AC 2010-2149: MAXIMIZING BENEFITS OF SERVICE-LEARNING IN ENGINEERING

Linda Barrington, University of Massachusetts, Lowell

John Duffy, University of Massachusetts Lowell

Maximizing Benefits of Service-Learning in Engineering

Abstract

Are engineering educators maximizing the benefits of service-learning to students, community, faculty, and institutions? Are we collectively converging on desired goals of service-learning as a pedagogy/philosophy that take full advantage of the benefits elucidated by research?

A commonly utilized definition of service-learning is "a credit-bearing, educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility." (Bringle & Hatcher, 1995). Many past studies (e.g. Eyler and Giles, 1999) have shown service-learning to result in positive outcomes in cognitive and affective measures for students as well as benefits to the community, faculty, and institution.

Different embodiments of service-learning have developed in engineering in recent years. Direct placements in the community are utilized in the first year programs, such as at Cornell and Virginia Tech, for example. More often indirect community interfacing (similar to a consultant-client relationship model) is used. Some programs seem to be focused mainly on student skill development, such as teamwork and communication (e.g., IPRO at IIT). EPICS, which incorporates multidisciplinary elective courses that can be taken over seven semesters, emphasizes design and professional skills. Other models, such as SLICE, focus more on subject matter comprehension in existing core courses. Organizations, such as Engineers Without Borders, focus on service with no formal link to credit-bearing educational experience (and thus are not considered service-learning). A faculty member interested in incorporating service-learning into a course or degree program may focus on one approach and may miss the richness and full potential of service-learning, as seen in recent literature. Benefits for the students include increased subject matter comprehension, higher GPA, retention, critical thinking skills, tolerance for diversity, writing skills, and citizenship. Communities benefit by the services and problem-solving provided by the students.

In conclusion, engineering educators can maximize the rich benefits of service-learning for the common good by revisiting the literature on service-learning in higher education and systematically laying out the advantages and structuring the service-learning projects appropriately within their unique academic programs.

1. Introduction

Service-learning is gaining ground as an educational method in engineering. However, engineering educators are relative newcomers to the service-learning field. As late adopters, it is important to recognize that the field of service-learning in education has had a research life of its own for years, and has a whole body of knowledge as a discrete discipline.

The motivation for this work is to begin with a review of literature for service-learning as an educational method prior to its wider adoption by the engineering education community. As we move forward in looking at the impact of service in engineering education, it is opportune to look at the gains of our predecessors and take what they have to offer us. Looking back grounds engineering work within the historical context of research progress to date. In defining terms with the same meanings as in the existing service-learning field, we build on existing research and maintain the respect of the larger academic service-learning community.

2. Service-Learning in Higher Education

2.1 Historical context of service-learning

Service-learning is used to engage students in grade levels from kindergarten through graduate school. Since the focus here is on higher education, Table 1 contains a summary of selected highlights.

Table 1: Condensed history of service-learning in higher education (Learn and Serve America's National Service-Learning Clearinghouse, 2009)

Date	Activity
Circa 1905	William James, John Dewey develop intellectual foundations to service-based learning
1910	American philosopher William James envisions non-military national service in his essay "The Moral Equivalent of War"
Circa 1915	Some Folk Schools in Appalachia become two- and four-year colleges with work, service, and learning connected
1933-1942	Through the Civilian Conservation Corps (CCC), created by Franklin D. Roosevelt, millions of young people serve terms of 6 to 18 months to help restore the nation's parks, revitalize the economy, and support their families and themselves
1944	The GI Bill links service and education, offering Americans educational opportunity in return for service to their country
1965	College work-study programs established
1966	"Service-learning" phrase used to describe a TVA-funded project in East Tennessee with Oak Ridge Associated Universities, linking students and faculty with tributary area development organizations
1969	Atlanta Service-Learning Conference. Southern Regional Education Board defined Service Learning as the integration of the accomplishment of the tasks that meet human needs with conscious educational growth
1971	White House Conference on Youth report full of calls for linking service and learning.
Circa 1971	National Student Volunteer Program (became the National Center for Service-Learning in 1979) established. Published Synergist, a journal promoting linking service and learning
1979	"Three Principles of Service-Learning" published in the Synergist [1) Those being served control the services provided 2) Those being served become better able to serve and be served by their own actions 3) Those who serve are also learners and have significant control over what is expected to be learned(Sigmon, 1979)]
1985	Campus Compact started by the presidents of Brown, Georgetown and Stanford

	Universities and the president of the Education Commission of the States. [Now 1,100 college and university presidents — representing some 6 million students (Campus Compact, 2009)]
1981	National Center for Service-Learning for Early Adolescents established
1989	Wingspread Principles of Good Practice in Service-Learning written-more than seventy organizations collaborate to produce the ten principles [1. An effective program engages people in responsible and challenging actions for the common good. 2. An effective program provides structured opportunities for people to reflect critically on their service experience. 3. An effective program articulates clear service and learning goals for everyone involved. 4. An effective program allows for those with needs to define those needs. 5. An effective program clarifies the responsibilities of each person and organization involved. 6. An effective program matches service providers and service needs through a process that recognizes changing circumstances. 7. An effective program expects genuine, active, and sustained organizational commitment. 8. An effective program includes training, supervision, monitoring, support, recognition, and evaluation to meet service and learning goals. 9. An effective program insures that the time commitment for service and learning is flexible, appropriate, and in the best interests of all involved. 10. An effective program is committed to program participation by and with diverse populations. (Honnet & Poulsen, 1989)]
1990	Congress Passes, and President Bush signs, the National and Community Service Act of 1990. The legislation authorizes grants to schools to support service-learning and demonstration grants for national service programs to youth corps, nonprofits, and colleges and universities. Learn and Serve America established (as Serve-America). The legislation also authorizes establishment of the National Service-Learning Clearinghouse.
1993	Association of Supervision and Curriculum Development endorse the importance of linking service with learning
[1994	Michigan Journal for Community Service-Learning begun as the first refereed journal for the service-learning field (http://www.umich.edu/~mjcsl/)]
1995	Service-Learning network on the internet, via the University of Colorado Peace Studies Center April
1997	Wingspread Declaration Renewing the Civic Mission of the American University published
2001	First International Conference on Service-Learning Research held. Wingspread conference on student civic engagement held.
[2006	Carnegie Foundation elective classification for institutions of higher education: Community Engagement. Categories include Curricular Engagement, Outreach & Partnerships, or Curricular Engagement and Outreach & Partnerships. (http://classifications.carnegiefoundation.org/descriptions/community_engagement.php)]

