2006-615: UNDERGRADUATE CURRICULUM REFORM IN CIVIL ENGINEERING BY INTEGRATING SERVICE-LEARNING PROJECTS

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Undergraduate Curriculum Reform in Civil Engineering by Integrating Service-Learning Projects

Abstract

At the University of Massachusetts Lowell (UML), the goal in the Francis College of Engineering (CoE) is to integrate service-learning into a broad array of courses so that students will be exposed to service-learning every semester in the core curriculum in every program in the entire CoE, an initiative supported by NSF through the Department Level Reform Program. This paper presents the strategy in the Department of Civil & Environmental Engineering (CEE) of identifying and implementing S-L projects as a first step towards undergraduate curriculum reform.

Initially, three service-learning projects of various content, workload, and community partnering were identified and implemented in two core and one elective undergraduate courses in CEE in 2005. Over 80 undergraduate students ranging from freshmen to seniors participated in these community-based projects: (1) Davidson Street Parking Lot Redesign for the City of Lowell; (2) Intersection Analysis – Traffic Signal Control for the City of Lowell; and (3) Preliminary Building Structural Evaluation for the Architectural Heritage Foundation (AHF) In Lowell, MA.

Service-learning was found to be an effective approach to help meet several of the well-known ABET EC2000 educational outcomes. At the completion of these service-learning projects, the students not only accomplished the specific community objectives but also important technical objectives for the courses. Quantitative deliverables were presented to the community partners. Positive feedback from the students was received.

Introduction

Service learning (S-L) provides 1) learning for the student and 2) service to the community. The S-L approach motivates students to work harder, be more curious, connect learning to personal experience, and demonstrate deeper understanding of subject matter [1].

The Accreditation Board for Engineering and Technology (ABET) has a relatively new set of criteria for engineering programs. In addition to achieving the more traditional technical objectives, these criteria require that graduates demonstrate:

- an ability to function on multi-disciplinary teams
- an understanding of professional and ethical responsibility
- the broad education necessary to understand the impact of engineering solutions in a global and societal context
- a knowledge of contemporary issues [2].

Service-learning team projects have the potential to ensure students learn and demonstrate these qualities in addition to the ability of applying engineering to the design of systems and experiments. However, how to fit more material into an already packed curriculum is a continuing challenge to engineering educators and students. Service-learning offers a way to integrate activities designed to strengthen abilities in technical subject matter with otherwise separate activities focused on the above (ABET) aspects of student development.

While service-learning has been well established in many disciplines in higher education [1], engineering has been slow to adopt the pedagogy [3, 4]. Recently, efforts have been made to implement S-L in engineering contexts. Examples include civil and environmental engineering courses [5]; first-year introductory courses [6, 7]; capstone senior design courses [8]; multidisciplinary approaches [9, 10]; and the Engineering Projects in Community Service (EPICS) program at Purdue University [11]. However, it appears no program in engineering has service-learning spread throughout the curriculum in required mainstream courses.

At the University of Massachusetts Lowell (UML), the goal in the Francis College of Engineering (CoE) is to integrate service-learning into a broad array of courses so that students will be exposed to service-learning every semester in the core curriculum in every program in the entire CoE, an initiative supported by NSF through the Department Level Reform Program. As part of this broad effort of undergraduate curriculum reform in the CoE, this paper presents the strategy of identifying service-learning projects and how three projects were implemented as a first step towards undergraduate curriculum reform in the Department of Civil & Environmental Engineering (CEE).

UML CEE Curriculum

UML has a total enrollment of 11,000 students (undergraduate and graduate). The Francis College of Engineering provides education to approximately 900 undergraduate and 700 graduate students with about 72 full time faculty members. The Department of Civil & Environmental Engineering has 9 full time faculty members and offers degrees at the Bachelors and Masters levels. In the past decade, the department has typically enrolled 120-250 undergraduates at a time in the four years of the undergraduate program. The Civil and Environmental Engineering program is ABET accredited and requires students to earn a total of 128 credits leading to the degree of Bachelor of Science in Engineering with a major in Civil Engineering.

Identifying Community Partners and Projects

An essential element in implementing service-learning is identifying community partners who have project needs. Over 20 potential community partners and all faculty were invited to a planning meeting held at the UML campus in 2004. In the meeting, community partners were given the opportunity to present their project needs to the faculty. Afterwards, open discussion was held between interested faculty and community partners to identify potential projects and establish future dialogue. The Civil & Environmental Engineering Department identified three possible projects that are now finished. The associated community partners were: City of Lowell and Architectural Heritage Foundation (AHF) in Lowell. Over 80 undergraduate students ranging from freshmen to seniors participated in these community-based projects. See Table 1 for more detailed information on the projects and in which course each project was implemented.

