Service-Learning in Engineering: What, Why, and How?

John Duffy, Edmund Tsang, and Susan Lord
Mechanical Engineering Department, University of Massachusetts Lowell/
Mechanical Engineering Department, University of South Alabama/
Engineering Department, University of San Diego

Abstract

Service-learning is an emerging pedagogy, recently adopted in many academic disciplines and institutions. Campus Compact (a national group of about 620 colleges and universities) estimates over 11,000 courses have incorporated service-learning nationwide. Service-learning involves the joining of both academic coursework and community service with key features including reciprocity, reflection, and community-expressed needs. Previous studies have shown positive effects of service-learning on a wide variety of cognitive and affective measures, many of which match the criteria of ABET (for example, those dealing with interdisciplinary teams, ethical responsibility, impact of engineering in a global and societal context, and effective communication). Examples of service-learning in engineering range from first-year design courses coupled with local schools at University of South Alabama and at University of San Diego to senior and graduate courses at University of Massachusetts Lowell coupled with a local Habitat for Humanity chapter and medical clinics in Peru. The challenge in implementation is maintaining subject matter content in courses while meeting real community needs. A survey was distributed to engineering colleges throughout the US to discover how widespread service-learning and community-based projects are in engineering.

Introduction

In our collective experience, the mention of the term “service-learning” to engineering educators generally evokes one of three typical responses. The most common response is: "What is service-learning anyway?" The next most typical is exemplified by the remark: "We do that already." The third is typified by: "We have no room in our curriculum to add anything more given all that ABET requires." The aim of this paper is to address these responses.

In this paper, we will explain what the essential elements of service-learning are and review briefly the literature on positive cognitive and affective benefits. Even though many of us in engineering education may have course projects that provide community service and may therefore think we are already engaged in service-learning, we may not be including all the aspects of service-learning found to gain maximum benefit for our students, ourselves, and the community. And in response to the objection that there is no room and time for one more topic to be added to the curriculum, we make a case that incorporation of service-learning may in fact reduce the overall load of students and faculty in achieving ABET goals. Finally, we present a few examples of how to incorporate service-learning into a variety of engineering courses.

What is service-learning?

Service-learning has been defined as “a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development. Reciprocity and reflection are key concepts of service-learning.” [1] Service-learning has a two-fold focus: learning for the student and service to the community.

In engineering terms, service-learning is akin to a design problem: integrate the subject matter of a credit-bearing course with service useful to the community. Service-learning is neither volunteerism nor internship.

There are several principles of good practice in combining service and learning according to the National Society for Experiential Education[2]. These include: an effective and sustained program that engages people in responsible and challenging actions for the common good; allows for those with needs to define those needs; provides structured opportunities for people to reflect critically on the service experience; and includes training, supervision, monitoring, support, recognition, and evaluation.

Why service-learning?

The approach of service-learning is consistent with the theories and empirical research of a number of leading educators and developmental psychologists, including Dewey, Piaget, Kolb, Kohlberg, Perry, Belenky et al., Baxter Magolda, and Coles ([3] and references in [1]). The approach is also consistent with the recent change in paradigm in education from a focus on teaching to a focus on learning [4, 5]. Astin et al.[6], in extensive surveys of thousands of college students over a number of years, found service to be beneficial in retention, in community service after graduation, in racial interaction, in civic responsibility, and in development of a meaningful philosophy of life.

Recently Eyler and Giles[7] included 1500 students from 20 colleges and universities in a study of the effect of service-learning. Service-learning was found to impact positively: tolerance, personal development, interpersonal development, community and college connections. Students reported working harder, being more curious, connecting learning to personal experience, and *demonstrated deeper understanding of subject matter*. The quality of placements in the community and the degree of structured reflection were found to be important in enhancing these positive effects, significantly so for critical thinking increases. They summed up effective service-learning principles in five C's: connection (students, peers, community, faculty; experience and analysis); continuity (all four years; reflection before, during, after service); context (messiness of community setting is integral to learning); challenge (to current perspectives; not overwhelming); and coaching (opportunity for interaction; emotional, intellectual support). Based on these studies then, positive cognitive and attitude development is expected of students involved in service-learning.

Why service-learning in engineering?

In its Criteria 2000, the Accreditation Board for Engineering and Technology (ABET) outlines a new set of criteria for engineering programs[8]. In addition to the more traditional technical issues, the new criteria include the demonstration that graduates have:

- an ability to function on multi-disciplinary teams,
- an understanding of professional and ethical responsibility,
- an ability to communicate effectively,
- a broad education necessary to understand the impact of engineering solutions in a global and societal context,
- a recognition of the need for, and an ability to engage in life-long learning, and
- a knowledge of contemporary issues.