It is interesting to note the original connections to military service, and how service in peacetime echoed the top-down structure of service in wartime. Yet, there were grassroots alternative efforts working from the bottom up toward a mission for the public good. A broad history of service-learning is provided by Stanton, Giles, and Cruz (1999).

2.2 Pedagogy and philosophy of service-learning

As early as 1899 John Dewey was writing “The School and Society,” and later his essay “Thought and Its Subject Matter” Studies in Logical Theory,(1903). Toward the end of the twentieth century David A. Kolb published his cycle of learning in “Experiential Learning: Experience as the Source of Learning and Development” (1984), based on works of John Dewey, social psychologist Kurt Lewin, and developmental psychologist, Jean Piaget, among others. As community connections became useful educational methods, service to others – outreach to the unfamiliar – continued as the underpinning of serving communities in need.

The history of service-learning shows it embraced by early adopters as more than just a pedagogy, but as a philosophy as well. In service-learning there is an underlying belief that the community deserves to be served and that it is the role of colleges and universities to assist in serving them. This ethic is especially strong in attention to underserved communities. Therefore service-learning philosophy is the best fit with institutions, departments, and/or individuals who believe in this attitude of mission.

2.3 Definition of service-learning

There have been many definitions for service-learning in the literature over the years [e.g., (Jacoby, 1996), (Bringle, Hatcher, & Games, 1997), (Stanton, Giles, & Cruz, 1999), (Learn and Serve America, 2009). However, one of the earlier definitions is still widely accepted and comprehensive: Service-learning is “a course based, credit-bearing, educational experience in which students (a) participate in an organized service activity that meets identified community needs and (b) reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility." (Bringle & Hatcher, 1995). Note the three elements. To be defined as service-learning the activity must be in the context of a credit-bearing course, meet a real community need, and involve a reflection component.

2.4 Service-learning in the context of experiential learning

Service-learning is distinct from other forms of experiential learning and outreach. Diagramming these forms can be a useful exercise, as in the example below (Figure 1.)

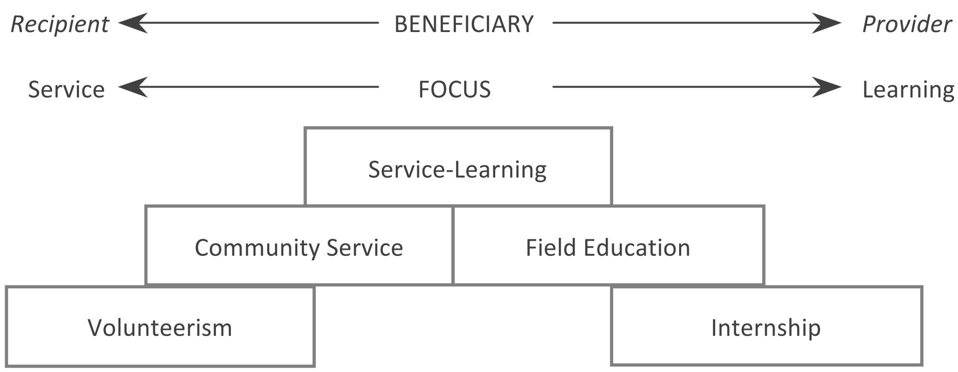

Figure 1: Distinction among service programs (Furco, 1996)

Even within the context of a credit-bearing course differences arise. One of the distinctions between service-learning and a practicum or fieldwork is who determines the tasks for the student to accomplish. If the community partner gets to determine what the student will do based on the needs of the community partner at that time, it may be service-learning. If there are set professional duties that every student must accomplish for licensure or certification, then the educational needs of the student are primary, so it in unlikely to be service-learning.

Another distinction is the receiver of the service. Generally, in the service-learning field the term “service” is short-hand for community service in the interest of the public good. Although laudable, military service in general is not included. However, community service requested of students within a credit-bearing ROTC course certainly might be. Student work for corporations and industrial partners may considered as an internship, industrial project, or (if in series) a co-op, but not service-learning. Most often, community partners are non-governmental organizations (NGOs), non-political governmental institutions and municipalities. At the University of Massachusetts Lowell this includes local and international non-profit agencies and municipalities, individuals with disabilities, and for-profit micro-enterprises in developing countries. While students may design and install solar systems for schools and health clinics in remote Peruvian villages, photovoltaic panels are not installed on an individual’s home (Duffy J. , 2008) Yet, individuals are often served through personalized assistive technology (ATP, 2009). These distinctions are important to the definition of service-learning in order that the reported research all has the same basis.

