Diverse Models for Incorporating Service Learning in Capstone Design

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Service learning (SL) provides a benefit to partner communities/clients while also achieving core learning outcomes for the student participants. Many senior capstone design courses around the country have incorporated SL as optional and/or mandatory projects. Most instructors have found that SL projects pose some unique challenges in comparison to senior design projects that are simply learning exercises for the students. However, there are generally a variety of beneficial learning outcomes that are unique and/or enhanced by SL projects compared to non SL projects. These outcomes will vary substantially based on the length and context of the projects, in particular for international versus domestic SL projects. The large number of student chapters of Engineers Without Borders (EWB) serves as one source of international SL projects. These types of projects highlight the importance of sustainability as a key project criterion, but also are some of the most challenging projects to successfully execute. This paper summarizes 10-years of personal experience and published information on SL projects in capstone design.

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Service Learning

Service learning (SL) provides a benefit to partner communities/clients while also achieving core learning outcomes for the student participants.[1] Formal SL is also defined as being course based and including structured reflection activities for the students.[2] Given the universal need for engineering projects and the motivation that students derive from working on real-world problems, SL projects are a natural fit for capstone design courses. At the 2007 National Capstone Design Conference six paper abstracts emphasized SL projects, with four focused on international SL.[3] A few examples of programs that use SL projects in their capstone design courses include: capstone projects in electrical, mechanical, and multi-disciplinary engineering associated with the SLICE program at the University of Massachusetts Lowell[4]; a multi-disciplinary capstone in humanitarian engineering at the Colorado School of Mines[5]; EPICS as an optional capstone for Electrical and Computer Engineering at Purdue University[6]; the civil engineering capstone at Rose-Hulman[7]; and the civil-environmental inter-disciplinary international senior design course at Michigan Technological University[8]. SL projects may serve local communities (as are most EPICS projects) or international communities. Most international projects tend to focus on meeting basic human needs for water, sanitation, shelter, and energy. Many of these international projects have been conducted in collaboration with extracurricular Engineers Without Borders (EWB-USA) activities. Since its inception in 2001 at the University of Colorado at Boulder, EWB-USA has grown to more than two hundred university chapters.[9]

Environmental Capstone Course at CU

Since 1998, more than 200 students in the Environmental Engineering (EVEN) Design course at the University of Colorado at Boulder (CU) have worked on 15 SL and 20 non-SL projects. The single-semester course is 3-credits. EVEN students are required to take the course as their senior capstone, while civil engineering (CVEN) students can elect to take the course as their capstone. Three different types of projects have formed the basis of the course:

- Local SL projects [8 projects since 2003]
  - Client CU: LEED certified dorm, food waste composting from dorm
  - Wastewater/waste treatment for local community or small business, typically facilitated by iCAST (a local non-profit group)
- SL projects for international or distant communities [5 projects since 2001]
  - Design water or sanitation for a developing community
    - Affiliated with EWB project
    - Facilitated by iCAST
    - Mentored by EDC program at CU
- Non SL projects [20 projects since 1998]

- Upgrades to local municipal water or wastewater treatment plants mentored by the facility and/or consultants
- Remediation of contaminated sites mentored by consultants
- Local and national design competitions, such as the Water Environment Federation

In a typical semester, there are 3 to 5 different projects. Through a combination of student preference and project needs, teams of 3 to 6 students are assembled. In some semesters, more than one team may work on the same project. Students indicated that they preferred having a range of projects to choose from and minimal intra-class "competition". The entire course was coordinated by a single faculty person.

An example of one of the local SL projects was to design an upgrade for the evaporative wastewater treatment lagoons used by a Native American community. Three of the students on the team, the instructor, and the iCAST facilitator visited the community in the first month of the class. The group met with community leaders, the sanitation operators, and the local representative from the Indian Health Service. The students collected site data on the existing lagoons and wastewater samples. Then for the rest of the class the students conducted a comparison of multiple wastewater treatment options that were evaluated using criteria weighted by the community representatives. After the end of the semester, one student and the instructor returned to the community to present our design recommendations and gather more data to account for seasonal variations in water quality. The student conducted an independent study project to finalize the work. Then iCAST helped the community acquire grant funding and after 3 years the student-designed system was operational.

Civil Engineering Projects Course at CU

The alternative capstone design course for CVEN students is a 4-credit, 1-semester projects course (2006-present); prior to 2006 steel design or reinforced concrete design were considered culminating design experiences. Prior to 2009 all of the CVEN course projects were non-SL. Teams of ~6 students all worked on the same project with a total enrollment of 24-35 students. Examples of projects included partial design of a building that was already being constructed on campus, an upgrade design for a municipal wastewater treatment plant, and the design of a bridge. In 2009, the students worked on a real project and the winning design was actually constructed. The fall 2009 course of ~70 students worked on 2 separate SL projects. The course was taught with a faculty coordinator, and 3-4 additional faculty and 4 professional mentors to assist with each sub-discipline area of CVEN (structures, geotechnical, water resources, environmental, and construction management). Teams of 6 students developed designs, and then community representatives selected the winning design for each project.

