AC 2008-1525: SERVICE-LEARNING PROJECTS IN 35 CORE UNDERGRADUATE ENGINEERING COURSES

John Duffy, University of Massachusetts Lowell
Professor, Mechanical Engineering

Carol Barry, University Massachusetts Lowell
Associate Professor, Plastics Engineering

Linda Barrington, University of Massachusetts-Lowell
Service-Learning Coordinator, College of Engineering

David Kazmer, University of Massachusetts-Lowell
Professor, Plastics Engineering

William Moeller, University of Massachusetts Lowell
Professor Emeritus, Civil Engineering

Cheryl West, University of Massachusetts Lowell
Doctoral Student, Work Environment Department

Service-Learning Projects in 35 Core Undergraduate Engineering Courses

Abstract

The College of Engineering at the University of Massachusetts Lowell (UML) has integrated service-learning (S-L) into many of its core required undergraduate courses over the last three years. Projects that meet real community needs and that help students achieve academic objectives in the courses are difficult to create. Projects for 35 different undergraduate required courses are summarized to help faculty, staff, and students develop S-L projects for their own courses. Faculty at UML were encouraged to "start small rather than not at all." Courses and projects include, for example: first-year introduction to engineering with 340 students in which student teams have designed and built moving displays illustrating various technologies for 60,000 middle school students that every year visit a history center which is part of a national park; sophomore kinematics in which student teams visit local playgrounds to assess safety using the equations for deceleration, forces, and impact from the course in a structured way; junior heat transfer courses in which analyses of heat loss and suggestions for heating system savings for a local food pantry, a city hall building, and community mental health center as well as the university itself were developed and presented to the stakeholders; sophomore materials in which student teams 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 are having 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. These S-L projects are integrated into a wide variety of core courses (and not just design courses) and represent typically from 10 to 20% of the grade.

Introduction

We define service-learning as a hands-on learning approach in which students achieve academic objectives in a credit-bearing course by meeting real community needs. In engineering the students become better professionals and better citizens while the community benefits. There are many other definitions in the literature, for example, service-learning is the integration of academic subject matter with service to the community in credit-bearing courses, with key elements including reciprocity, reflection, coaching, and community voice in projects (Jacoby, 1996)[1]. Service-learning (S-L) 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, recruitment of under-represented groups in engineering, retention of students, and citizenship (as shown below), as well as helping meet the well-known ABET EC2000 criteria (a)-(k) (ABET, 2007)[2].

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. Instead of adding more courses to satisfy ABET requirements, these criteria are met by S-L projects in existing core courses. For example, having community partners on S-L projects essentially guarantees that students will work on multidisciplinary teams. With the correct structure of S-L projects, the students will examine the impacts of engineering solutions in a societal context. Also, if S-L projects replace traditional analytical exercises in courses, the overall workload will typically not increase for the students. If students are motivated to spend more time on S-L projects, they are free to do so and should learn more in the process.

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 Brandenberger[3] and Jacoby[1]. The approach is also consistent with the recent change in paradigm in education from a focus on teaching to a focus on learning[1,3]. Astin *et al.*[4] found with longitudinal data of 22,000 students that service participation 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. "These findings directly replicate a number of recent studies using different samples and methodologies."(p.ii) [5] They found that S-L to be significantly better in 8 out of 11 measures than just service without the course integration and discovered "strong support for the notion that service learning should be included in the student's major field."(p.iii)[6].

Eyler and Giles[7] included 1500 students from 20 colleges/universities in a classic study of the effect of S-L. Service-learning was found 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 subject matter. The quality of placements in the community and the degree of structured reflection were found to be important in enhancing the positive effects, significantly so for critical thinking increases. They found that the "students who participated in service-learning differed significantly from those who did not participate on almost every outcome we measured."(p.182)[8] They summed up effective S-L principles in: 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).

There are varied opinions in the literature regarding whether S-L projects should be required or not. Eyler and Giles[8] state: "Service-learning is often better academic learning and thus a legitimate requirement of an academic program…Students who are most in need of the developmental opportunities afforded by service-learning may be less likely to choose such course options voluntarily" (p. 182). In contrast, Clary, Snyder, and Stukas[9] and Werner[10] argue for voluntary S-L, based on research showing a required activity reduces intrinsic motivation. In addition, S-L appears to have the potential to attract and retain underrepresented populations in engineering through meaningful and experiential applications. Recent experience at Purdue indicates that voluntary S-L courses attract twice the percentage of women engineering students compared to the student engineering population[11]. Our own experience with voluntary capstone courses also indicates a similar overrepresentation of women (in one course 4 to 1 over 6 years) and older and more diverse students (Duffy, 2008; Barrington et al., 2007)[12, 13].