2.5 Service-learning impacts

Since research on the impacts of service-learning is the subject of other papers in this session, below are some seminal studies for background purposes.

Service-learning has been shown to be effective in a large number of cognitive and affective measures, including critical thinking and tolerance for diversity, and leads to better knowledge of course subject matter, cooperative learning, and recruitment of under-represented groups in engineering; it also leads to better retention of students, and citizenship (Eyler & Giles, 1999).

Eyler and Giles also found service-learning to impact positively: tolerance for diversity, personal development, interpersonal development, and community-to-college connections. Students reported working harder, being more curious, connecting learning to personal experience, and demonstrated deeper understanding of subject matter. They found that service-learning is more effective over four years and that the messiness inherent in helping solve real community-based problems enhances the positive effects (Eyler & Giles, 1999).

Astin et al. found with longitudinal data of 22,000 students that service-learning had significant positive effects on 11 outcome measures: academic performance (GPA, writing skills, critical thinking skills), values (commitment to activism and to promoting racial understanding), self-efficacy, leadership (leadership activities, self-rated leadership ability, interpersonal skills), choice of a service career, and plans to participate in service after college. In all measures except self-efficacy, leadership, and interpersonal skills service-learning was found to be significantly more effective than service alone (Astin A. , Vogelgesang, Ikeda, & Yee, 2000) (Astin A. W., et al., 2006) This longitudinal study is ongoing.

Community impacts have been less researched, but in his "balanced approach" Furco (1996) echoed the importance of true reciprocity identified by Sigmon (1979). The service and the learning must go both ways; the community learns and serves as well as the student.

Key elements that appear to be important to researchers and practitioners include: projects or placements that meet academic objectives in a credit-bearing course, the meeting of real community needs, analysis or reflection on the part of students to relate the service to the subject matter of the course, and reciprocity with the community partner. The approach of S-L, with its roots in experiential learning, is consistent with the theories and empirical research of a number of leading educators and developmental psychologists, as documented by Jacoby (Jacoby, 1996). The approach is also consistent with the relatively recent change in paradigm in education from a focus on teaching to a focus on learning (Bradenberger, 1998).

More recently, Astin's group reported that its 2007-2008 survey of over 12,000 full time faculty members at 379 institutions that the percentage of faculty who found it "very important" or "essential" to encourage commitment to community service rose 19 percent compared to 2004-05 (55.5 % vs. 36.4 %), the largest increase in any of the survey items (DeAngelo, Hurtado, Pryor, Kelly, & Santos, 2009).

2.6 Service-learning projects vs. placements

Much of service-learning in the academic disciplines is conducted by students spending a number of hours working with the community partner on site. This is especially true in the social sciences where service-learning has had a strong foundation. For the sake of convenience these arrangements are often referred to as placements, despite the student passiveness the term connotes, which raises occasional objections from faculty. In contrast, much of engineering service-learning is project-based. In project-based service-learning the accomplished deliverable marks the completion of the service, regardless of the number of hours spent. Perhaps because it is a way to measure across all types of service-learning, there is still a bias toward reporting hours of service-learning, e.g. Carnegie Community Engagement criteria(Carnegie Foundation, 2010).

3. Service-Learning in Engineering

3.1 Service-learning gains a foothold in engineering

At the time when it appears that service-learning was first gaining a foothold in engineering education, around 1995 (Tsang, 2000), other disciplines had already adopted the approach. For example, a survey of psychology programs revealed that over half had already incorporated service-learning into their curriculums in 1995 (Murray, 1997). Individual faculty champions have been creating opportunities for their students for years, often well before the beginning of established programs in engineering service-learning, as documented in Tsang (2000), for example. Some examples of institutionalized programs are listed below (Table 2.) It should be noted, however, that individual faculty members can incorporate S-L into their courses without a formal program. Nevertheless, having the help of coordinators and funding is certainly helpful.

Table 2: Engineering service-learning sampler with program links

Global Perspectives Program (GPP) – WPI – begun prior to 1985	http://www.wpi.edu/academics/GPP/Overview/index.html
Engineering Projects in Community Service (EPICS) – begun at Purdue in 1995	https://engineering.purdue.edu/EPICS/
Illinois Institute of Technology - 1995 Interprofessional Projects (IPRO)	http://ipro.iit.edu/
Design for the Other 80% (D80) – Michigan Tech since 1996	http://www.mtu.edu/d80/
University of Michigan Ann Arbor - Program for Civic Engagement in Engineering Design (ProCEED) c. 2000	http://www.engin.umich.edu/societies/pts/ProCEED/
Service-Learning Integrated throughout a College of Engineering (SLICE) – UMass Lowell begun in 2004	http://slice.uml.edu/
Humanitarian Engineering Program – Colorado School of Mines	http://humanitarian.mines.edu/
Humanitarian Engineering and Social Entrepreneurship Program – Penn State	http://www.engr.psu.edu/ece
International Journal of Service Learning in Engineering (IJSLE) – first issued 2006	http://library.queensu.ca/ojs/index.php/ijsle/index
Club based w/ some curricular engagement:	
Engineers Without Borders (EWB) – University of Colorado Boulder - 2000	http://ewb-usa.org/about.php
Engineers for a Sustainable World (ESW) – Cornell - 2001	http://www.esustainableworld.org/

All levels of study from first year undergraduate through doctoral work are represented. There is great variety in the details of how curricular service is incorporated into engineering. Bill Oakes described a number of universities in the U.S. and around the world that are intentionally serving the needs of the poor locally and across continents through service-learning (Oakes W. , 2009).