Assessment Methods

The standard course deliverables including oral presentations and written design reports provide direct evidence of student learning. In addition to the traditional grading by the instructor, expert panels with additional faculty or professionals can evaluate the deliverables. For SL projects, community representatives and/or clients should evaluate the project. Scoring rubrics are generally used to assist this process.

Good practice for SL requires that students conduct self-reflection exercises, and these same essays provide excellent sources of information to assess the learning outcomes from the course. In the EVEN design course, students were required to write reflection essays starting in 2006. These essays appear helpful regardless of whether or not the students worked on an SL project. However, the students need to see the value of this activity or else they resent having a seemingly worthless course requirement. Various ethnographic methods can be used to explore these essays for emergent themes, and then code the essays for frequency. For example, in the CU EVEN design course in 2006-2009, sustainability was only discussed in the essays of students who worked on SL projects.

Students can be asked to self-assess their learning. In the CU design courses, students fill out standard faculty course questionnaires (FCQs) at the end of the semester, and routinely rate fulfillment of the ABET A-K outcomes and program specific criteria. A summary of the basic FCQ data is given in Table 1 below, which illustrates that the semesters where the courses were based entirely or primarily on SL projects were rated higher by the students (based on students t-test, $p=0.07$, 0.10 for EVEN and CVEN, respectively). The higher ratings of the EVEN course may be due to its smaller size and/or availability of multiple project options ($p=0.04$ and 0.10 for SL and non SL, respectively).

Table 1. Average ± Standard Deviation of Course Ratings on the FCQs, on a scale of 1 to 6 (highest)

	SL semesters	Non SL semesters
EVEN	5.5 ± 0.5	4.6 ± 0.9
CVEN	4.5 ± 0.3	3.9 ± 0.5

Another survey instrument has been used to solicit student and alumni opinions on SL versus non-SL projects.[10] There was generally strong agreement among the students from both the EVEN and CVEN courses that "service learning projects are appropriate to include in the class"; with an average rating 2.7 on 1-3 scale (disagree, neutral, agree; n=59). Only 4 students disagreed with the statement.

Other assessment instruments used historically have included the community service attitudes scale (CSAS)[11] and an instrument to measure universal-diverse orientation (which is similar to cultural competency)[12]. Of concern is ensuring that the students don't feel burdened by the assessments, which can be the response when numerous instruments are used.

Community partners should assess both the students and the project success, although the ultimate success of a project is often not known within the tight timing constraints of semester-based grades. In addition, in team settings it is common that a smaller subset of the students may have extended, direct interactions with community partners. This is particularly true with EWB-type projects where financial and other constraints may rationally limit the number of students who work for an extended time in the community.

Enhanced Outcomes from SL Projects

Faculty have reported that a variety of knowledge, skills, attitudes, and identity outcomes are enhanced when students participate in SL projects. In general, these findings are anecdotal and not yet supported by rigorous research with statistical significance. However, commonly reported benefits of SL projects to students are: understand a broader range of design constraints; greater understanding of the impacts of engineering solutions in a societal and global context; understanding of professional and ethical responsibility; communication skills, particularly to non-technical individuals; ability to function on multi-disciplinary teams; applying principles of sustainability; creativity; critical thinking skills; develop greater cultural competency (particularly due to international SL projects); more positive attitudes toward community service; and increased self-confidence, self-efficacy, self-esteem.[9] Various learning theories support these findings, where increased student motivation (Kolb[13]) and challenges/conflicts (Piaget[14]) will ultimately lead to greater learning.

At CU, the largest differences in students' self-reported learning outcomes based on SL versus non-SL projects were found in the CVEN course. The ABET learning outcomes with the greatest benefit from the SL projects in the CVEN course were: design and conduct experiments; oral communication; realistic design constraints; understanding impact of engineering solutions in a societal context; and understanding of business and public policy (based on SL 1.7 to 1.3 points higher than non SL on scale of 0 to 6). In the EVEN class, differences in the student ratings of the ABET criteria were only significantly higher on the SL projects for the ability to solve engineering problems. This indicates that well designed projects of any type can achieve the ABET outcomes, although SL projects may facilitate this process.

More rich information was available from the self-reflection essays written by students in the EVEN design course. Based on statistically significant differences the percentage of the SL and non-SL students that discussed different themes in their essays, the SL projects enhanced: real world experience, communication, ability to serve community; data issues (too much, too little, assumptions), importance of non technical aspects, relationship with community was motivating, disparity of stakeholder goals, and the importance of sustainability.

Unique Challenges of SL Projects

The SL projects have often been less technically sophisticated than the non-SL projects. This has raised concerns among some faculty that the students receive a less rigorous course. However, the SL projects generally require significantly more attention to a wide range of non-technical constraints and criteria, and stakeholders. Student feedback has not indicated that they felt disappointed with "simpler" designs. Designs should be approved by a PE, which may be the course instructor or else the student work must be passed to a different licensed PE.

Service learning projects have generally been more poorly defined than non-SL projects. The lack of detailed information on the project and the requirement to make engineering assumptions can be very challenging and frustrating to students, but they often acknowledge that this was also the most beneficial aspect to their learning.