It appears that service-learning team projects have the potential to ensure students learn and demonstrate these qualities in addition to the ability to apply engineering to the design and analysis of systems and experiments.

How to fit more material into an already packed curriculum is, of course, a continuing challenge to engineering educators and students. Service- learning offers a way to integrate activities designed to strengthen abilities in technical subject matter with otherwise separate activities focused on the above "soft science" aspects of student development. There is thus a potential to meet ABET criteria in a more efficient manner with the use of service-learning, thus reducing rather than adding topics to a curriculum.

Service-learning has been integrated into some engineering courses, some as described in Tsang (2000), particularly capstone design courses or directed studies courses. For example, Purdue University initiated the EPICS program in Electrical Engineering (http://epics.ecn.purdue.edu/root.asp), now spread to Notre Dame and Iowa State; University of Utah has many courses involving service-learning, some in engineering; Colorado State, and other universities have service-learning programs in engineering (see Campus Compact web site: http://www.compact.org). However, service-learning engineering courses appear to be few in number compared to the 11,800 service-learning courses reported by the then 575 member campuses of Campus Compact (1998 survey reported in [7]). Consequently, we undertook our own survey to assess how extensive the use of community projects and service-learning is in engineering.

Our Own Survey

We sent a survey to all known deans of engineering in the US (about 350 in number), asking them to forward the survey to those faculty who used community service or service-learning projects in courses. A paper version, e-mail, and world-wide-web-based version were available. The survey was brief and asked for each relevant course: name of instructor and contact information, title and number of the course, level of course (first year, sophomore, etc.), number of students, and a brief description.

We received fifty-two responses. There were sixty-one engineering courses reported at a variety of levels (first year through graduate) encompassing a variety of topics including "mainstream" discipline- specific courses, design courses, and two engineering community service courses. Summaries of the discipline, level of students, frequency of offering, and number of students participating are shown in Table 1. Note that senior and first-year level courses were the most frequently reported. The first-year courses were introduction to engineering design courses while the senior courses were about half capstone design courses and half traditional engineering courses such as "Vibration Analysis" or "Urban Transportation Planning". We suspect that there may still be many unreported capstone design projects geared toward community service. Whether they have all the recommended aspects of service-learning such as community-defined needs, reciprocity, and reflection is unknown.

Our survey results show that service-learning is being used in a variety of engineering disciplines, with engineering students at all levels, in large and small classes, and usually incorporated more than one semester in a given course. However, twelve of the respondents indicated that they had only used service-learning once. This may be seen as evidence of the growing importance of service-learning in engineering education. It will be interesting to track the progress of these courses to see if they continue integrating service-learning. Given that we have reports of about sixty engineering courses compared to over 11,000 courses in other disciplines, we can infer that the use of service-learning in engineering courses is small.

Table 1 Summary of 1999 Survey Data on Service-Learning Courses in Engineering

	# of students participating	**# of times offered**
Average	33	5
Minimum	4	1
Maximum	226	30

Level of students	**%**	**Discipline**	**%**
First year	16	Other	33
Sophomore	6	Mechanical Engineering	25
Junior	10	Civil Engineering*	17
Senior	38	Electrical Engineering*	15
Graduate	12	Biological Engineering	2
Junior/Senior	2	Computer Science	2
All years undergraduate	12	College of Engineering	2
No response	4	Diversity in Education Initiatives	2

*Note that Civil Engineering also includes Environmental Engineering and Electrical Engineering also includes Electrical and Computer Engineering.

Examples of service-learning

We provide below a few examples (not necessarily models) of service-learning in engineering which we hope may result in the more widespread use of a pedagogy which has been shown to effect deeper understanding of course subject matter in addition to increase motivation, retention, and citizenship. The courses described range from first-year introduction to engineering to graduate level specialized courses.

Introduction to Engineering Courses

At the University of South Alabama, in ME 125, "Introduction to Mechanical Engineering," the service-learning projects consist of teams of 3-to-5 first-year mechanical engineering students paired with teams of math and science teachers to design, build, and deliver "hardware" and "software" that meet the needs and specifications of the teacher clients. At the fourth week of the academic quarter, the engineering undergraduates received a memorandum from the instructor with a general statement of the design project and the names of the teacher clients. The engineering students then interviewed the teachers to identify the needs of the clients and project specifications, and they visited the school to gain an overall impression of how their design will be used. The engineering students then generated solution ideas, analyzed and evaluated the ideas to select the optimal one(s) for implementation.

Finally the engineering students delivered their design to the teacher clients and demonstrated its use. To complete the design assignment, students submitted written reports and made oral presentations. First-year engineering students learn the engineering design process via a case study during the first three weeks of the academic quarter. The instructor then guides them as they complete their service-learning design projects.

