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Vertical Integration of Service-Learning into Civil and Environmental Engineering Curricula*

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Department level reform efforts funded by the National Science Foundation were instituted for the civil and environmental engineering (CEE) programs at the University of Vermont. The overall goal of the reform was to educate and have students apply a systems approach to civil and environmental problems. A key strategy for practicing a systems approach was through service-learning (S-L) projects that were introduced into existing courses. The reform began in 2005 and now includes S-L projects in required courses in each of the four years of the programs. Students have worked with community partners (e.g. Vermont towns and non-profit organizations) on inquiry-based, open-ended, real-world S-L projects. Student work and assessments showed that the S-L projects provided ideal platforms for CEE undergraduate students to grasp systems concepts while accomplishing academic goals, civic engagement and improving personal/interpersonal skills. The S-L projects also contributed toward meeting the program accreditation criteria (ABET outcomes 3a-k).

Keywords: community partnership; service learning; systems approach; capstone design; inquiry-based learning; ABET; assessment

INTRODUCTION

CIVIL AND ENVIRONMENTAL ENGINEERING (CEE) programs at the University of Vermont (UVM), Burlington, Vermont, USA, initiated National Science Foundation (NSF)-funded department level reform in 2005 with a vision of creating an inquiry-based, environmentally conscious undergraduate learning experience. The goal was to prepare students to adopt a systems approach to problem solving. Specifically, we wanted our students to become capable of considering short and long-term environmental, social, political, regulatory, and economic issues while identifying, defining, and solving engineering problems. The reform also included development of essential tools and skills for students such as critical thinking, modeling, and the use of information technology, and personal/ interpersonal skills (e.g. group participation, technical writing, presentation skills, deliberation skills, communicating with stake holders including people with non-technical backgrounds) through inquiry-based learning. At the core of the reform was a service-learning (S-L) component, where students worked with Vermont towns and non-profit organizations on civil and environmental engineering-related projects. We developed S-L projects for students to experience an inquiry-based approach to learning as well as practicing a systems approach. S-L was also a way of developing students' personal and interpersonal skills. Projects that reach out to the community also generated greater interactions among students, faculty, and local townspeople, which we believe develop a greater sense of connection within the programs and the communities in which we live. The CEE professions are largely service based, while education is often theoretical based. We wanted to include the components of the profession within the academic environment. While S-L is not necessarily a new educational approach, it is usually incorporated piecemeal into engineering curricula.

Specifically we address the following:

1) implementation of S-L within existing courses including a brief description of select S-L projects;
2) student learning/experiences and assessment of student learning/experiences;
3) challenges and opportunities for vertically implementing S-L in engineering.

We also present our conclusions on whether S-L was appropriate for our CEE curricula from both the faculty and student perspectives as a pedagogical technique (academic enhancement, civic engagement, and personal growth), and as a platform for achieving our reform objectives (systems approach, inquiry-based learning, and interpersonal skills) and expected ABET (Accreditation

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Board for Engineering and Technology) outcomes 3a-k [1].

BACKGROUND

Service-learning is a teaching and learning approach in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development [2, 3]. S-L promotes academic enhancement and personal growth through civic engagement in a credit-bearing course [4]. S-L is often experiential in nature, especially in engineering, and this can help students develop a variety of investigative, organizational, creative, and interpersonal skills [5]. Duffy [6], Zang, et al. [7], and Christy and Lima [8] viewed S-L projects as a way to meet the ABET outcomes, especially those that are non-technical in nature.

Reflection is a critical aspect of S-L [2, 9–12]. It is the time provided for the instructor and students to think critically about issues raised by working with the community and how scientific and engineering concepts and skills relate to those issues [10]. Although many definitions of reflection exist [e.g. 13–15], it is agreed that reflection is essential to the learning process and improves retention of academic material [16]. Through reflection students connect thinking and action, and stimulate the use of higher-order thinking skills such as analysis, comprehension, problem solving, evaluation, and inference [11]. Reflection has many forms such as in-class discussions, keeping journals, writing papers/reports, and making presentations. Bringle and Hatcher [12] suggest five guidelines for reflection activities; they should link experience to learning; be guided; occur regularly; involve feedback; and help clarify values. The reflections should also take place before, during, and post S-L activity [9, 12].

While S-L has been well established in many disciplines and from grade school to higher education, engineering has been slow in adopting a true S-L pedagogy [5, 7, 18, 19]. Recent efforts to incorporate S-L within the engineering context are emerging as noted in the literature (e.g. 5–8, 18–27]. However, it appears that only a few engineering programs [e.g. 7, 26] are working toward integrating S-L vertically into their curricula. The effort described in this paper includes integration of S-L into all four years of CEE curricula in at least one required course per year.