In questionnaires prepared by Duffy[14], only approximately 20% of 260 student responses in his courses with S-L from 1997 to 2004 disagreed with the statement that service and academic coursework should be combined. Responses were correlated with age and gender, with older students and women more positive about the integration of service with learning. Eyler and Giles[7] had a similar percentage with their 1500 students in many disciplines.

Service-learning itself is certainly not new, and S-L in engineering is not new. Oakes (2004)[15] has a list of 33 universities that have S-L in engineering and describes a number of examples of S-L. In 2004-05 the National Science Foundation (NSF) funded ten programs to introduce S-L into engineering, which would add about 8 more universities to the previous list of 33. Perhaps best known is EPICS (Engineering Projects in Community Service), which started at Purdue and now includes 17 universities. The program involves elective interdisciplinary S-L courses that students can take from first year to senior year[16]. Tsang (2000)[17] and Lima and Oakes (2006)[18] describe more examples of S-L in engineering courses. Most of these S-L courses are capstone or elective courses with some first-year introduction to engineering courses.

By contrast, the college of engineering at UML has integrated service-learning into many of its core required undergraduate courses over the last three years. The thesis is that 1) service-learning spread throughout the core curriculum is more effective than one intensive course, 2) a mixture of required and elective service-learning is more effective than either one or the other, and 3) service-learning could result in less coursework time than traditional programs satisfying ABET 2000 criteria. In fact, most engineering work involves initial contact with clients (here community partners) to ascertain needs and then design and analysis and manufacturing of a device (or system or study) and then delivery of the device (or system or study) to the client. In other academic areas, placements in the community agencies are common; however, in engineering placements as such are not typical and generally not appropriate. The program at UML is called SLICE (Service-Learning Integrated throughout a College of Engineering).

Since the S-L projects are designed to not add more class or homework time for students (by replacing existing “paper” projects), projects that meet real community needs and that help students achieve academic objectives in the courses are difficult to create. Service-learning projects include direct and indirect involvement of the students with the community. Direct involvement is, of course, the ideal for the students and the community to obtain maximum benefit of learning from each other. While the goal remains to maximize the direct projects, these projects are not always practical for all the students in all the courses. For example, not all the students can travel internationally. Sharing of experiences with other students does maximize the benefit of those students who do work directly with the community (e.g., go to Peru). Therefore, opportunities were provided for students to share with each other results and experiences, thus creating a means of reflection and of extending the benefit of the S-L project.

So far, UML has identified service-learning projects for 35 core courses in five engineering disciplines. This paper presents the types of projects that faculty successfully incorporated into their undergraduate courses.

Identifying Service-Learning Projects

A full-time permanent College Coordinator of Service-Learning helps faculty identify service-learning opportunities and is the main link between existing and potential community partners and faculty. The current coordinator has a background in nursing and mechanical engineering. S-L coordinators in each of the College's five departments also assist faculty identify courses within their respective departments that would be candidates for S-L projects; assist faculty in discovering projects and partners; and help with incorporation of the project into courses. The coordinators have already incorporated service learning into some of their courses and are given course release time of one course per semester (or its equivalent) from the University.

Potential community partners enter the University from a wide range of contacts, but are typically steered to the Service-Learning Coordinator. In preliminary discussions, the Coordinator and community partner discuss the organization's goals and identify potential service-learning projects. These projects must have the potential to meet the community partner's needs; fulfill the technical objectives of targeted courses; and have a scope suitable for a one or two-semester course or courses. The Coordinator filters these projects and refers service only projects to another office within the University.

The S-L coordinators role has typically been to 1) identify courses ammenable to service-learning projects and 2) persuade the faculty teaching those courses to incorporate service-learning projects. This role has required an understanding of the course offered by the respective departments and obtaining specific objectives for those courses. Although $1000 mini-grants (four per department per semester) and course release time (for one member of each of the College's five departments per semester) have been offered to faculty for extra compensation, supplies, or student assistance required for the development of S-L modules, these incentives have been less effective than simply having the S-L coordinators encourage the faculty to "start small rather than not at all." Graduate research assistants (one per department) have helped faculty develop course materials; assisted faculty in implementing service learning projects; and administered and analyze assessment measures.

