical objective of the project conducted during the fall 2002 semester was to study three different brick formulations. These brick formulations were different from the bricks tested in prior semesters because they used the garden additive, perlite, as the main insulative medium in lieu of air holes formed by burning out sawdust during the firing process. Each laboratory section tested a different brick formulation.

The laboratory course is offered as a co requisite to the junior level, Introduction to Materials lecture course that all Mechanical and Aerospace Engineering students are required to take. The main educational objective of the laboratory is to reinforce some of the fundamental material concepts taught in the lecture course. Some of these concepts include design of experiments, material testing, data analysis and material properties and characteristics. The most important educational goal of this service-learning project was to provide the students with a solid understanding of these concepts. In addition to these technical skills, another educational goal of the service-learning project was to provide the students with an opportunity to enhance

their soft skills including program management, teamwork, creative problem solving, computer and communication skills. Additionally, it was hoped that this project would provide the students with the opportunity to draw upon knowledge gained from prior courses. The final educational goal of this project was to expose the students to ideas of appropriate technology, environmental responsibility, ethics and cultural diversity and sensitivity.

In an effort to meet these educational objectives, the students were required to develop a test plan, design molds, manufacture and fire the bricks, inventory and track the resultant test materials, interpret and apply the appropriate American Society of Testing Materials (ASTM) test standards, locate the needed test equipment, conduct the tests, analyze the data, compare the data with data generated from previous semesters and make conclusions from this data. Additionally, the students had to coordinate their activities among the three sections and manage their time as they only had one semester in which to complete the project. In all sections of the laboratory, students were required to maintain a laboratory notebook. However, in one of these sections, the students' notebooks consisted of both a reflection journal and a technical logbook. In the technical logbook, the students recorded data and the technical activities accomplished during a particular laboratory session. In the reflection journal students responded to specific questions on assigned non-technical readings, current events related to the project, reactions to interaction with students who had served as interns in some of the developing countries currently using the stoves and other non-technical learning opportunities. The purpose of these journals was to provide the students with an opportunity to reflect upon the impact of their work on society as well as issues of environmental and social responsibility and ethics, cultural sensitivity and appropriate technology.

Students culminated the semester by making a formal technical presentation to the campus community. In addition to the presentation made by the class, two students from the laboratory class were sent to the 2003 ETHOS conference in Seattle, Washington to present the data generated from this project, to interact with other students and professionals and to assess the need for further work in this area. A letter report was provided to the service organization, Aprovecho, and the data from this project was posted on the ETHOS website. In the spring of 2003, another student presented technical information gained from this service-learning project at an American Society of Mechanical Engineers (ASME) Regional Student Conference in Toronto, Canada. At this same conference, another student participated in a poster session describing some of the work done in the winter of 2002 in support of this project.

Assessment:

An effort was made to assess the effectiveness of this service-learning project at meeting particular educational goals through an end of the semester survey. Students from the three sections of the laboratory course were asked to fill out an evaluation form at the end of the semester that consisted of twenty statements that summarized both the course specific and non-course specific educational objectives of this project. The students were asked to respond to each statement by providing a score from one to five indicating how effective the service-learning project was at meeting a specific educational objective. A score of five indicated that the project did an excellent job at meeting the specified goal, whereas a score of one indicated that the project did not meet the specified goal. The students were also asked to provide written

responses to three questions: (1) What did you like most about this project; (2) What did you like least about this project; (3) What are your suggestions for improving this type of project?

Results of these evaluations were positive, but indicated some need for improvement, Table 1. The total averaged score for all three sections of the materials laboratory (three sections, with two instructors) was 3.69. These results were separated by the type of educational objective (technical skills and soft skills) being assessed. Scores for the course related technical educational objectives had an averaged value of 3.83 with a standard deviation of 0.22. Of these technical educational objectives, those that were most effectively met through this service-learning project (score of 4.00 and above) included gaining technical knowledge related to materials and testing and understanding how to design and run experiments. Although still receiving a fairly high score (3.63), the technical educational objective that was least effectively met was developing an ability to analyze data and draw conclusions from data. Scores provided for the non-course specific educational objectives (development of soft skills) had an averaged value of 3.64 with a standard deviation of 0.27 indicating that the course did a good job at helping the students further develop their soft skills. The non-course specific educational objectives that were most effectively met (score of 4.00 and above) included developing teamwork skills and gaining an appreciation for appropriate technology. Also scoring high in this category (3.96) was gaining an understanding of others such as classmates, engineers, professors and the "client." The soft skill educational objectives that were least effectively met including developing written communication skills (3.08) and developing oral communication skills (3.28). The question, "This project was enjoyable and made me excited about being an engineer," received an average score of 3.58 where three students provided a score of five, thirteen students provided a score of four, four students provided a score of three, three students provided a score of two and one student provided a score of one.