3.2 Service-learning elements specific to engineering

The word reflection seems to cause engineering faculty to become uncomfortable. In fact, Bill Oakes uses the word analysis instead of reflection in his guidebook on service-learning for engineers (Oakes W. , 2004). Yet, reflection in engineering service-learning may be actually less difficult than for our social science colleagues dealing with student placements. Recall the three aspects of reflection cited above: "reflect on the service activity in such a way as to gain [1] further understanding of course content, [2] a broader appreciation of the discipline, and [3] an enhanced sense of civic responsibility." (Bringle & Hatcher, 1995) In engineering there appears be little trouble with the first aspect since projects can be structured to require use of the subject matter of the course. For example, a project calling for recommendations for a local food shelter to save money on heating bills can be tied to the appropriate equations and models from a heat transfer course. The linking of subject matter to the service project was found to be a very key factor in the benefits found by Astin et al. (Astin A. , Vogelgesang, Ikeda, & Yee, 2000).

The second aspect of a broader appreciation of the discipline also would appear to be straightforward since students presumably gain a broader appreciation of what engineers can do in the process of providing useful services to community groups. Embedding S-L projects in required courses sends a message that service is part of what engineers do as professionals. In other words, it is a given that service is part of the curriculum and part of the profession. Interviews with students and faculty who have participated in such projects have independently identified this aspect of S-L (Burack, Duffy, Melchior, & Morgan, 2008) (West, these proceedings, 2010). For example, solving community problems was discussed with student's often emphatically stating, "*That is the role of an engineer!*" One faculty member even said, "It [service-learning] will change the way we think about engineering. It adds an additional dimension." (Burack, Duffy, Melchior, & Morgan, 2008)

The third aspect of reflection, enhancing a sense of civic responsibility, appears more challenging for engineering educators. The importance of analyzing with the students how their project will meet community needs and that it will satisfy the civic responsibility of themselves and their institution is obvious. Is civic responsibility a part of the profession? Are we trying to create better engineers and better citizens with S-L?

Reflecting to analyze whether in the long-run S-L activities may be helpful is important. For example, installing a water purification system in a remote village may appear beneficial in the short run as a S-L project, but if no provision is left for continued operation, maintenance, and repair, the community benefits may in fact not outweigh the costs in the long run (Duffy J. , Village Empowerment: Service-learning with continuity, 2008).

The "how" of reflection in engineering is related by Lima and Oakes (Lima & Oakes, 2006), for example, through class discussions, journals, student reports, and interviews. Reflection in S-L in general is treated, for example, in (Eyler, Giles, & Schmiede, 1996). Reflection is considered by some as part of critical thinking (Ahmed, Hutter, & Plaut, 2008), as in taking different viewpoints considering evidence, utilizing inductive and deductive reasoning.

Reflection can be utilized to help students deal with the messiness of real, open-ended problems. There are typically no right-or-wrong, black and white solutions to solving real community problems. Dealing with messiness seems to result in positive intellectual development in general, based on several different models, such as those based on classic works of Perry, Belenky et al., and Baxter-Magolda, nicely summarized in Chapter 2 of Pascarella and Terenzini (2005). Nevertheless, open-ended projects such as in service-learning can make some students highly anxious, especially when the stakes are raised by doing work with a real community partner who is depending on them. Reflection and discussion on this aspect of S-L projects can prepare students to expect some frustration and see the open-endedness in a positive light. Feedback from students in Duffy, Barry, Barrington, and Heredia (2009) indicated a desire to be warned of such frustration and not that the messiness not be a part of their projects.

Some authors equate the reflection in service-learning to critical thinking skill development. Some researchers have tried to link the reflection in service-learning projects to the reflective judgment model of King and Kutchner (Huyck, Bryant, & Ferguson, 2009). It appears from this work that more than a couple of courses are needed to bring about profound changes in intellectual development. Reflection has many aspects and corresponding benefits.

3.3 Required vs. optional

Within the larger academic service-learning community there is an ongoing debate: should service-learning always be optional, or is it beneficial to make it a required part of a course? The believers of optional-only service-learning have generally experienced that their students will do a better job at something they volunteer to do. Additionally, students who do a poor job reflect badly on the academic institution and may have a significantly negative impact on the community partner. The greater the number of required contact hours, the greater the risk may be. Faculty teaching with optional service-learning may simply offer extra credit for the service-learning, but more often have alternate assignments of equal work and grade value for the students choosing not to do the service-learning.

In engineering, most students are eager to apply what they are learning. In engineering, having some courses with required service-learning and additional choices for those who opt to do more, seems to be a good mix. Service-learning team projects have the potential to ensure students learn and demonstrate these qualities in addition to ensuring the students have the ability to apply engineering to the design and analysis of systems and experiments.

3.4 Service-learning as distinguished from other engineering service

As discussed above under definitions, differentiating service-learning in engineering from other forms of service is important for comparisons of research in the literature and for practitioners to know which research can apply to their courses. There is great good that comes from engineering service in general, but for the research to be respected and utilized using terms properly is crucial. Club level activities, while not service-learning, may or may not be coordinated with curricular work. For example, University of Colorado Boulder and Lafayette College have Engineers without Borders (EWB) projects running concurrently as capstone design projects and extracurricular projects (Bielefeldt, Paterson, & Swan, 2009), but the labeling of extracurricular projects as "project-based service-learning" (Bielefeldt, Paterson, & Swan, 2009) confuses researchers and practitioners alike. Another example is the Extracurricular NSF scholarship program at the Colorado School of Mines using international community service in all four years (Burke & Moskal, 2008).