IMPLEMENTATION OF S-L PROJECTS VERTICALLY

CEE programs at UVM

Currently (Spring 2009), about 200 students are enrolled in the CEE programs at UVM. The number of female students (about 22%) is slightly higher than the national average but the number of minority students (1%) is lower than the national average. The latter is low but consistent with the State of Vermont demographics. There are nine program faculty members consisting of four males and five females, with four members originally from foreign countries. Both programs are ABET accredited.

Implementation of S-L projects

The preliminary plan for the S-L component was to have each incoming class adopt a town in Vermont that was interested in working with CEE students on real-world engineering projects. Throughout their four-year tenure at UVM and in numerous engineering courses (starting in their first year), students would work on projects with their community in various courses. Much of Vermont is rural; numerous small towns need engineering expertise that they typically do not have access to and cannot afford. However, during the initial phase of the implementation, we realized it would be quite difficult to work with the same town on relevant projects that align well with individual course objectives for four consecutive years. Therefore, we decided to match individual course objectives with the needs of appropriate community partners (towns as well as nonprofit organizations), while still having an S-L component in at least one required course per year.

Table 1 summarizes the S-L courses and some of the projects conducted thus far. Required versus elective courses are identified in the table along with other relevant information such as percent of grade the S-L project was worth, community partners, total number of projects/teams per course, and total number of students in the course. It is worth noting that for all courses listed in Table 1, student teams worked on separate, self-contained projects or different aspects of the same overall project.

COURSES WITH S-L PROJECTS

Introduction to Civil and Environmental Engineering (First Year—Required)

This first-year first semester introductory course is designed to introduce the incoming students to the CEE community, CEE topical areas, teamwork, systems thinking, and the systems approach to engineering problem solving. The course revolves around weekly hands-on group activities.

About four weeks into the course, S-L projects were introduced. The projects spanned eight weeks and were worth 25% of the course grade. Students were allowed to select their own teams of 4–5 members. This selection was informal and worked well because they knew quite a few of their classmates by that time. Some class or laboratory time (depending on the activity) was provided each week to work on their projects, but research and writing was done primarily outside of

Table 1. S-L projects integrated into civil and environmental engineering courses

Academic Year	Course	Required/ Elective	Terms	Brief Descriptions of Projects	% of Grade	Community Partner	Number Groups Per year	Total Students Per Year
First year	Introduction to Civil and Environmental Engineering	Required	Fall 2006, 2007, 2008	Analyzed/designed traffic solutions at problematic intersections; Developed interactive exhibits on engineering/ environment	25	2006- Town of Essex, Town of Monkton; 2007, 2008- ECHO Lake Aquarium and Science Center Burlington	12–16	55, 63, & 80
Sophomore	Geomatics	Required	Fall 2006	Mapping a bike path in Chittenden County	5	City of Burlington	15	45
	Environmental and Transportation Systems	Required	Spring 2008, 2009	Rain Garden monitoring, analyzing runoff and design using HydroCAD	10	AWWA Student Chapter and UVM	10–20	47, 67
Junior	Water and Wastewater Engineering	Required	Spring 2007	Onsite wastewater treatment for two communities	25	Town of Monkton Long Point Community	8	40
	Modeling Environmental and Transportation Systems	Required	Spring 2008	Mentored home schooled children on biomimicry projects	20	IBM, ECHO Lake Aquarium and Science Center Burlington, and UVM	10	33
Senior	Capstone Design	Required	Spring 2006, 2007, 2008, 2009	Stormwater evaluation/design, water treatment, small hydro, building preservation and design, bridge reconstruction, street reconstruction	100	2006: Recycle North, Burlington Airport; 2007: Towns of Essex, Greensboro, Taluabe, Chelsea; VT Ag Museum; Preservation Trust; 2008, 2009: VT Agency of Transportation, City of Burlington, Essex, Milton, Shelburne.	6–9	30–45
	Geotechnical Design	Elective	Fall 2005, 2006, 2007	Analyzed/designed remedial measures associated with historic structures	35	(1) Preservation Trust of VT (2) Shelburne Farms, Shelburne	4–5	15–20
	Hazardous Waste Management	Elective	Offered 7 times	Pollution prevention projects in local institutions and businesses that benefit whole community	35	Examples include, Fletcher Allen Hospital, University of Vermont, Blodgett Oven, Offset Printing, Dynapower, Medical Center of VT	2–5	5–15

class. Students were also introduced to S-L and asked to do a guided pre-reflection on the upcoming site visit and project. They were required to do some preliminary reading or Internet research before visiting the site. A field trip was then taken to the site of the S-L project. After this visit, students wrote a reflection on the project and assessed their role in it. They also started researching issues related to the project and developed an introduction with project goals and a timeline for the remaining semester. The reflection was individual; but reports were team written. Pieces of the reports were turned in early to provide regular feedback. Weekly assignments were developed around the projects to keep students on track. Project time in class or laboratory was provided weekly.