The laboratory students provided many comments on the evaluation sheet that summarized their thoughts on this service-learning project. Some aspects of the project that the students found favorable included getting to help people in another country, working on a team, having a deadline, gaining an idea of how data is obtained for certain materials and learning about ETHOS, time management, testing materials, interpreting test standards, using the test equipment and designing a test program. Some aspects of the project that the students did not like included having no resources around to get information, a lack of communication among the lab sections, not having a lot of direction, lack of project organization and not being sure what the classes really accomplished. One student indicated that they did not like the project at all. Some of the suggestions provided by the student to help improve the laboratory and service-learning projects included more project organization, providing more emphasis on how the project will help people and providing better coordination among the classes to ease data analysis.

In addition to conducting a survey, the students' reflection journals required in one section of the laboratory were thoroughly examined. One goal of any experiential learning endeavor is to increase the students' motivation to learn. One student indicated that the service learning-project was effective at doing this when she wrote, "I'm really excited to be working on this project, a project that can potentially help thousands around the world. The fact that we could really make a difference in so many people's lives is probably the best motivation I've

ever had to work hard and do well in a class." The University of Dayton's motto, "learn, lead and serve," reflects the Marianist tradition of the University. This motto was effectively expressed by a student when he wrote, "My work has some affect on our society. Other engineers see us using our knowledge for the betterment of others and these engineers might become inspired to do the same. Our work helps to create a more humanitarian environment in the engineering world." Another student expressed a personal connection with the project and the ETHOS organization when she wrote, "Being from the Caribbean, I know how many people live. This is definitely helping a lot of people and countries. I am actually very interested in this project."

Table1. Summary of MAE Assessment Survey Responses

	Average
Course Related Educational Objectives	
This project was an asset to the lecture portion of the course	3.58
This project provided me with the technical knowledge related to materials and testing.	4.04
This project helped me to understand how to design and run experiments	4.04
This project helped develop my ability to read and interpret test standards.	3.88
This project helped me to understand how to analyze data and draw conclusions from data.	3.63
"Soft Skill" Educational Objectives	
This project helped to develop my ability to manage a project and helped me to develop business awareness and skills.	3.46
This project helped me to develop my written communication skills.	3.08
This project helped me to develop my oral communication skills.	3.28
This project helped me to develop my teamwork skills.	4.04
This project helped me to understand others (classmates, engineers, professors, "client").	3.96
This project helped to develop my interpersonal skills.	3.79
This project helped to develop my leadership skills.	3.63
This project aided in preparing me for the workplace.	3.46
Engineering and Service	
This project gave me an appreciation for appropriate technology.	4.00
This project gave me an appreciation for the humanities via the need to have some understanding of the Latin-American culture.	3.67
This project helped me to understand issues related to the global economy.	3.63
This project helped me to understand or reinforced my understanding of community and/or public service.	3.75
This project made me aware or reinforced my awareness of environmental responsibility.	3.71
This project helped to increase my sense of ethics and moral knowledge.	3.57
This project was enjoyable and made me excited about being an engineer.	3.58

Conclusions and Recommendations:

The brick characterization service-learning project done in the materials laboratory course gave the students the opportunity to practice program management, presentation preparation, and problem solving that they may not have received from the traditional laboratory course comprised of "cookbook" type laboratory experiments. Furthermore, this project allowed the students to reflect upon some of the social, ethical and humanitarian issues associated with engineering. Based on student evaluations, the project appeared to be fairly successful at meeting the educational goals of the laboratory course. As expected, some of the students really enjoyed participating in the project while a few did not. It appears as though some of the students may not have felt completely comfortable with the uncertainties associated with a real research project. In many cases the students felt as though the project was unorganized. This was due in part to the fact that the project was a real research project where flexibility is required, but also due to the fact that the three section of the course were taught by two different instructors. Many students expressed that greater communication among the sections and between the instructors would have greatly enhanced this project. A few students were given the unique opportunity to travel and present their work in a professional setting. Overall, it appears that service-learning projects can add great value to a laboratory course.

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Bibliographic Information:

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