3.5 Influence of ABET 2000 Criterion 3

In 2000, when new accrediting standards took effect (Table 3), specific engineering program outcomes were detailed in a manner that supported the work of faculty implementing service-learning(Accreditation Board for Engineering and Technology [ABET], 2009).

Table 3: ABET Criterion 3. Program Outcomes

Engineering programs must demonstrate that their students attain the following outcomes:
(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(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
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

These abilities, which students must possess upon graduation, are efficiently addressed through the type of open-ended course-based team engineering service projects exemplified in service-learning.

Nevertheless, instead of adding more elective courses (just so that service-learning projects can be implemented), or instead of adding more courses to satisfy ABET requirements, service-learning projects can be incorporated into existing core courses. For example to meet ABET requirements, having community partners on service-learning projects essentially guarantees that students will work on multidisciplinary teams, and that with the correct structure of service-learning projects, the students will examine the impacts of engineering solutions in a societal context, both of which are ABET requirements. In the end, the idea is that service-learning projects can replace traditional analytical exercises in courses and that, consequently, the overall workload will typically not increase for the students; if students are motivated to spend more time on service-learning projects, they are free to do so and should learn more in the process.

4. Maximizing the Benefits of Service-Learning in Engineering Education

4.1 Service-learning impacts on professional and technical skills

Well established service-learning programs, especially those using multidisciplinary teams (e.g. EPICS, IPRO), promote their impacts on students' professional skills. These include skills such as the ability to work in teams, to communicate well, to behave ethically, to identify the current societal context of their work, etc. Service-learning is definitely an effective tool for teaching these skills that students need to be effective in the workplace and in their communities beyond school. But why not utilize service-learning as a vehicle for engineering technical skills as well?

As early as 1999 studies began noting the gains from service-learning in subject matter understanding (Eyler & Giles, 1999). In engineering, students must be able to assess the needs of constituents, apply math and science knowledge, handle data, use current technology, solve problems, identify limitations, and project future issues. Service-learning in core engineering science courses (such as fluids, heat transfer, materials, etc.) can be effective ways for students to learn these technical skills.

One engineering program found that students and the faculty who taught them identified service-learning students as more motivated to learn the subject matter, and the students reported voluntarily spending extra time on task (Duffy, Barry, Barrington, & Heredia, 2009). Another program found that students with service-learning experience scored better in technical areas on measures of analytical, practical and creative skills (Swan & McCormick, 2009).

Whether addressing learning improvements in professional or technical skills, fulfilling ABET requirements through service-learning can be an effective strategy. Providing more elective choices that afford students opportunities to build their professional and technical skills is likely to be received quite positively. One word of caution should be noted, however: ABET reviewers may consider a program outcome as met if, and only if, all students in that program are required to participate in the associated activity.

4.2 Incorporating engineering service into electives, capstone and design courses

Service-learning is often applied in elective courses where instructors have more freedom in the topics that are covered and more freedom to decide on the time that needs to be allotted for each topic [e.g., EPICS (Coyle, Jamieson, & Sommers, 1997).] Oakes (2004) has a list of 33 universities that had service-learning in engineering and described a number of examples of service-learning. Tsang (2000) and Lima and Oakes (2006)describe more examples of service-learning in engineering courses.

In first year engineering courses, California Polytechnic State University in San Luis Obispo has required service-learning for all materials engineering majors (Bielefeldt, Paterson, & Swan, 2009). While Columbia University's mandatory service-learning in the first year design course is for all engineering students and uses different types of projects with local community partners to appeal to different majors (Dutta & Haubold, 2007).

A wide variety of institutions have service-learning in senior capstone design courses. Examples include Tufts (Swan, Gute, Matson, & Durant, 2007), Michigan Tech's International Senior Design (ISD) program (Paterson & Fuchs, 2008), and Rose-Hulman IT international senior design projects (Hanson, Houghtalen, Houghtalen, Johnson, Lovell, & Van Houghten, 2006). Rowan University has service-learning in mandatory Engineering Design Clinics throughout all 4 years (Mehta, Jansson, & Dorland, 2007).

As mentioned earlier, a number of faculty have integrated service-learning into their individual courses. Quite a few schools include service-learning in environmental engineering lab courses including Tufts (Swan, Rachell, & Sakaguchi, 2000) and University of Colorado Boulder, among others (Bielefeldt, et al., 2005). University of Dayton uses service-learning in their materials lab (Bielefeldt, Paterson, & Swan, 2009).

The college of engineering at UMass Lowell has integrated service-learning into many of its core required undergraduate courses over the last five years using both international and local service. All the approaches have their advantages and disadvantages.

4.3 Incorporating service-learning into core engineering science courses

In the fall of 2004 the engineering college at the University of Massachusetts Lowell began a unique program to integrate service-learning projects into required engineering courses throughout the curriculum, so that students would be exposed to service-learning in at least one course in each of eight semesters. The ultimate goal is to graduate better engineers and engaged citizens and to improve communities, i.e., to engineer the common good.

The program started at the "grass roots" by one faculty member in Mechanical Engineering (Duffy J. J., 2000) and two in Electrical Engineering [D. Clark and A. Rux (ATP, 2009)] several years earlier. The dean (John Ting) and the five department chairs lent their support in 2004. A workshop for faculty was held in August 2004. New community partners were approached. A part-time staff coordinator started in late fall of 2004. Faculty were encouraged to "start small rather than not at all." Biweekly community of practice (Wenger, McDermott, & Snyder, 2002) gatherings have been held roughly every two weeks since then. A full-time staff coordinator has been on the project since the fall of 2005 and is now supported entirely by the university. Graduate research assistants have been available to help faculty members integrate service-learning into their courses. A few course releases have been available; a few faculty have taken advantage of small stipends.