Table 1. S-L Projects Implemented within CEE Curriculum

Projects	Courses	Course Title	Community Partners	Projects
Project 1	Freshmen (core)	Intro. to Eng. (II)	City of Lowell- Traffic Department	Davidson Street Parking Lot Re-design
Project 2	Junior (core)	Transportation Engineering	City of Lowell – Traffic Department	Intersection analysis – Traffic Signal Control
Project 3	Senior (elective)	Design of Masonry Structures	Architectural Heritage Foundation (AHF)	Preliminary Building Structural Evaluation

Project 1: Davidson Street Parking Lot Re-design (Implemented in Spring 2005)

The Davidson Street Public Parking Lot is owned and maintained by the City of Lowell. Located on the western edge of Downtown, it borders the Concord River and Merrimack Street. The city is considering putting a 10-12' bike trail and eliminating some of the fences within the exiting parking lot. The objectives of this project were to (1) re-design the parking spaces, (2) allocate a 10'– 12' right-of-way along the Concord River to provide sufficient room for the development of a neighborhood bike trail.

Figure 1. Freshmen were bused to the parking lot to do on-site measurements with RollaTapes.

Due to the irregular shape and the size of the parking lot, we divided the parking lot into three sections. The students were assigned into groups with each group having 3 or 4 students to work on one section of the parking lot. Each group was asked to deliver an AutoCAD generated parking lot design and a written report on the design.

The 40 freshmen in two sessions of core course "Introduction to Engineering II" participated in this project. Students were bused to the site, measured the parking lot with RollaTapes (Figure 1), and produced dimensioned drawings of the new parking lot design with the AutoCAD program they just learned in this course. A total of 221 parking spots were designed, with an individual number of 65, 121, and 35 for each section.

The City of Lowell's planners received 10 AutoCAD-generated parking lot re-designs and written reports on the designs (a design example is shown in Figure 2). They are currently determining which design will be used when the parking is redone in 2006. The students enjoyed doing a community-based project and the fact that one of the designs would actually be used by the City.

This project met several course objectives and ABET objectives simultaneously, including being able to make 2D line and dimensioned engineering drawings using AutoCAD; being able to communicate technical information to an audience in written form; and being able to function effectively in groups.

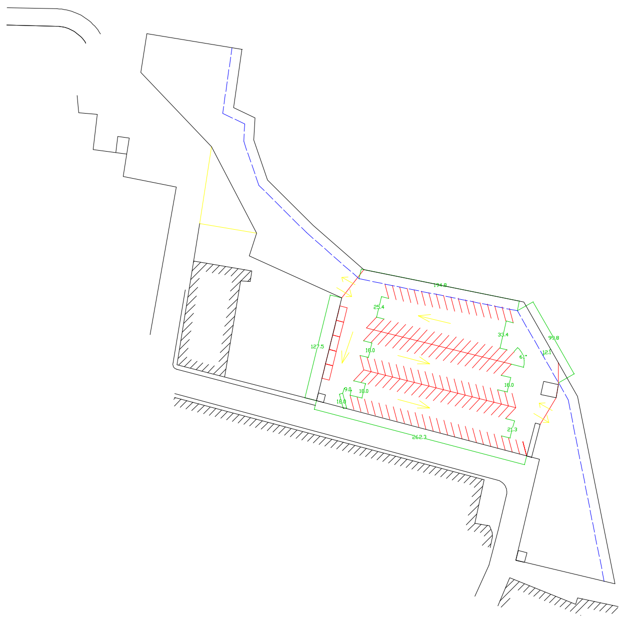

Figure 2. Example design for Davidson Street Parking Lot Re-design Project.

Project 2: Intersection Analysis – Traffic Signal Control (Implemented in Fall 2005)

The intersection of University Avenue and Riverside Street in Lowell is highly congested and the City of Lowell plans to optimize the traffic signal settings to improve the operational efficiency and effectiveness of this intersection control.

A traffic study was performed by the Junior class taking core course "Transportation Engineering" in Fall 2005. The objectives of this project were two fold: (1) to assess the performance of the existing signal control at the intersection of University Avenue and Riverside Street, located in Lowell, MA, and (2) to optimize the signal settings with existing traffic operations software, reassess the performance, and make recommendations to the City. 42 students worked in groups on this project.

The software package that was used in this project was Synchro 6. Synchro 6 is a software package for modeling and optimizing traffic signal timings. The package includes the simulation model Sim Traffic for microscopic analysis of the results. Sim Traffic can model networks of signalized and unsignalized intersections, including roundabouts. In addition to calculating capacity, Synchro allows you to quickly generate optimum timing plans by optimizing the splits, cycle length, and offsets to reduce delays and stops. Tables 2 and 3 show the results generated by these tools.