Part of the challenge in this project, however, was to sell more faculty on the effectiveness of S-L not only to meet individual course objectives but also to help faculty and the institution fulfill their overall missions of teaching/ learning, discovery, and engagement. This objective along with the lack of information barrier was addressed through faculty scholarly workgroups. The student testimonials on how S-L affected them were very popular and effective in convincing faculty about the value of S-L. In addition, a S-L website was developed to provide information to facilitate partnerships among faculty, students, and community organizations. For example, the website lists community needs, courses available for projects, examples of previous projects, background and further reading for S-L, and contact information. Approaches suggested in "The Engaged Department Toolkit," by Campus Compact were also utilized. The advice and examples of other engineering faculty as reported in, for example, Tsang (2000) and the Campus Compact web site also proved useful.

Table 1 shows the distribution of courses containing service-learning projects over the four-year undergraduate curricula of five engineering departments (chemical engineering, civil engineering, electrical engineering, mechanical and plastics engineering). in which the S-L projects are required (☻) and which are elective (☺).

Table 1. Distribution of courses with S-L by semester in each program 2005-07.

Year	**ChE**	**CE**	**EE**	**ME**	**PE**
FR 1	☻	☻	☻	☻	☻
FR 2	☻	☻	☻	☺	☻
SO 1		☺		☻ ☺	☻
SO 2			☻	☺ ☺ ☻	☻ ☻
JR 1		☺	☻ ☻	☻ ☻ ☺	
JR 2	☻ ☻	☻ ☻	☻	☻ ☻	☻
SR 1		☻	☻	☺ ☺ ☺	
SR 2			☻	☺ ☺	☺
Tech.Electives	☻	☻ ☻ ☻	☻	☻ ☻ ☻ ☻	

Introduction to Engineering I and II

At UML, Introduction to Engineering I is one class of 300-400 students for all five engineering disciplines. As shown in Table 2, service-learning projects have been required in this course for the past four years. Typically, the projects are worth 20-25% of the grade in the course. Introduction to Engineering II, however, is a discipline-specific course. Therefore, implementation of service-learning projects varied by department.

Table 2. Service Learning in Introduction to Engineering I and II

	F 04	S 05	F 05	S 06	F 06	S 07	F 07	S 08
Chemical Engineering	●	●	●	●	●		●	■
Civil Engineering	●	●	●	●	●	●	●	■
Electrical Engineering	●	●	●	●	●		●	■
Mechanical Engineering	●	○	●	○	●	○	●	□
Plastics Engineering	●	●	●	●	●	●	●	■

● mandatory; ○ optional; ■ □ planned

Introduction to Engineering I. Groups of freshmen have partnered with the Tsongas Industrial History Center (2004-06) and Zoo New England (2007) for required service-learning projects. A joint venture between the Lowell National Historical Park and the University of Massachusetts Lowell's Graduate School of Education, the Tsongas Industrial History Center permits primary and secondary students to learn about the American Industrial Revolution by experiencing history where it happened through hands-on activities. The learning objectives met by these projects were for the students to 1) understand the role of analysis in engineering, 2) be able to structure an engineering analysis, 3) understand the product development process, 4) be able to objectively evaluate the performance of a design, 5) be able to perform a design/ build/ test project, and 6) be able to work constructively within a team.

- In fall 2004, 80 teams of freshmen engineers designed and built Rube Goldberg devices illustrating principles of engineering for the Tsongas Industrial History Center. Eight of the educational displays were chosen to be on display in the Center, which is visited by over 60,000 school children each year.
- For the fall 2005 project, the Tsongas Industrial History Center asked teams of students to design and build models to illustrate principles of engineering mechanisms that have been employed historically in Lowell industries (e.g. waterwheels running textile mill machinery). The Tsongas displays, which were aimed at middle school students, had to include appropriate mathematical formulas and definition of critical parameters for the working model. Several of the educational displays were selected to be on display in the Center.
- The following year, approximately 354 freshmen students created working educational exhibits illustrating "energy around us" principles of engineering. The Tsongas Industrial History Center displayed the exhibits to educate K-12 students about energy.
- With a new community partner (Zoo New England) the freshmen designed and built "toys" for big cats (lions, tigers, etc.) in fall 2008. After individual students prepared preliminary designs, the classes reviewed the designs and selected the "best" for group projects. The selected designs were upgraded and presented to personnel from Zoo New England for approval. Toys were then built for approved designs and all projects meeting specifications were presented to the Zoo at the end of the semester.