In the current program, the service-learning projects are intended replace existing "paper" projects so they do not add more class or homework time for students. Courses and projects include, for example, a first-year introduction to engineering course in which up to 420 students, divided into teams, designed and built moving displays illustrating various energy transformation technologies and recycling for 60,000 middle school students that annually visit a history center that is part of a national park. Another example is a sophomore kinematics course in which student teams visited local playgrounds to assess their safety using deceleration, force, and impact equations learned from the course. Junior heat transfer courses focused in analyzing heat loss and making suggestions for heating system savings for a local food pantry, a city hall building, and a community mental health center, as well as for the university itself; these analyses were developed and presented to the stakeholders. Sophomore student teams from the materials course presented findings to the staff of a local textile history museum to help it begin updating its displays on recent developments in materials. Junior fluids, junior circuits, senior microprocessor, senior design of machine elements, and senior capstone design had students design and build various parts of an automated canal lock opener for a local national park. Many of the projects are low-cost and can be implemented by individual faculty members without the requirement of a formal institutional program.

Four of the five degree programs have achieved on average one course each semester, with an actual coverage of 80% of the possible semester slots. The fifth program is in process. Roughly 750 students each semester do service-learning projects in courses, 60% of which are considered engineering science. More than fifty courses having service-learning components have been offered under the program. Over half of the 70 full-time faculty members have been involved. In written surveys over two-thirds of the students and faculty members expressed agreement with the basic idea of SLICE, with about 15% opposed. Twenty-three percent of entering students cite service-learning as one of the reasons for enrolling in engineering at UMass Lowell and more than two-thirds of the students reported that service-learning helped keep them in engineering. The program represents perhaps the largest experiment with service-learning in mainstream engineering courses in the country in terms of courses, students, and faculty.

4.4 Practical Suggestions for Faculty Implementers

This discussion focused on benefits is not meant to mask costs. Time and resources are needed to obtain the benefits. The message from faculty and students is that S-L is worth the extra work it requires. Based on the literature and the authors' own experience, some concrete suggestions are offered to minimize the extra work and to avoid some pitfalls.

1. "Start small rather than not at all." It is much better to start off small and have a successful project and then to expand the project if warranted. The ideal initial target is to replace an existing paper exercise or activity with a real S-L project. The faculty members known to have tried and then abandoned the use of S-L were unrealistic in their initial efforts, and the S-L projects were overwhelming for both the instructor and the students.
2. Start with a community partner you care about. One faculty member teaching engineering economics works with local recreational facilities because he likes athletics. Another is a member of his hometown board of health, and the community problem he addressed was tackled by a sequence of S-L courses. If it's interesting to you, it's more fun!

3. Alternatively, allow students to commit to their own community partners. A playground that needs improving, a favorite science teacher to work with or a person who is elderly/disabled in need of help can be great incentives. Have students provide proof of their selection early in the project timeline and require project approval to enhance quality.
4. Focus on some subject matter that the students are struggling with, so that the S-L project will give them extra work in that area. Application can lead to deeper understanding.
5. Choose projects that can be iterated. K-12 schools are a great resource: you each have new students every year. Replicate a useful project in new locations: many municipalities and non-profits need help with energy conservation, water distribution, materials selection, etc. Repeating a project with new parameters or new community partners improves the project implementation over time.
6. Caution new community partners that students are not yet professionals and that students can learn from their feedback. Assigning groups of students with mixed abilities, having more than one group tackle the same problem, or assigning groups/individuals to separate aspects of a larger project are all strategies that can help ensure a project useful to the community partner. Negotiate project deliverables of more limited scope when not all students on a team are "A" students. However, it is important to keep in mind that students who get high grades in traditional courses may not do well in open-ended problem solving and the "messiness" of community projects, and vice-versa.
7. Grade on the subject matter comprehension, not the service directly.
8. Recall the three aspects of reflection cited above: linking the S-L project with the subject matter, developing a broader appreciation of the discipline, and an enhancing a sense of civic responsibility. For the first and most important part of the reflection, structure the project so that the community objective is met through the use of the material from the course in question (e.g., theory, tools, equations, methods). In the authors' experience, almost all engineering course S-L projects are structured in this way. The other two aspects of reflection appear more challenging for engineering instructors and students. The experience of having S-L projects scattered through the curriculum sends a message that service and citizenship are expected parts of the profession and thus address these two aspects. Asking students in a structured manner to assess and report on benefits of, and costs to, the community of their project is also helpful. For example, why was the project needed? What impact can be expected? What are the possible negative consequences? Having students self-assess what they learned from a project can trigger another aspect of reflection, enhancing the learning cycle in Kolb's model, for example. There are many facets to reflection, and hence many approaches.
9. Structure the project to finish when the students do, or structure a sequence of projects to extend from one semester to another. Offering to combine student projects, or take them to the next step, may not be sustainable for you. However, provisions for the community partner to maintain installed devices and systems are essential.

10. Give a heads up to students about the potential messiness of the S-L projects. Communities generally have ill-defined problems with open-ended solutions. Students tell us that they get frustrated with the messiness of S-L projects but ask us just to warn them about this phenomenon, not to remove messy problems from the courses. There are no right or wrong answers. By contrast, many engineering courses involve solving problems that have one and only one right answer. Reassure students that this is good preparation for their work as professionals later on.