In the Fall 2006, the class worked with two communities (Towns of Essex and Monkton) on town traffic issues. Half of the students visited their site one week (the other half did an activity in the laboratory) and the next week the other group went to their sites, while the first group worked in the laboratory. Students counted number and speeds of cars passing the intersections and they timed lights at the intersections. They analyzed these data, as well as State traffic data for these sites. They developed a model of the study intersections using the computer traffic simulation program *SYNCHRO* [28]. Different groups investigated different intersections in the community, and recommended improvements to the current situation. They analyzed their designs using the computer models. Some of the solutions included adding a lane, changing light timings, and/or adding stop or yield signs. The final requirements of the project were a written report and a high profile poster session where they had to discuss their posters and computer models with faculty, students, and community partners.

In 2007 and 2008, the whole class worked with ECHO Lake Aquarium and Science Center (ECHO) on developing interactive display ideas, and fabricating models of their display exhibits. Teams researched topics related to Lake Champlain (Burlington is located on the shores of the Lake) and developed an interactive exhibit that included civil/environmental engineering, the Lake, and environmental or social issues. Topics included eutrophication of Lake Champlain by stormwater, drinking water treatment, breakwater design, wind energy, irrigation and other factors. The project began with a visit to ECHO, where they explored the various hands-on interactive exhibits and activities, and learned about what goes into designing and implementing these exhibits from the staff there. As a final requirement of the project, the teams wrote reports, and presented their exhibits and project posters at ECHO during regular hours.

In the above activities, the students visited the project sites in large groups, worked with teammates throughout most of the semester, and finally presented their work to the entire class as well as faculty, community partners, and the general public. This helped in building a sense of community in the students early in the program. They also researched and experienced in a small way (consistent with their academic level) how civil and environmental engineers contribute to today's society.

Geotechnical Design (Senior–Elective)

In the Geotechnical Design course, students learn about subsurface investigations, and analysis and design of shallow and deep foundations, retaining structures and slope stability. The course builds upon a required introductory soil mechanics course where students learn about index, compaction, hydraulic, compression, and shear strength characteristics of soils. Typically, about 20 seniors and a few graduate students take the geotechnical elective course.

In 2005–07, teams of four to five students were formed in the second week of the course and each student team was assigned an historic structure in Vermont. The projects spanned 12 weeks and were worth 35% of the course grade. Students worked on shallow foundations, retaining structures, and slope stability issues related to heritage facilities. As part of the project work, students typically completed damage surveys, participated in archival research, and conducted site investigations using hand augers and sampling equipment. *In-situ* testing included borehole shear tests to estimate shear strength properties of soils. Soil samples were collected to determine relevant soil properties. At a minimum, students performed index testing on soil samples. If the soil samples were of a reasonable quality, students could perform consolidation and shear strength testing using fully automated consolidation, triaxial, and direct shear devices. Collected data were used in performing analyses, making recommendations for repairs, and preparing cost estimates. The projects concluded with writing comprehensive technical reports and a formal presentation to faculty, students, and community partners.

This project experience was unique because students developed remedial schemes, while maintaining as many original elements of the structure as possible. They used the geotechnical skills they had obtained in the previous course and the first part of the semester of this course to analyze problems and design solutions. They were also introduced to the historic preservation, societal, and economic aspects of the project. They employed new technologies, either testing equipment (e.g. borehole shear testing) or modeling software (e.g. slope stability), and interacted with and presented their findings to the community partners who were not engineers so enhancing their interpersonal skills.

Capstone Design Course (Senior–Required)

The purpose of the required senior Capstone Design course is to develop a culminating design experience for our seniors. Student teams work on real-world multifaceted, multi-disciplinary design projects related to civil and/or environmental engineering systems. Before 2006, these projects typically involved already designed projects and came from the instructor's experience or through local industry contacts. However, since 2006, these capstone projects have been S-L projects.

Thus far, over 130 seniors worked on a senior capstone S-L project, completing 23 different projects. Each S-L project included multiple subdisciplines of civil or environmental engineering. Some projects had background information available, whereas in some cases, students had to start from scratch. Sometimes the community partner did not have a civil or environmental engineering background, and in these cases, the instructor had to enhance the scope of work envisioned by the community partner to ensure the students were getting a significant design experience as per ABET requirements. The projects spanned the entire semester and were worth 100% of the course grade.

The course revolved around the projects, so in the first week of class, the community partners presented their needs to the class. Students wrote short proposals to the instructor stating which two projects they were most interested in and why, and what special qualifications they would bring to the project. The instructor(s) then developed appropriate teams. If the project scope was large, multiple teams worked on the project. In those cases, the different teams collaborated with each other in the initial stages to develop their own scope of work with minimal overlap. During the course of the project, students had to keep communication lines open among the teams to progress efficiently. The projects concluded with final presentations made to the faculty, community partners, and local practicing engineers, and provided an opportunity for the audience to offer feedback and request any additional information to be included in the final reports.