The course objectives and the methods of assessment are: (1) Students demonstrate engineering design - this objective was assessed by the design project written report evaluated by the instructor and by oral presentation evaluated by another ME faculty other than the instructor; (2) Students demonstrate teamwork - the process of teamwork was assessed by minutes of meetings and student attitude toward teamwork was assessed by a retrospective survey; and (3) Students demonstrate awareness of community service - student attitude on community service was assessed by a retrospective survey.

Between 1995-1998, 96 students enrolled in ME 125 and 25 sets of course wares were designed and delivered to math and science teachers through the service-learning projects. Results of student assessment indicate a majority of the students achieved the course learning objectives.

Based on the experience gained in the ME 125 project, the service-learning pedagogy was applied in Fall, 1997, in EG 101, "Introduction to Engineering," targeting two student populations for the purpose of student retention and recruitment. For retention, EG 101 targets those first-year students whose ACT Math score disqualifies them from beginning the Calculus sequence (ACT Math score less than 27); normally these students spend their first year to year-and-a-half taking remedial math courses and have little or no contact with engineering faculty in the classroom. For recruitment, EG 101 targets high-school seniors who are qualified to enter

USA under the early-admission policy (at least 25 composite in Enhanced ACT and "B" average in academic subjects). Preliminary results based on student assessment from 1997-1999 indicate that USA first-year engineering students who have enrolled in EG 101 are retained at a higher rate than those first-year engineering students who did not take EG 101: 54% of students who did not take EG 101 are still enrolled in USA in Fall 1999 compared to 65% of students who took EG 101; Of those who are enrolled in USA in Fall, 1999, 57% of those who did not take EG 101 are enrolled in engineering compared to 75% of those who took EG 101. For recruitment, of the 11 early-admission high-school seniors who did not take EG 101, only one is enrolled in engineering in fall 1999. Of the 31 high-school seniors who took EG 101 between 1997-1999, 9 are enrolled in engineering in fall 1999. The mean ACT scores of high-school seniors who took EG 101 and are in engineering at USA is higher than the average for regular entering first-year engineering students (28 versus 23), which indicates that EG 101 is helping USA to attract higher quality students. Assessment results also show that a majority of students in EG 101 achieved the course objectives of demonstrating engineering design and teamwork, and increased awareness of community service.

In the fall of 1998, community service-learning was incorporated into “Introduction to Engineering” at the University of San Diego (USD) to meet community and academic needs. In this project, first-year engineering students worked with 6th grade students in a science class at a local middle school with an economically disadvantaged and ethnically diverse student body. Middle schools need to keep students interested in science and motivated to go to college, become technically literate, and possibly pursue technical careers. First-year engineering students need to learn about what engineering is, why it is useful to society, and other nontechnical skills such as communication and teamwork. Students worked in teams to prepare a hands-on, fun, and educational activity. The academic learning goals for the project were to effectively communicate to a "real live" nontechnical audience, to creatively design and implement an activity, to complete a project as a team, and to deepen students' understanding of engineering related topics. Students produced the following deliverables: materials for 6th grade students, team teaching in class at USD before going to the middle school, team teaching at the middle school, and a reflection memo. Although some students were initially resistant to the idea of service-learning in engineering, after working with the middle school students, most college students were excited that they had done something worthwhile. The engineering students reported that the service-learning project helped them learn about communicating to a real audience and working as a team. The 6th graders were enthusiastic and appreciative of the college students' efforts. More details are available in Lord[9].

Upper Division Examples

At the University of Massachusetts Lowell in a junior and senior level mechanical engineering laboratory and statistical methods two-part course (22.302/403), service-learning was introduced into both parts in 1998-99. In Part I, some of the learning objectives include sensor familiarity and use, field sampling and analysis, quantitative uncertainty (error) analysis, written communication. At the same time, several neighborhood groups in Lowell were concerned with the water quality and appearance of a local river (one that flows into the Merrimack River of Thoreau fame). The instructor became aware of the concern through AmeriCorps volunteers working at the university. The thirty students were sent out in four groups at different times to measured the flow, temperature, pH, and dissolved oxygen at different points in the river's cross-section. They reported the results to the community in posters displayed during an Earth Day fair. They reported the quantitative uncertainty analysis results to the instructor in reports.

In Part II, the learning objectives included design of an experiment, data collection, and statistical hypothesis testing with the results. The local Habitat for Humanity(HfH) chapter rebuilds homes and depends on volunteer labor and materials. Initial contact was through the Office of Community Service at the university. Five experiments were developed to help HfH in testing and building houses. These included blower door tests for weatherization improvement, coheat tests to determine the overall heat loss coefficient of a house, daylighting measurements, tracer gas tests for infiltration estimation, and comparison of the compressive and bending strength of 100-year-old existing wood studs to new wood. Several of these had to comply with ASTM or ASHRAE standards. The last set of experiments were carried out in front of the city building inspector, with the results convincing all that the old wood was safe. Student reports were presented to the Habitat for Humanity volunteers with some making their way to the building inspector.

