

Incorporating Service-Learning Projects Dealing with Sustainability within the Civil and Environmental Engineering Capstone Design Course

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As part of a National Science Foundation Department Level Reform (DLR) grant, the civil and environmental engineering programs at the University of Vermont (UVM) incorporated systems thinking and a systems approach to engineering problem solving within their programs. A systems approach means incorporating long-term social, environmental and economic factors within the context of the engineering problem solution and thus encompasses sustainable engineering solutions. As a way of practicing the systems approach, we have incorporated service-learning (S-L) projects within the curricula, culminating with the senior capstone design course. Projects that focus on sustainable solutions are especially sought after and have included projects in the following areas; stormwater management and design, small hydroelectric, local water and wastewater solutions in Honduras, and historical preservation. We have used a variety of assessment methods to gauge student understanding and attitudes including student surveys, focus groups, and assessment of student projects. This paper presents some of the results related to the service-learning projects specifically focusing on sustainability and their impact on student learning.

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Introduction and Background

In 2005, the Department of Civil and Environmental Engineering received a NSF Department Level Reform (DLR) Grant entitled “*A systems approach to civil and environmental engineering: incorporating inquiry based learning, systems thinking and catamount community service-learning projects.*” The two major components of this reform were to include systems thinking (which encompasses sustainability) and service-learning (S-L) projects within the curricula through a series of courses. We teamed up with the UVM education department for assessment and education reform assistance, and then modified courses, content and pedagogy. Forthcoming papers^{1,2} outline some of the overall reform and assessment efforts, while recent papers^{3,4} focus on some of the service-learning aspects of the reform.

Systems thinking or a systems approach in engineering problem solving means looking at the short and long-term relationships and connections among the various components of a problem when developing problem solutions. It is a multi-stakeholder approach and as such includes social justice and environmental stewardship within the problem solution. Because systems thinking focuses

on the whole, optimal solutions are also sustainable solutions.

Service learning is an educational approach in which students provide a service to a community partner that helps the students achieve academic, civic and personal goals. Service-learning projects should be designed to provide real-world learning that relates to course objectives. Service learning should also include critical reflection opportunities for students. These formal and informal reflections allow students to connect their experiences with their goals, and create a deeper understanding of the issues that the service learning opportunity addresses^{5,6}.

During the last five years, the civil and environmental engineering programs at UVM have teamed up with a variety of community partners to develop capstone design course S-L projects. Partners have included officials and citizens from a number of the surrounding towns (e.g. Milton, Burlington, Essex, Chelsea, Greensboro, Shelburne), a community abroad (Taluabe Honduras), state agencies (e.g. Agency of Transportation), and nonprofit groups (e.g. Recycle North, Preservation Trust of Vermont). While we have required that students consider social, environmental and economic issues within the problem solution for all of these projects, some projects by their very nature were much more focused on long-term environmental

and social stewardship aspects. For example, many of the projects dealt with the preservation of historic buildings, and therefore had a important social component. Others had a stronger environmental stewardship component and included stormwater management engineering, green roofs and a micro hydroelectric project. Details of the service-learning aspects of the DLR can be found in Dewoolkar, et al.^{3,4}.

Overall Course Description

The senior capstone course is a spring course consisting of B.S. civil and B.S. environmental engineering seniors. The course is geared entirely around the project, with weekly project assignments. The class size for the past five years has ranged between 30 and 42 students. Community partners and projects are selected prior to the start of the spring semester. This includes a fair amount of preparation by the instructor(s) ahead of time. Typically six to eight projects are developed with teams of students ranging from 3-5 per team. Community partners present their projects during the first few classes of the semester, and students submit a brief proposal of the two projects they are most interested in working on and why. Students also need to submit their résumés and a description of what they will bring to the project. Teams are selected by the instructor(s) and are based primarily on student interest and abilities. Compatibility of team members is also given some consideration.

After the teams and projects are selected, students visit their sites, work with the community partners and the instructor(s) to develop a detailed scope of work, and develop a project timeline. They also start writing the report. One of the first sections is the introduction section and a section that deals with the social, environmental, historical, political, and economic considerations of their specific project. This section is important for students to develop an understanding of the broader context of their project. The various sections of the report are reviewed by the instructors as the course progresses with feedback provided in a timely fashion. Typical instructor comments for the introductory sections include a request for more investigation and consideration of the multiple aspects of the projects. As these are service learning projects, we also include various critical reflection exercises throughout the semester for students to reflect on their personal/interpersonal goals, as well as academic and civic engagement aspects of the projects.

Teamwork is an important aspect that is stressed in the course. Work turned in for review and grading is generally a team effort. In order to ensure that all

team members are contributing to the project, team and self evaluations are done during and at the end of the course. The instructor(s) also work closely with teams and have a relatively good understanding of who may be having problems and not fully contributing. If this happens, the instructor can intercede to try to ensure everyone is working. However, in a few cases this has been an issue and has been addressed in a case by case basis.

Final reports and presentations are given to community partners and outside evaluators. Surveys are also taken of these people to gain external comments regarding the project and the process.

Other assessment tools have been used as part of the DLR grant, and include attitude surveys, service learning and sustainability surveys, focus groups, faculty interviews and others. In the case of focus groups, these have often focused on seniors during the capstone course.