Some examples of the projects conducted thus far have included the design of:

- stormwater management systems for towns;
- retrofits for existing bridges, streets and buildings;
- new bridges;
- pipelines for a small hydropower plant; a new agricultural museum building;
- mitigation alternatives for a landslide.

Surveying important site features, collecting and testing soil samples, and collecting hydraulic information were required for most projects. Students analyzed existing situations, designed new systems or strategies for retrofitting/mitigating existing problems, and developed cost estimates for each alternative. In all projects, students were expected to research relevant regulations and, in some instances, help prepare documents for necessary permits. They were also required to research and discuss the societal and environmental aspects of the project, even if the community partners did not specifically request these. The environmental and social aspects typically included issues such as stormwater treatments during and after construction, effects of projects on wetlands, possibilities for groundwater contamination, acquisition of private properties for public works projects, and disrupting traffic during construction.

REFLECTION METHODS

Reflection is an important component of S-L projects [2, 9–12]. In our courses we incorporated reflection exercises throughout S-L projects. We accomplished this through formal guided written questions that linked the experience to the content learned; instructor-facilitated formal and informal classroom discussions about student experiences and perspectives and how they linked to academic, civic and personal goals; and by providing detail feedback on student work (e.g. progress reports, draft reports, presentations, reflection essays). In senior courses, students also reflected on the technical service they provided by keeping track of "billable" and "administrative" hours they spent on the project.

Attending project presentations made by other students was also viewed as an opportunity for reflection, particularly through the question-and-answer period following each presentation. Another particularly useful activity was to have students read and critique each other's work. In senior courses, students wrote various sections of their reports throughout the semester, providing several opportunities for them to critically review each other's work. This served two purposes:

1) First, it gave students an opportunity to learn about technical and non-technical aspects of other S-L projects as well as examples of writing styles. While reviewing the other group's work, the students naturally reflected on their own work because they compared the two products.
2) Second, this saved some review time for the instructor because the students already marked most of the grammatical and other errors.

ASSESSMENT METHODS

Various assessment methods evaluated student learning (academic enhancement) and experiences (civic engagement and personal growth) throughout all the different S-L projects. We also assessed the effectiveness of S-L projects in meeting ABET requirements (Outcomes 3a-k) and the reform programmatic goals. Table 2 provides a brief description of the various assessment methods employed. All S-L projects used these assessment methods except oral presentations. They were typically not used in S-L projects that were worth less than 10% of the course grade. Although these protocols were not exactly the same in the various classes, they generally followed a similar format with the exception of the surveys, which were standardized for use in courses with S-L projects.

Grading open-ended team projects was a difficult task for instructors. It was important to provide ample feedback at early stages to ensure that all students engaged and participated in the projects. Various assessment rubrics were helpful in that regard, as well as providing samples of past project work. A rubric can be helpful in grading S-L projects because it is clear what the expectations are for both the student and instructor. Therefore, a rubric was developed that defined criteria for evaluating student analysis and design work, quality of their reports and presentations, and individual participation.

Stressing the accountability of all team members including the instructors (e.g. providing feedback and clear expectations) was critical for the success of S-L projects. Students were held accountable, and assessed by their peers as part of the final

Table 2. Assessment methods

Assessment	Brief Description
Written Reports	Written reports were evaluated for technical components as well as organization, format, and grammar. In the first year and capstone courses, social, environmental, economic and other systems components were included and evaluated.
Oral Presentations	Oral presentations varied in length and scope depending on the project. For example, the first-year course required students to orally present their project poster to the instructor and teaching assistants in the class. The Capstone course required 30 minute presentations to community partners, practicing engineers, and program faculty with a 20 minute questioning period.
Self Assessment	Students formally assessed themselves by answering a number of questions provided by instructor. Students informally assessed themselves in response to instructor feedback on assignments.
Peer Evaluation	Students formally assessed their teammates one to two times within the project on all aspects (e.g. technical work, team meetings, site visits, presentations) by answering a number of questions.
Faculty Observation	Since class time and field trips were devoted to the S-L project, instructors and teaching assistants observed student participation during project activities.
S-L Surveys	Pre and post surveys were given to students in S-L courses.
Community Partners	Both formal and informal evaluations of the satisfaction of community partners were also conducted during and after the projects.
Student Course Evaluations	Final course evaluations were used to ask specific questions related to S-L projects and related activities.

grade. This was one way to ensure a more equitable workload so that each student participates to the completion of the project equitably. Students performed self- and peer assessments twice for extensive projects such as those given in the first-year, capstone, and senior electives. The purpose of the first assessment given halfway through the project was to identify group members who might not be contributing sufficiently to the project. The team, alone, or with the instructor, could then take appropriate action to remedy the situation. The second peer evaluation was conducted after the projects were concluded to assess each group member's contribution in all aspects of the project. This was factored into the grading rubric when determining individual grades.