Lowell is home to a considerable Asian immigrant population. The university is assisting in the development of a Tilapia fish aquaculture system. In a senior course in dynamic systems (UML 22.451), learning objectives include: develop an appropriate mathematical model of the dynamic response of a "real" system to various inputs, design a simple automatic control system to meet desired output characteristics of an actual system, and evaluate the potential positive and negative impacts of technology on the local community. In the fall of 1999, the thirty seniors visited the prototype fish tank system of the Cambodian Mutual Assistance Association (CMMA). They formed teams to model and predict the temperature response of the tank to various forms of inputs, to design a simple control system to keep the water temperature at 90 °F, to predict how long oxygen would be sufficient for fish survival if power were lost, and to evaluate three potential environmental, sociological, or economic impacts of their analyses and designs. Students are writing reports on these miniprojects done in phases, which will be presented to the CMAA.

Capstone design courses (both senior and graduate level) are a "natural" for incorporating service-learning. Projects at UML have included designing, building, and actually installing solar systems for providing vaccine refrigeration, lights, transceiver radio communication, and water purification in remote Peruvian villages with no electricity. Other projects have dealt with designing the thermal and structural aspects of new houses with the local Habitat for Humanity chapter and a local volunteer architect. Still others involved the designing, building, and testing of solar coffee dryers in Central America. The effort and commitment of students in these projects have been exceptional.

In three other graduate courses (manufacturing systems, solar fundamentals, solar systems engineering), miniprojects have been assigned involving practical applications of the theory and techniques covered in the courses in conjunction with Habitat for Humanity, Peruvian communities, CMAA fish aquaculture group, and a coffee-growing coop in Costa Rica.

Assessment of these upper division courses has been through reports, presentations, and student questionnaires. The percentages of the courses involving service-learning ranged from 10% to 100%. In general, the community groups report that they value the student contributions and are interested themselves in learning more about technologies involving, for example, energy efficiency and solar energy. The students are discovering that concepts learned in their courses can be applied in concrete ways to improve the lives of people in their community, both local and global. Students polled indicate they spend more time on the service-related projects, and a majority favor combining service-learning with traditional course work (17% disfavor the idea). They are learning from the community how to make engineering designs, measurements, and analyses more practical, affordable, and consistent with the needs of their "customers". Improvements in the larger courses would be to involve more reflection on the impact of the service on the community and more direct interaction of the students with the community.

Discussion and Conclusions

More details on the above courses and projects are included in several chapters in the AAHE monograph on service-learning in engineering[10].

Based on our collective experience and the experience of others obtained through personal contact and the literature, we give the following informal advice to would-be practitioners of service-learning:

- Try it. You'll like it. Those who do seem to become deeply committed to it. If you as an educator become more enthusiastic, your students will indirectly benefit.
- The joining of existing course learning objectives with community needs is challenging and in itself can be considered a design challenge for the instructor and students, which can involve refreshing creativity.
- As help for busy faculty, contact the community service or public relations office in your institution for assistance in contacting community groups in need.
- Service-learning can be integrated into any course you teach. Contact the Campus Compact website for ideas and examples: http://www.compact.org and also the other seventeen AAHE monographs on service-learning in the disciplines.
- The ABET 2000 accreditation guidelines call for traditionally non-technical objectives but they also allow for greater flexibility in attaining those objectives. Service-learning appears to be a viable means of integrating those non-technical areas into engineering courses to meet those objectives. As an instructor, try to get proper credit for yourself and your students if you collectively achieve those objectives.

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JOHN J. DUFFY
John J. Duffy is a Professor in the Mechanical Engineering Department at the University of Massachusetts Lowell and is the coordinator of the interdisciplinary graduate program in solar engineering. His current endeavors encompass international rural development, course assessment methods, solar design optimization, stochastic systems, fuel cells, and electrolyzers.

EDMUND TSANG
Edmund Tsang is Associate Professor of mechanical engineering at the University of South Alabama. His current professional interests are enhancement of lower-division curriculum and K-12 outreach. He is the editor of a monograph titled *DESIGN THAT MATTERS: Service-Learning in Engineering* to be published by the American Association for Higher Education in Spring 2000.

SUSAN M. LORD
Susan M. Lord received a B. S. in Electrical Engineering & Materials Science from Cornell University and the M.S. and Ph.D. in Electrical Engineering from Stanford University. Dr. Lord taught at Bucknell University from 1993-1997 and is presently an Associate Professor of Electrical Engineering at the University of San Diego. Her teaching and research interests focus on optoelectronic materials and devices as well as first year engineering courses.