Significant lead time should be devoted to developing relationships with a community prior to the start of the semester. The community should be given an accurate perception of the outcomes that can reasonably be expected from the students, and the time commitments expected from their side. The community partners should be informed that the ability of the final product to meet their needs will be largely determined by the level of interaction they have with the students. In particular, students find it very frustrating when they are unable to get the level of support from the community that they require. In projects with local partners we have found that even a modest monetary investment on the part of the community/client can significantly increase their devotion to the project. A common model that we have used is that the community pays the costs associated with student travel to the site and associated analytic or testing costs. The students have been more motivated when they realize that their client has invested in their project.

Community partners may find it confusing if more than 1 team of students is working on the same project. This is because the student teams will have different designs, and this may make it difficult for the community to decide which is best. There will also typically be greater demands on their time to interact with larger numbers of students. However, the design competition format used in the CVEN course was successful as perceived by the community; the winning design was constructed within 1 year of project completion.

It is nearly impossible to appropriately serve community partners in a single semester capstone design course. Many students, regardless of project type, have also indicated that they would prefer a year-long capstone. However, when this is attempted it is useful if there is a longer-term relationship with the community via EWB or a non-profit facilitator such as iCAST. For example, the EWB group may do a needs assessment visit prior to the semester, and will work with the community after the semester for implementation of the design. For other cases, one student has continued their project as an independent study in order to advance it to a level where it can truly benefit the community.

Unique Challenges of International SL Projects

The challenges of SL projects are compounded when the community partners are distant and/or international. Students and alumni (n=85) felt strongly that "the ability to tour existing facilities and the locally relevant area would be a significant advantage over projects where this was not possible"; with an average rating of 2.6 (1=disagree; 2=neutral; 3=agree). Culture and language differences complicate communication and understanding challenges. It is a financial burden to have all of the students working on the project visit the community. The timing of these visits is also difficult. However, many students at CU have found international SL projects very attractive. For example, in 2006 three teams wanted to work on the single international SL project (12 students) compared to only 1 team each on the two local SL projects (9 students total). In 2010, one of the international SL projects was the most preferred project choice among 12 of the 26 students in the class; the next most popular project was the SL project for CU (which was the first choice for 6 students).

References

1. Bringle, R. G., Phillips, M. A., Hudson, M. 2004. The Measure of Service Learning: Research Scales to Assess Student Experiences, 227 pp. American Psychological Association, Washington, DC.
2. Furco, A. 2003. Issues of Definition and Program Diversity in the Study of Service-Learning, In Studying Service-Learning, S.H. Billig (Ed.), p. 13-34, Lawrence Erlbaum Assoc., Mahway, NJ.
3. Zable, J. (chair). 2007. National Capstone Design Course Conference Proceedings, Sponsored by the ASEE and NSF. June 13-15, University of Colorado – Boulder, CO. 91 pp.
4. Burack, C., Duffy, J., Melchior, A., Morgan, E. 2008. Engineering faculty attitudes toward service-learning. American Society for Engineering Education (ASEE) Annual Conference Proceedings. Paper AC 2008-1521.
5. Moskal, B.M., Skokan, C., Munoz, D., Gosink, J. 2008. Humanitarian Engineering: Global Impacts and Sustainability of a Curricular Effort. Int. J. Engrg. Ed. 24 (1), 162-174.
6. Coyle, E.J., Jamieson, L.H., Oakes, W.C. 2005. EPICS: Engineering Projects in Community Service. Int. J. Engrg. Ed. 21 (1): 139-150.
7. Aidoo, X. 2007. International Senior Design Projects – More Lessons Learned. Engineering Capstone Design Course Conference Proceedings.[3]
8. Phillips, L., Brady, A., Jousma, K. 2007. Interdisciplinary International Senior Design: How service learning projects in developing countries support ABET accreditation. ASEE Annual Conference Proceedings. Paper AC 2007-1638.
9. Bielefeldt, A.R., Paterson, K.G., and Swan, C.W. 2010. Measuring the Value Added from Service Learning in Project-Based Engineering Education. The International Journal of Engineering Education. 2. 6 (3): 535-546.
10. Bielefeldt, A.R., Amadei, B., Sandekian, R. 2007. Engineering For The Developing World Course Gives Students International Experience. ASEE Annual Conference Proceedings. Paper 2007-799.
11. Shiarella, A.H., McCarthy, A.M. 2000. Development and Construct Validity of Scores on the Community Service Attitudes Scale. Edu and Psychological Measurement. 60 (2): 286-300.
12. Fuertes, J.N, Miville, M.L., Mohr, J.J., Sedlacek, W.E., Gretchen, D. 2000. Factor structure and short form of the Miville-Guzman Universality-Diversity Scale. Measurement & Evaluation in Counseling and Development. 33(3): 157-170.
13. Kolb, D. A. 1984. Experiential Learning: Experience as the Source of Learning and Development. Prentice Hall, Englewood Cliffs, N.J.
14. Piaget, J. 1977. The development of thought: Equilibration of cognitive structures, Viking Press, New York.