Table 2. Traffic Optimization Condition Reports Generated by Synchro 6

MOE*	Existing Conditions	After Optimization	Improvement (%)
HCM* Average Control Delay for Intersection (sec)	27.3	18.2	33
HCM Level of Service for Intersection	C	B	

*MOE- Measures of Effectiveness
*HCM-Highway Capacity Manual

Table 3. Performance Results Generated by Sim Traffic

MOE	Existing Condition	After Optimization	Improvement (%)
Total Delay (hr)	5.5	3.5	36
Delay/vehicle (sec)	42.8	31.9	25
Average Speed (mph)	17	19	12
Fuel Efficiency (mpg)	13.3	15.2	14
HC* Emission (g)	80	39	51
CO* Emission (g)	2622	1304	50

*HC-Hydro Carbon
*CO-Carbon Monoxide

As part of the project, the students did an hour-long volume study at the intersection, including turning movements, and measured the existing signal timings. The existing cycle length for the intersection was 90.5 seconds, with a green time of 45.4 seconds for Riverside Street and a green time of 45.1 seconds for University Ave. After the optimization with the measured volume data, the optimal cycle length for the intersection was found to be 55 seconds, green time of 31 seconds for Riverside Street, and 24 seconds for University Ave. The HCM level of service for the intersection was improved from C to B after the optimization.

As a result of the optimization, the software calculated that the HCM average control delay for the intersection would be cut by 33%. The microscopic simulation SimTraffic indicated that the total delay of the intersection and the delay per vehicle would be reduced by 36% and 25%, respectively. Both HC emission and CO emissions would be cut by 50%. In addition, the average speed and fuel efficiency would be improved by 12% and 14%, respectively. Thus, the results clearly indicate a significant improvement in terms of MOE after optimization of the signal settings.

Recommendations made to the City of Lowell were: to use during the study time period a cycle length of 55 seconds for the intersection, green time of 31 seconds for Riverside Street, and green time of 24 seconds for University Ave to improve the operational efficiency and effectiveness of this intersection control.

This project met two course objectives, including being able to conduct an intersection volume study and calculate traffic signal timings at an intersection.

Project 3: Preliminary Building Structural Evaluation (Implemented in Spring 2005)

The primary objective of this project was to perform a preliminary structural evaluation of a community building that is being re-developed by the Architectural Heritage Foundation (AHF) on behalf of the Cambodian Mutual Assistance Association (CMMA). A team of three students (two undergraduate and one graduate) participated in this project.

The project implementation started with planning meetings to determine the project stages, identification and acquiring of national and local masonry codes and other useful resources, and purchasing of necessary equipment such as a laser range meter to minimize the risk of accidents during field measurements. Two site visits were conducted (see Figure 3) and on-site measurements and visual inspection were performed. Typical dimensions were obtained for structural evaluation, structural members and material systems were identified, and calculations were conducted to check the expected performance of structural members.

Figure 3. Students examining CMAA building

The students produced a draft report summarizing useful information regarding the structural system, visual inspection of the building, typical spans and dimensions, and preliminary structural evaluation.

This project served meeting several course objectives such as understanding the structural behavior of masonry structures, functions of structural components made of different material systems and their interaction, mechanisms of degradation and failure, their impact on the service life, and the structural implications of re-development and renovation actions.

ABET Objectives Met

In addition to the course specific objectives as described in each project, these S-L projects also met several ABET objectives [2]. Such as (1) knowledge & ability to apply engineering & critical thinking skills to engineering analysis, (2) knowledge & skills to design, conduct, evaluate experiments & work in teams, (3) an understanding of professional and ethical responsibility, (4) the broad education necessary to understand the impact of engineering solutions in a global and societal context, and (5) a knowledge of contemporary issues.

Assessment

A survey instrument was developed by Duffy et al. [12] which was filled out by 29 out of 40 freshmen taking "Introduction to Engineering II". The average age of these students was 20. These students were asked to rank several attributes representing their career values based on their S-L experience.

They ranked challenge/helping/independent as the most important career values for them (2 out of 5, 1 being the most), followed by income/outdoors/physical/prestige/public/security (3 out of

5), and creativity/variety/team (4 out of 5). Students also gave positive response to the following survey questions (7 out of 9, 9 being strongly agree):

- In this service project, I learned how to apply concepts learned in class to real problems.
- In this service project, I learned how to work with others effectively.
- I feel that I can have an impact on solving problems that face my local community.
- It is important to me personally to face a career that involves helping people.

Challenges Faced and Issues Identified

This paper presents the initial effort of undergraduate curriculum reform in the CEE department at UML. Several challenges and issues were identified while incorporating S-L into the curriculum.

Challenges faced: Through faculty and student surveys developed by Duffy et al. [12], the key challenges identified by the faculty were: lack of time, lack of resources, and finding the right project. The key challenge identified by the students was: spent more time on service oriented projects. With the additional three-year support from NSF, many challenges identified are being addressed. Such as a college wide S-L coordinator has been hired, each department has a dedicated S-L coordinator. These coordinators will help find community partners and match community needs with faculty interests.