Student surveys (self-assessment) were also administered as a formative assessment. The core questions of these surveys were standardized and administered in all S-L courses since Fall 2007. Additional course-specific questions were added to these surveys in some cases to assess if the particular course objectives were met. These surveys were administered online using WebCT, the system used for online course management at UVM. To ensure all students take the surveys, they were assigned for nominal credit.

These assessments enabled the instructors to examine what students perceived, learned, or experienced in regards to:

1) the S-L objectives (i.e. academic enhancement, civic engagement, and personal growth);
2) the reform objectives (i.e. systems approach, inquiry-based learning, and interpersonal skills);
3) accomplishing ABET outcomes.

STUDENT LEARNING/EXPERIENCE ASSESSMENT RESULTS

Survey results are summarized in Tables 3 through 5, each addressing a particular set of objectives (S-L, the reform, and ABET outcomes). All survey questions allowed students four choices: strongly agree, agree, disagree, and strongly disagree. Responding with either "stongly agree" or "agree" was considered a "positive response"; while the latter two responses were considered a "negative response".

Table 3 summarizes the student responses to questions related to the S-L objectives. These self-assessment results are presented as the percentage of students with positive responses. In general, student responses were positive on achieving the stated outcomes. Especially noteworthy are the high percentage of positive responses to questions on academic enhancement. Between 76% and 100% of the students thought the projects enhanced their learning experience and they could relate the course material to real world situations. Between 79% and 100% of the students preferred real-life S-L projects to the made-up or already done projects. About two-thirds of the students thought that they put extra effort because the projects involved service and provided needed work to their community partner. It is noteworthy to see that after doing the comprehensive projects in the elective and capstone courses, over 90% of the students thought that they could use their engineering training to address community problems. The greatest testament to this success is that these students would take or recommend other students to take S-L courses, as well as the high quality work they did in the projects.

Table 4 summarizes the student responses to questions related to the reform objectives. Between

Table 3. Student survey results on accomplishing S-L goals

Goal	Survey Question	CEE Course		
		Intro CEE*	Senior Elective†	Capstone Design‡
		Percentage of Positive Responses		
Academic enhancement	I feel that the project enhanced the learning experience of the class.	76	94	88, 100
	As a result of the project, I could relate to the concepts/materials presented in the course to real world situations.	81	94	88, 96
	This project experience was better than another type of project (e. g. fabricated, "made-up" project, a project which has already been done or not having any projects).	88	88	79, 100
	The amount of effort I put into the project was greater than what I would have put in for an equivalent made-up project not involving service.	62	76	60, 89
	I learned a new technology (i.e. software, testing equipment) and/or became more experienced with a technology, as a result of this project.	66	88	65, 78
	The project activities I participated in during this course made me more interested in the course content.	66	100	70, 89
Civic engagement	Our project provided needed information to the community partner.	74	71	59, 81
	After doing this project, I feel that I can use my engineering training to address problems that face my local community.	65	94	91, 89
	I will take or recommend other students take courses with a service-learning component.	76	100	93, 81
Personal growth	During the course of the service project, I identified personal weaknesses with myself while working in a team setting, and attempted to improve them.	69	82	93, 89
	There were some group members who were difficult to work with.	33	47	70, 74
	In future projects, I would be able to deal with difficult group members better, as a result of this project experience.	79	65	68, 78
	Working on this project gave me an extra sense of accomplishment.	80	94	77, 100
	Working on this project increased my confidence.	68	76	67, 93

*: 59 respondents, Fall 2007.
†: 17 respondents, Fall 2007.
‡: 43 respondents Spring 2008, 27 respondents Spring 2009.

Table 4. Student survey results on accomplishing curricular reform goals

Goal	Survey Question	CEE Course		
		Intro CEE*	Elective†	Capstone Design‡
		Percentage of Positive Responses		
Systems approach	This project helped me understand the diverse nature of engineering problems and solutions, societal, economic and environmental impact of engineering and the personnel involved.	83	100	84, 93
	As a result of this project I have better insight into what civil and environmental engineers do.	74	88	84, 89
Inquiry-based learning	The S-L project was open-ended in nature.	90	88	84, 93
	This project gave me confidence for working on open-ended projects in future.	79	88	81, 93
Interpersonal skills	During this project, I had to deal with other individuals who were different from me either in race, culture, age or economical and professional background.	66	88	84, 55
	I enjoyed giving the project presentation.	78	53	48, NA
	I feel it was a good professional experience to give and hear the project presentations.	87	88	93, 96
	The project gave me significant experience in writing technical reports.	48	76	84, 100
	I am proud of the quality of our work and final report.	97	94	88, 100

*: 59 respondents, Fall 2007.
†: 17 respondents, Fall 2007.
‡: 43 respondents Spring 2008, 27 respondents Spring 2009.