With these large classes, all four projects required extensive cooperation between faculty and the community partners. Several planning sessions permitted clear definition of the objectives and constraints of the projects. The community partners presented their organization and the project to the freshmen at the starts of the project and then returned to evaluate preliminary results, assist with grading the projects, and judge projects for permanent exhibits (Tsongas Center) and testing with the big cats (Zoo New England). The Tsongas Center staff also hosted a reception for all the first-year students at the Center. Although the freshmen liked all three projects, the selection of limited number projects for exhibition at the Tsongas Center disappointed many of the students (Kazmer et al., 2007)[19]. All of the toys projects meeting specifications, however, went to the Zoo, making this project more rewarding.

In 2005, some of the freshmen also partners with GEAR-UP (Gaining Early Awareness and Readiness for Undergraduate Programs), program that aims at increasing the number of low-income students who attend college, by interventions that raise expectations and provide support for students to succeed; this program targets 7th graders at the Robinson, Sullivan, Rogers, Butler and Stoklosa schools in Lowell, MA. Freshmen students volunteered to present and test the design and construction of toothpick bridges, which they had studied earlier in the semester. These students presented the bridge building project and then broke into teams of one engineering student per one 7th grader and one parent. Together each team designed a bridge out of toothpicks. All of the bridges were then tested to see which were the strongest and how they failed. Time for discussion was included at the end of interaction and focused upon analysis of why the 7th graders thought the failures had occurred, and what were considered the optimal design features. Everyone had such a great time that the engineering students came back again and repeated the project with another group of 7th graders and their parents!

Introduction to Engineering II. The focus of this course varies across the College of Engineering. In general, however, the course is used to acquaint the freshmen with their discipline and the department's faculty; teach communication skills; and start the teaching of software packages such as MATLAB and CAD packages. All of these courses include small design projects. The service-learning projects were typically worth 15-20% of the course grade and, when optional, replaced another project in the course.

- **Chemical Engineering.** Implementation of service-learning projects in Introduction to Engineering II has varied with the instructor and content of the course. Chemical Engineering students have partnered with the Village Empowerment Peru Project[12] (a long-standing collaboration between the University and a group of Andean Villages in Peru) to create vinegar-based disinfectants for remote clinics in Peru and with the University's Office of Environmental Health and Safety (EHS) to raise awareness of improvements to the campus recycling programs. In preparation for the latter project, the faculty member met with the EHS supervisor who also served as a resource for students during the S-L components and linked them with other contact people. The students researched the chemical structure of materials and their relevance to recycling; explored behind the scenes campus functions and personnel; and created posters to explain the work of the EHS and raised awareness of ways to reuse and recycle different materials on campus.
- **Civil Engineering.** Civil Engineering students have partnered with various organizations, including City of Lowell (2005), Lowell Community Health Center (2006) and University of Massachusetts Lowell Facilities (2007-08) to redesign parking lots. In preparation for these projects, the faculty member has met with community partner to discuss the objectives and issues associated with the redesign as well as the timeline. To start the project, the students visited the site, learned about the facility and constraints of the project from the community partner, and measured the parking lot. For the Lowell Community Health Center, a new addition would eliminate a portion of existing 48 parking spaces, but through traffic and handicapped parking locations has to be maintained in the new design. The students used their new skills to create 2D line and dimensioned engineering drawings of the parking lot design using AutoCAD and presented their results in a written report and oral presentation to the community partner.
- **Electrical Engineering.** Service-learning projects in Electrical Engineering are based on the Department's long-established assistive technology program[20]. In spring 2006, 94 electrical engineering freshman constructed approximately 100 client-enabling electronic devices (big button switches) for distribution among disabled clients associated with a range partner organizations including Kennedy Day School; Hogan Center, Mass Department of Mental Retardation; VA Hospital; Nashua Center; Shore Educational Collaborative; Coastal Education Collaborative; Life Links; Helping Hands; New England Education Consortium; Seven Hills; Boston Home; and the Wang Middle School Special Education Program. The students learned about the impact of such designs on the quality of life for individuals with special needs; learned about electrical theory, technology, and application; and designed and fabricated devices. The partner organizations provided engaging on-campus presentations for freshman courses, describing client context and needs; helpful communication and feedback between student and clients, such as a *Service-Learning Project Checklist*; and reports of such projects and their related client/ organization impacts. These devices, which

were designed to meet specific and often unmet client needs, were delivered to the partner organizations free of charge.