5. Discussion

Service-learning as a curricular educational approach has existed for decades in higher education and has its ideological roots as non-military service to community. Service-learning has been embraced by the engineering field as containing the benefits of hand-on, experiential learning with the added motivation of service to communities, often different than one's own. There are other forms of engineering service outside of the curricular service-learning model which share some of the benefits of service-learning but not to the same degree. Many engineering service-learning programs focus on professional skills (e.g., teamwork and communication) as service-learning benefits and incorporate service-learning into mainly design courses and electives. However, there is great potential in integrating service-learning into core engineering science courses to enhance specific subject matter comprehension and the notion that service is an expected part of the profession. This later approach has the added advantages of not requiring additional time and tuition for students, of inclusion of required S-L projects for consideration in ABET accreditation, and of not requiring additional courses in the curriculum to meet ABET professional requirements.

In conclusion, engineering educators can maximize the rich benefits of service-learning for the common good by revisiting the literature on service-learning in higher education and systematically laying out the advantages and costs and then structuring the service-learning projects appropriately within their unique academic programs.

Acknowledgements

The SLICE program has been supported by the volunteer efforts of many students, faculty, administrators, and community partners as well as financial support of the National Science Foundation (Grants EEC-0431925 and EEC-0530632) and UMass Lowell. Thanks to all the faculty members in engineering and other colleges who have tried service-learning in their courses as part of this program. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

Accreditation Board for Engineering and Technology [ABET]. (2009). *Criteria for accreditating engineering programs-Effective for evaluations during the 2009-2010 accreditation cycle.* Retrieved March 11, 2009, from ABET web site: http://abet.org

Ahmed, Z., Hutter, J., & Plaut, J. (2008). *Reflection in higher education service-learning*. Retrieved 2010 йил 12-March from Learn and Serve America's National Service-Learning Clearinghouse: http://www.servicelearning.org/instant_info/fact_sheets/he_facts/he_reflection/

Astin, A. W., Vogelgesang, L. J., Misa, K., Anderson, J., Denson, N., Jayakumar, U., et al. (2006). *Understanding the effects of service-learning: A study of students and faculty.* Los Angeles, CA: Higher Education Research Institute at UCLA.

Astin, A., Vogelgesang, L., Ikeda, E., & Yee, J. (2000). *How service learning affects students.* UCLA. LA: Higher Education Research Institute.

ATP. (2009). *Assistive Technology program U Mass Lowell*. Retrieved 2009 йил 8-March from http://atp.caeds.eng.uml.edu/index.html

Bielefeldt, A. R., Summers, R. S., Amadei, B., Pinnell, M., Moeller, W., Sandekian, R., et al. (2005). Creating an engineering for developing communities (EDC) emphasis in environmental engineering. *ASEE Annual Conference Proceedings* (p. 15). Portland, OR: American Society of Engineering Education.

Bielefeldt, A., Paterson, K., & Swan, C. (2009). Measuring the impacts of project-based service learning. *Annual Conference Proceedings* (p. 15). Austin, TX: American Society of Engineering Education.

Bradenberger, J. W. (1998). Developmental psychology and service-learning: A theorectical framework. In R. Bringle, & D. K. Duffy (Eds.). Washington, DC: American Association of Higher Education.

Bringle, R. G., & Duffy, D. K. (1998). *With Service In Mind: Concepts and Models for Service-Learning in Psychology.* Washington, DC: American Association for Higher Education : American Psychological Association.

Bringle, R. G., Hatcher, J. A., & Games, R. (1997). Engaging and supporting faculty in service learning. *Journal of Public Service and Outreach , 2*, 43-51.

Bringle, R., & Hatcher, J. (1995). A service-learning curriculum for faculty. *Michigan Journal of Community Service Learning , 2*, 112-122.

Burack, C., Duffy, J., Melchior, A., & Morgan, E. (2008). Engineering faculty attitudes toward service-learning. *American Society of Engineering Education Annual Meeting Proceedings.* Paper AC 2008-1521.

Burke, L., & Moskal, B. (2008). Engineering students apply their skills to community service: Efforts in Uganda Africa. *ASEE Annual Conference Proceedings* (p. 17). Pittsburgh, PA: American Society of Engineering Education.

Campus Compact. (2009). *Who We Are.* Boston, MA: Campus Compact.

Carnegie Foundation. (2010). *Community Engagement Designation*. Retrieved April 11, 2010, from Carnegie Foundation: http://classifications.carnegiefoundation.org/descriptions/community_engagement.php

Coyle, E. J., Jamieson, L. H., & Sommers, L. S. (1997). EPICS: A model for integrating service-learning into the engineering curriculum. *Michigan Journal of Community Service Learning , 4* (1), 81-89.

DeAngelo, L., Hurtado, S., Pryor, J. H., Kelly, K. R., & Santos, J. L. (2009). *The American college teacher: National norms for the 2007-2008 HERI faculty survey.* Los Angeles, CA: Higher Education Research Institute at UCLA.

Dewey, J. (1903). *Studies in logical theory.* Chicago: University of Chicago Press.

Duffy, J. J. (2000). Service learning in a variety of engineering courses. In E. Tsang (Ed.), *Projects that matter: Concepts and models for service-learning in engineering.* Washington, DC: American Association of Higher Education.

Duffy, J. (2008). Village Empowerment: Service-learning with continuity. *International Journal of Service-Learning in Engineering* , Vol. 3, No. 2, pp. 1-17.

Duffy, J., Barrington, L., & Heredia, M. (2009). Recruitment, Retention, and Service-Learning in Engineering. *Proceedings of the American Society of Engineering Education Annual Meeting* . ASEE.