Table 5. Student survey results and faculty assessment on accomplishing ABET outcomes

(a) student survey responses

Goal	Survey Question	CEE Course: Intro to CEE*	Elective†	Capstone Design‡
		Percentage of Positive Responses		
a	an ability to apply knowledge of mathematics, science, and engineering	49	100	93, 100
b	an ability to design and conduct experiments, as well as to analyze and interpret data	62	100	84, 93
c	an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	75	82	88, 96
d	an ability to function on multi-disciplinary teams	97	94	86, 96
e	an ability to identify, formulate, and solve engineering problems	75	100	95, 96
f	an understanding of professional and ethical responsibility	85	94	86, 96
g	an ability to communicate effectively	92	100	96, 100
h	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	85	88	84, 93
i	a recognition for need to & ability to engage in life-long learning	71	88	88, 93
j	a knowledge of contemporary issues	83	71	79, 93
k	an ability to use techniques, skills & modern engineering tools for engineering practice	80	94	88, 93

*: 59 respondents, Fall 2007; †: 17 respondents, Fall 2007; ‡: 43 respondents, Spring 2008, 27 respondents Spring 2009.

(b) faculty perspective

Course	ABET Outcomes: a	b	c	d	e	f	g	h	i	j	k
Introduction to Civil and Environmental Engineering	1	2	1	2	1	2	1	2	1	2	1
Geomatics	2	0	0	2	1	1	0	0	0	0	2
Environmental & Transportation Systems	2	0	1	0	2	1	1	1	1	2	1
Water & Wastewater Engineering	2	0	2	2	2	1	1	1	0	1	1
Modeling Environmental & Transportation Systems	1	0	1	2	2	1	2	1	1	2	2
Geotechnical Design	2	2	2	1	2	2	2	2	2	1	1
Hazardous Waste Management	1	0	2	2	2	2	2	1	1	2	2
Capstone Design	2	1	2	2	2	2	2	2	1	2	2
Capstone Design 2009 Student Responses (average) (self-assessment done in teams)	2	2	1.9	1.7	2	1.7	1.7	1.9	1.7	2	1.9

0: little or none, 1: moderate, 2: strong

74% and 100% of the students agreed that the projects enhanced their understanding of what civil and environmental engineers do and how open-ended and complex the real life projects are. These indicated that the adopted inquiry-based learning approach was successful and the students experienced taking the systems approach to CEE.

The student responses related to personal growth and personal/interpersonal skills are also summarized in both Tables 3 and 4. Although about half the students in the elective and capstone courses did not usually like giving presentations, nearly 90% of the students thought it was good professional experience. The students were able to identify weaknesses within themselves as well as their teams and were able to improve upon them. Overall, 90% of the students were proud of their work on the projects, which is an indication of their sense of accomplishment/success.

Table 5a summarizes the student responses to questions related to the ABET outcomes. It is interesting that the responses are generally more positive in senior courses than in the first-year course. This may be due to the greater comprehensiveness of the projects in senior courses than the first-year course. In the senior courses, at least 84% of the students thought positively about meeting all ABET outcomes, except outcome j on contemporary issues for which the responses were between about 70% and 80%. Both the senior elective and capstone courses dealt with contemporary issues such as ailing infrastructure, heritage preservation, wetlands, stormwater, and sustainability, so the lower score was surprising. Students may not generally see these as contemporary issues, so perhaps in the future some reflection and discussion of this is warranted.

Table 5b presents faculty's viewpoint on which of the ABET outcomes are addressed through the S-L projects in the courses that have used a S-L project. The same three courses presented in Table 5a, are highlighted bold in Table 5b. The numbers 0, 1 or 2 in Table 5b indicate the degree to which the instructors think the module addresses the particular ABET outcome (0 indicates little to none, 1 indicates moderately, and 2 indicates strongly). The student responses match the faculty viewpoint of how the ABET outcomes are addressed through the S-L projects. The last row in Table 5b summarizes the responses of student teams in the Capstone Design course in Spring 2009. Students were asked to self-assess how extensively each outcome was addressed by the S-L project as a team exercise. They were also required to provide examples of activities.

The student self-assessment surveys were found to be effective as a formative tool for instructor feedback and demonstrated that the students felt the S-L projects were open-ended in nature and promoted the systems approach to engineering. They served as an inquiry-based learning platform for the courses and provided meaningful service for the community while helping students develop interpersonal skills and achieve personal growth. Most S-L projects were able to meet many of the ABET outcomes, especially those of non-technical nature (e.g. c, d, f, g, h, i, and j, listed in Table 5a), from the perspectives of both the students and instructors.

CHALLENGES AND OPPORTUNITIES

Introducing S-L into a curriculum within many required courses is a significant but rewarding change. There are also challenges in institutionalizing S-L in a curriculum. The entire faculty needs to be on board with the S-L philosophy, although S-L would not be included in all courses. Being a relatively small program of nine faculty, the faculty buy-in was mostly straightforward in our case. At larger units however, this might become a difficult task.