Even with the help of the S-L coordinators, finding the right project for the community and students can be challenging. The project has to be the "right size" and "right topic" so that it is feasible for the students to accomplish within class time and be able to deliver the product to the community partner. Therefore, adequate planning and detailed coordination with the community are both critical to the success of each project. For the three projects presented, only project 3 didn't get finished.

How to fit more material into an already packed curriculum is a continuing challenge to engineering educators and students. However, from our experiences, we found that a S-L project can be seamlessly integrated into a course without taking out course materials and huge time commitment. With careful planning, we were able to cover all the subjects that we can normally cover. For courses with existing lab exercises already directly related to projects that are of service to the community, only minimal additional time is needed for implementation, e.g. "Transportation Engineering."

Issues identified: (1) pre-test survey should be conducted in order to evaluate the impact of S-L experience on students; (2) substantive assessment should be developed for future S-L implementation, in particular, students should be asked to reflect on their S-L experience and provide feedback on attitudes, broader citizenship, and academic performance. Exit interviews will also be conducted for graduating students on the impact of S-L experience have on their life, overall academic performance, and career choices; (3) collect background information or supporting material from community partners ahead of time; (3) feedback survey from the community partners should be conducted after the product is delivered.

Conclusions

The integration of service-learning has been demonstrated in three courses within the civil and environmental engineering undergraduate curriculum at UML. Community partners were identified and actively involved during the completion of these projects. Quantitative deliverables were presented to the community partners.

At the completion of these service-learning projects, the students not only accomplished the specific community objectives but also important technical objectives for the courses. Service-learning was also found to be an effective approach to help meet several of the well-known ABET EC2000 educational outcomes. Unique assessment instruments were used and informative student and faculty feedback was collected.

The integration of service learning into the curriculum is a first step towards undergraduate curriculum reform in the Department of Civil & Environmental Engineering at the University of Massachusetts Lowell. This process added breadth to the course content and made a positive contribution to the curriculum development.

Bibliographic Information

1. Eyler, J. and Giles, D.E. (1999). *Where Is the Learning in Service-Learning?* Published by Jossey-Bass, San Francisco, CA.
2. ABET, *Criteria for Accrediting Engineering Programs, 2002-2003.* (2001). Accreditation Board for Engineering and Technology, Baltimore, MD, available at http://www.abet.org/images/Criteria/2002-03EACCriteria.pdf.
3. Duffy, J. J., (2000). *Service-Learning in a Variety of Engineering Courses.* Projects That Matter: Concepts and Models for Service-Learning in Engineering, ed. E. Tsang, (ed.). American Association of Higher Education. Washington, DC.
4. Oakes, W., Duffy, J., Jacobius, T., Linos, P., Lord, S., Schultz, W. and Smith, A. (2002). *Service-Learning in Engineering*. in *Proceedings of the Frontiers in Education Conference, American Society of Engineering Education*.
5. Piechota, T. and Nambisan, S. (2005). *Integration of Service Learning into Civil and Environmental Engineering Curriculum.* in *Proceedings of the ASEE 2005 Annual Conference*. Portland, OR.
6. Thompson, M., Oakes, W. and Bodner, G. (2005). *A Qualitative Investigation of a First-Year Engineering Service-Learning Program.* in *Proceedings of the ASEE 2005 Annual Conference.* Portland, OR.
7. Hobson, R.S. (2000). *Service-Learning as an Educational Tool in an Introduction to Engineering Course.* in *Proceedings of the ASEE 2000 Annual Conference*. St. Louis, MO.
8. Catalano, G.D., Wray, P. and Cornelio, S. (2000). Compassion Practicum: A Capstone Design Experience at the United Sates Military Academy. Journal of Engineering Education, *90*(4), 471-477.
9. Nagchaudhuri, A., Eydgahi, A. and Shakur, A. (2000). *Slope: An Effort towards Infusing Service-Learning into Physics and Engineering Education*. in *Proceedings of the ASEE 2000 Annual Conference.* St. Louis, MO.
10. Coyle, E.J., Jamieson, L.H. and Sommers, L.S. (1997). EPICS: A Model for Integrating Service-Learning into the Engineering Curriculum. Michigan Journal of Community Service Learning. *4*, 81-89.
11. http://epics.ecn.purdue.edu, last accessed March 7th, 2006.
12. Duffy, J., Ting, J., Zhang, X., Kazmer, D., Rux, A. Barry, C. and Clark, D. (2006). *Service-Learning Integrated Throughout a College of Engineering*. in *Proceedings of the ASEE 2006 Annual Conference.* Chicago, IL. (Accepted)