Duffy, J., Barry, C., Barrington, L., & Heredia, M. (2009). Service-learning in engineering science courses: Does it work? *ASEE Annual Conference Proceedings* (p. 24). Austin, TX: American Society of Engineering Education.

Duffy, J., Barry, C., Barrington, L., Kazmer, D., Moeller, W., & West, C. (2008). Service-Learing Projects in 35 Core Undergraduate Engineering Courses. *ASEE Annual Conference Proceedings* (p. 20). Pittsburgh, PA: American Society of Engineering Education.

Dutta, P., & Haubold, A. (2007). Engineering design via team-based service learning projects: Case survey of five unique project genres. *ASEE Annual Conference Proceedings* (p. 13). Honolulu, HI: American Society of Engieering Education.

Eyler, J., & Giles, D. E. (1999). *Where's the learning in service-learning?* San Francisco, CA: Jossey-Bass.

Eyler, J., Giles, D., & Schmiede, A. (1996). *A practitioner's guide to reflection in service-learning: Student voices and reflections. Vanderbilt University: TN.* Vanderbilt U. .

Furco, A. (1996). Service-learning: A balanced approach to experiential education. *Expanding Boundaries: Service and Learning* , pp. 2-6.

Hanson, J., Houghtalen, R., Houghtalen, J., Johnson, Z., Lovell, M., & Van Houghten, M. (2006). Our first experience with international senior design projects - Lessons learned. *ASEE Annual Conference Proceedings* (p. 13). Chicago, IL: American Society of Engineering Education.

Honnet, E. P., & Poulsen, S. J. (1989). *Principles of good practice for combining service and learning: A Wingspread special report.* Racine, WI: Johnson Foundation, Inc.

Huyck, M., Bryant, K., & Ferguson, D. (2009). The impact of reflections in service learning and other undergraduate team projects on learning. *Proceedings ASEE Annual Conference* (pp. AC 2009-1032). Austin, TX: American Society of Engineering Education.

Jacoby, B. (1996). *Service-learning in higher education: Concepts and practices.* San Francisco, CA: Jossey-Bass.

Kolb, D. (1984). *Experiential learning: experience as the source of learning and development.* Upper Saddle River, NJ: Prentice Hall.

Learn and Serve America. (2009). *What is Service-Learning?* Retrieved 2010 йил 7-January from Learn and Serve America: http://www.learnandserve.gov/about/service_learning/index.asp

Learn and Serve America's National Service-Learning Clearinghouse. (2009). *Brief Historical Time Line.* Washington, DC: Corporation for National and Community Service.

Lima, M., & Oakes, W. (2006). *Service-learning: Engineering in your community.* Okemos, MI: Great Lakes Press.

Mehta, Y., Jansson, P. M., & Dorland, D. (2007). Learning through the design of a fish hatchery for a community on the Cheyenne River Reservation - An EWB service-learning project. *ASEE Annual Conference Proceedings* (p. 9). Honolulu, HI: American Society of Engineering Education.

Murray, B. (1997 йил February). Service learning grows more popular. *American Psychological Monitor* , p. 44.

Oakes, W. (2009). Creating effective and efficient learning experiences while addressing the needs of the poor: An overview of service-learning in engineering education. *ASEE Annual Conference Proceedings* (p. 17). Austin, TX: American Society of Engineering Education.

Oakes, W. (2004). *Service-learning in engineering: A resource guidebook.* Boston: Campus Compact.

Pascarella, E. T., & Terenzini, P. T. (2005). *How college affects students, Vol 2.* San Francisco: Jossey-Bass.

Paterson, K., & Fuchs, V. (2008). Development for the other 80%: Evaluating program outcomes. *ASEE Annual Conference Proceedings* (p. 10). Pittsburgh, PA: American Society of Engineering Education.

Sigmon, R. L. (1979). Three principles of service-learning. *Synergist , 8* (1), 9-11.

Stanton, T. K., Giles, D. E., & Cruz, N. I. (1999). *Service-learning: A movement's pioneers reflect on its origins, practice, and future.* San Francisco, CA: Jossey-Bass.

Stanton, T., Giles, D., & Cruz, N. (1999). Service-Learning: A Movement's Pioneers Reflect on Its Origins, Practice and Future . Jossey-Bass.

Swan, C., & McCormick, M. (2009). ABET outcomes via project-based service learning attributes: Assessment via successful intelligence. *ASEE Annual Conference Proceedings* (p. 12). Austin, TX: American Society of Engineering Education.

Swan, C., Gute, D., Matson, D., & Durant, J. (2007). International community-based projects and engineering education: The advisor's viewpoint. *ASEE Annual Conference Proceedings* (p. 13). Honolulu, HI: American Society of Engineering Education.

Swan, C., Rachell, T., & Sakaguchi, K. (2000). Community-Based Service Learning Approach to Teaching Site Remediation Design. *ASEE Annual Conference Proceedings.* St. Louis, MO: American Society of Engineering Education.

Tsang, E. (. (2000). *Design that matters: Service-learning in engineering.* Washington, DC: American Association of Higher Education.

Wenger, E., McDermott, R., & Snyder, W. (2002). *Cultivating communities of practice: a guide to managing knowledge.* Cambridge, MA, USA: Harvard Business School Press.

Werner, C. (1998). Strategies for Service-Learning: internalization and empowerment. In R. Bringle, & D. Duffy (Eds.), *With service in mind: Concepts and models for service-learning in psychology.* Washington, DC: American Association of Higher Education.