Because S-L takes additional instructor time as well as financial (e.g. transportation, equipment, supplies) and human (e.g. teaching assistants) resources, support from administration is needed. Along with the individual faculty interested in incorporating S-L in their courses, other faculty in the department and the administration need to recognize and support the value in S-L. This becomes particularly important for promotion and tenure, which is especially challenging for untenured faculty whose extra time on S-L courses may be underappreciated at their institutions as compared to their research activities. This may also be the case for tenured faculty in terms of promotion or resource allocation. As a way of encouraging S-L in engineering curricula, promotion and tenure criteria should recognize S-L as a valid pedagogy and also as "scholarship". Martin and Coles [26] present a set of very useful promotion and tenure guidelines for including S-L in teaching as well as scholarship evaluations.

Other important challenges and opportunities are incorporated within the following sections;

1) Selecting courses for incorporating S-L;
2) Finding S-L projects;
3) Implementing the projects; and
4) Presenting and following up the projects.

Selecting courses for incorporating S-L

Since our goal was to vertically integrate S-L within the curricula, we needed to think about what courses were appropriate for S-L, and how to incorporate projects into the courses so that they fit both the course objectives and the overall objectives of our reform efforts (e.g. systems approach, inquiry-based learning). The key prerequisite for incorporating any new pedagogy is an interested faculty member. Forcing faculty or not providing appropriate training could create problems. The UVM CUPS (Community-University Partnerships and Service–Learning) Office offers fellowships and workshops for faculty interested in integrating service-learning experiences into their curricula. Each of the authors participated in one of these faculty service-learning fellowship programs. Beyond that, however, there may be some courses that are more suitable than others. During the freshman year in CEE at UVM, only one civil and environmental engineering course is taught, the introductory course, and since the instructor was willing, that was chosen. Likewise, in the senior year, the most logical choice was the capstone design course consisting of all seniors in civil and environmental engineering. Incorporating S-L into some of our senior electives also made sense based on the course material, including the design component of the course and the instructor's interest.

The sophomore and junior years have posed a greater challenge. For example, the Geomatics course in the sophomore year and the Decision Analysis in Environmental and Transportation systems seemed to be good choices, but given the loss of two interested faculty members, we have been using adjuncts and others to teach those courses. Thus, we implemented S-L in the other systems courses taught by the authors. The recent addition of new faculty members who have shown interest in S-L, will likely result in S-L offerings in the Geomatics and Decision Analysis courses in the coming years.

Upfront organization and outside of class S-L project work involves more faculty time, as does the assessment and grading. Likewise, class projects always require class time; therefore, if the course did not previously have a project, adding an S-L project will take additional class time and some course topics will have to be reformatted or prioritized. However, if the S-L project is a good match with the course goals, academic learning and experience can be significantly enhanced. Likewise, other goals such as decision making, teamwork, and communication will be enhanced. In the authors' opinion, this real-world experience is typically more valuable to the students when compared, for example, to a topic that was covered in lesser detail in the syllabus. Nonetheless, careful thought about the integration of S-L should be made before deciding to implement it.

Finding S-L projects

Finding appropriate projects and partners are the cornerstones for S-L success. Community partners must be invested in and participate fully in the project. With that said though, they do not necessarily have to invest a lot of their time, depending on the project. The partner should be available to meet with the instructor, provide information and ideas before starting the course, be available for questions during the project, and attend at least the final presentation.

We have found partners and projects through contacts with State Agencies (Vermont Pollution Prevention Division, Agency of Transportation) and State Non Profits (Preservation Trust of Vermont), cold calls made to Town Engineers, Executive Directors of Non Profits, and UVM alumni, and inquiries from communities directly to us. Often the projects that the community partners have in mind do not match the projects we have in mind, so a conversation needs to occur to make sure that both parties are interested and have the time and resources to ensure success. Face-to-face meetings are preferred. Also, we should make sure that students will be providing a true service to the partner and not taking potential work away from other businesses. This is the behind the scenes logistics that is necessary for successful S-L projects. This is also the time to develop a preliminary project scope so that both instructor and partner have the same expectations. It is also very important to clearly discuss all logistical issues with the community partners, specifically deliverables, up front. They need to be aware that these are students and that the quality of the end product, although usually very good to excellent, cannot be guaranteed. The quality of the group dynamics can sometimes be an issue. The best way to guarantee success is to ensure that the community partner takes an active involvement in the project.

Scheduling and transportation are two important criteria for selecting appropriate projects. This is especially critical for large classes. Scheduling site visits during class or lab time is generally the best. This may limit a community partner based on drive time. This has been less of an issue in the senior courses as the students generally have access to cars and can meet on their own with the partners.