Course Results

Project Descriptions

Service-learning projects have been incorporated within the senior capstone design course for the past five years (2006-present). During that time almost half (15 out of 32 total projects) have dealt with topics that are specifically related to sustainability issues. Figure 1 shows students engaged in field work related to their S-L project.



Figure 1. Students surveying as part of S-L project.

Stormwater management and retention facility design is an important issue facing many small and large towns in Vermont. Not only is this important to prevent stormwater erosion, flooding and civil infrastructure issues, it is also important from a water quality and ecological perspective for many streams and lakes in Vermont. Most of the projects students have worked on have dealt with trying to mitigate stormwater issues created by poor planning when

roads and subdivisions were initially installed twenty or more years ago. These projects provide an opportunity for all students in the class to see the problems with short-term solutions that do not address long-term environmental concerns. Our attitude survey specifically asks a question related to stormwater issues and results indicate that our seniors understand the importance of stormwater topics for today's civil and environmental engineer.

In many of these S-L projects dealing with stormwater, students have designed raingardens, retention facilities, and investigated green roof and porous pavement options. Since teams present various oral presentations related to their projects during each semester, all students in the class benefit from these topics even if they are not directly involved in the project.

Historic preservation projects also provide an opportunity for all students in the class to learn about the importance of historical structures from a societal and cultural perspective as well as the environmental benefit of restoring and thereby reusing buildings rather than demolishing and using new resources to build new structures. Historic preservation projects have included a historic arch bridge, and several historic buildings. Student teams have worked with preservation specialists (e.g. Preservation Trust of Vermont) related to their projects. Figure 2 shows the Grand Isle Lake House in which students worked on foundation and structural issues within this historic building.



Figure 2. Grand Isle Lake House historical preservation project.

This opportunity for teaming up with experts in fields other than engineering when working on solving problems is critical for today's engineers. Often engineering students do not have an appreciation for the nontechnical aspects of a project. In the case of a historic arch project, the team had a hard time understanding why the community partner wanted to restore the arch in a historic manner when it was under the road and no one would see it except

from pictures. This provided an opportunity for classroom discussion on the importance of appreciating others viewpoints and interests. This ability to appreciate other viewpoints is really at the core of a systems approach to problem solving.

A micro hydroelectric project in Greensboro, Vermont, was another service learning project that provided students with a fantastic opportunity to learn about local sustainable energy solutions, but also showed that even sustainable energy solutions can have negative impacts on the environment. A good example of the old adage, there's no such thing as a free lunch.

By their nature, micro hydro projects need to be near streams as water is removed from the stream to turn a turbine and then released back into the stream. Avoiding negative impact to the stream is critical to ensure this is truly a sustainable solution. Determining the allowable amount of water to remove from a stream without significant negative impacts, finding pathway for the pipeline that does not impact wetlands, and designing a method for the discharge of high velocity water after the turbine were all part of this service-learning project. Students learned firsthand about wetlands, their classifications and permitting requirements, also necessary permits for any in-stream work and stream crossings, as well as releasing water back into the stream. The preliminary work that the students did in investigating the permits, lay out of the route of the pipeline, and other design aspects of the project have been used by the town and State to move this project forward.

We have also worked with a professor (Dan Baker) from the Department of Community Development and Applied Economics (CDAE) and his community partner (Taluabe Honduras) on designing a small-scale water and wastewater systems for the community. Dan and his partners in Honduras have provided the much needed data and information about the site for the design aspect. One year, the team consisted of a student who had been to Honduras during one of Dan Baker's courses so he had firsthand knowledge about the project. Two students from the team went to Honduras after the capstone course as part of Dan Baker's summer course. One of those students became a CDAE graduate student working with Dan Baker on sustainable community development projects.

Assessment Results

Overall students are very positive about the work that they did and their final projects. This makes sense since students for the most part have an opportunity to self select the project of interest. In survey questions³, the majority of students respond

favorably (>80%) that the projects enhanced their learning and application of material to real world problems. This was reflected in the high quality work that students did over the course of the semester. One of the hardest things for students to do is to get their arms around the project initially and develop a reasonable scope of work. This usually takes several iterations between the instructors, community partners and the team. However, this is necessary to keep the students on task throughout the semester, enhance the project experience and ensure a high quality report and presentation in the end. Over 80% of the students preferred real-life S-L projects to projects that would be made-up or already implemented even though they may have struggled early on to figure out what to do. The instructors also noticed a greater sense of commitment and higher quality of work from the students in the service-learning senior design projects as compared to years previous to 2006 when the projects were derived from already completed 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. About 90% of the students thought that they can use their engineering training to address community problems after doing the projects.

The projects also help satisfy all eleven (a-k) ABET outcomes. The student work could be directly mapped to the a-k outcomes.

Student reflections were also generally very positive about the project and the team effort. Occasionally one or two students felt that they were taken advantage of, i.e. they provided valuable engineering services for free to the community partner. In some cases, when the community partners had limited engagement (mainly because of time constraints), the students were relatively less satisfied with their projects. In general, it appeared from the student reflections that although they appreciated the social and environmental aspects of the projects, they thought more highly of the projects because of its technical aspects.

Summary

Incorporating service-learning projects within the civil and environmental capstone design course provided an opportunity for practicing a systems approach to engineering problem solving. It also provided an opportunity for infusing sustainability topics and real world problems within the curricula. Students were positive about their experiences and the quality of their work was enhanced because of the service-learning aspects of the projects, and important sustainability aspects.

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