Implementing the projects

Selecting teams, getting teams to work together, guiding students in developing the project, meeting deadlines, incorporating reflections, self and peer evaluations, conducting research, analysis and design are all important aspects of implementing S-L projects. Depending on the course, project and instructor, these may vary somewhat. For example, in the projects during the first, second, and even the third year of the program, students generally select their own teams. This adds to the enjoyment of the project and may also be easier for them logistically since they may have similar schedules or live together, thus making it easier to get together outside class. There is also a comfort level in this arrangement especially for women and students from diverse backgrounds. Sometimes a student may not have friends in the class, for various reasons, and in that case the instructor helps in finding a suitable team.

In the senior courses and sometimes the junior courses, students are assigned teams based on their interest in the project. In the capstone course for example, the projects are presented to the class by the community partners; and students write a short proposal to the instructor stating which two projects they are most interested in and why, and what special qualifications they will bring to the project. The instructor then develops appropriate teams. Since these projects are much larger and more in-depth, part of the selection criteria by the instructors is to ensure that all teams have capable individuals, increasing the possibility of success in the projects. In other words, there should not be a team consisting completely of struggling or least interested students.

Initial student team activities are implemented that may include such things as discussing each member's strengths and weaknesses, developing "codes of conduct", exchanging contact information and schedules, and initial reflections. Codes of conduct are a good way to formalize the process by bringing to the student's attention the ethical responsibility toward the community partner and teammates.

Clear communication is essential for ensuring students develop an appropriate project scope, meet deadlines, and produce deliverables; therefore, it is useful to provide this information in writing to the students. Keeping a calendar with due dates such as is provided in WebCT or other electronic programs helps keep everyone informed. Having weekly or biweekly reports or updates also helps keep the project running smoothly. The instructor should also check in with community partners during the course of the project.

Comments on draft reports are also often presented as an annotated hardcopy and a brief document or email listing any additional comments. The final reports are required in both electronic (in a format that can be edited) and hardcopy. The instructors typically make minor final edits before passing the document on to community partners. Each report contains a "disclaimer" or a letter is sent from the instructor to the partner essentially stating that any part of the student work should not be adopted without being evaluated by a licensed professional engineer.

Community partners are requested to attend and participate in the various phases of the project. For example, in courses such as Geotechnical Design and the Senior Capstone Design, a representative of each community partner is typically present at the time of the initial site visit, mid-semester progress discussion and final presentation. Often times, the partners find time to comment on draft reports and designs, answering student questions and providing additional information throughout the semester. Their input is considered in the final grade and assessment of the report and oral presentation.

Presenting and following up the project

In all projects, there is some final presentation to the community partner. Generally, this is in the form of a written and oral report, and informal feedback from the partner on the usefulness of the project. This is the wrap up part of it. Keeping in touch with the community partner beyond the semester is often beneficial. In some cases, students want to know what happened with the project, and in others, new projects could be developed through continued interaction with the partner.

CONCLUSIONS

Service learning has been vertically integrated within the civil and environmental engineering programs at the University of Vermont as part of an NSF-funded Department Level Reform Grant. Required courses were selected in each of the four years to guarantee that students have multiple opportunities to engage in this type of open-ended experiential learning. The first-year introductory course and the senior capstone design course incorporated S-L in significant and comprehensive ways. Sophomore and junior level courses varied and had smaller S-L projects. In addition, two senior electives incorporated S-L within the courses. Thus far, a total of over 130 civil and environmental graduates have had at least one S-L project in their program. Since we began in 2005, some students have had S-L projects in four courses and all have had them in three courses (students graduated in 2009). As we progress, the goal is that each student will participate in at least four S-L projects throughout their tenure. The first group to experience at least four S-L projects started in Fall 2006 and will graduate in 2010.

In the authors' opinion and also supported by the assessment data, S-L projects are a great way to introduce civil and environmental students to the open-ended nature of engineering, as well as experience inquiry-based learning and promote a systems approach to engineering problem solving while simultaneously cultivating interpersonal skills in students. The S-L projects provided meaningful service for the community, while enhancing student academic experience. Most S-L projects were able to contribute toward meeting all of the ABET outcomes.

The students, instructors, and community partners may have challenges at times, but the end result is often very rewarding to all parties and outweighs the difficulties. Given the challenges, logistics and time constraints, it may not be necessary to incorporate an S-L experience in every year of the curriculum as the advantages of S-L will likely be experienced by the students even if they have it in only two to three courses in their curriculum. However, we felt that S-L is particularly useful for the first-year students because it is a good community-building activity and application to a systems approach to engineering, and the capstone course because it provides students a good culminating experience and transition into their careers.

Examples of "code of conduct", "disclaimer", S-L surveys, mid-activity, and final peer and self-evaluation forms, grading rubric, and guidelines for reflection essays developed and used in our reform are available from the authors and on the project website: http://www.uvm.edu/~sysedcee/

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