- **Mechanical Engineering.** Service-learning projects in mechanical engineering were built on previous partnerships with several science teachers at the Greater Lowell Technical High School (GLTHS). Renewable energy modules were piloted in 2005. In 2006, 13 freshmen, with the assistance of GLTHS science teachers, planned and taught renewable energy modules in 45-minute class periods; the GLTHS students later designed and tested solar ovens. For 2007, after the mechanical engineering students designed and built renewable energy projects, they developed presentations to demonstrate benefits of solar energy and explain their projects. Then three teams of freshmen delivered these presentations to the GLTHS students, introducing the high school students to the engineering discipline, helping them perform experiments with solar greenhouses and PV modules, and use of engineering analysis and calculations to predict outcomes (Bhattacharjee et al., 2008)[21].
- **Plastics Engineering.** Freshmen in Plastics Engineering have partnered with the NSF Nanoscale Science and Engineering Center - Center for High-Rate Nanomanufacturing (CHN) to develop and test nanotechnology modules used in the CHN's K12 outreach programs. To prepare for these projects, the freshmen were introduced to nanotechnology and requirements of K12 outreach modules. In 2006, the freshmen tested newly-designed middle school modules to be certain they worked as intended; and provided oral and written feedback about these modules directly to the graduate students who deliver the modules. As a result of their testing, CHN proceeded with one activity and used the students' feedback to modify another exercise. In 2007, the student groups design, built, and presented five new modules, two of which were incorporated into middle school outreach programs in spring 2007.

Thermodynamics, Fluids, and Heat Transfer Courses

Service-learning projects have been incorporated into thermodynamics, fluids, and heat transfer courses in several engineering disciplines. Implementation in heat transfer courses extended across chemical, mechanical, and plastics engineering (Table 3). Service-learning projects in all of these courses were required and accounted for 15-20% of the course grade. In addition, a group of seniors designed an air-to-air heat exchanger as part of a Thermo Applications course in mechanical engineering; this project was larger and counted for more of the course grade.

Table 3. Service Learning in Thermodynamics, Fluids, Heat Transfer Courses

	2005-06	2006-07	2007-08
Chemical Engineering	●	●	●
Civil Engineering			
Electrical Engineering	--	--	--
Mechanical Engineering	●●	●●●●	●●●●
Plastics Engineering	●	●	●

A typical project is illustrated by Chemical Engineering's partnership with the Merrimack Valley Food Bank (MVFB) in 2006. In this group project, junior chemical engineering students analyzed existing heat loss problems and proposed solutions to reduce energy consumption for the MVFB, which resides in a very old building within walking distance from campus. During the winter, the building is subject to significant heat losses, while in the summertime the heat increases more than normal. Prior to starting the project, the SLICE Coordinator and faculty member visited the facility to explore heat transfer issues. MVFB personnel provided the students with utility bills and energy consumption records for a full year; conducted three facility tours to allow the student to obtain measurements needed for calculations; and were available to respond to questions via phone and e-mail during the semester. The students 1) performed a heat transfer analysis on the second floor of the warehouse where the heat problems exist, 2) proposed alterations that focused on the reduction of energy consumption, 3) performed a heat transfer analysis with the alterations to determine whether the heat transfer improved, and 4) estimated the cost of the alterations and determine the payback period of the energy consumption reduction proposed. Students presented their findings in a formal report and presentation to the MVFB directors.

With lots of old buildings and rising energy prices, the analysis of energy losses in old buildings has been a good source of very useful service-learning projects. Chemical engineering students have also evaluated winter heat loss and alterations for the Mental Health Association of Greater Lowell, while plastics engineering students evaluated plastics insulation materials and designs for this project. Mechanical engineering students have examined a possible window replacements for the Engineering Building (the University also has old buildings), and winter heat loss and alterations for the City of Lowell's JFK Civic Center. Plastics engineering students also analyzed fresh water condensation through plastic using solar energy for remote villages.

Fluids projects have been implemented in mechanical engineering. As part of the Convective Processes course, juniors have evaluated friction loss in pipes and water supply system designs for two villages in Peru. They have also performed a hydrostatic analysis of canal locks wicket gate for the National Park Service. Seniors in an Analysis of Thermo-Fluid Processes course have analyzed heat exchanger possibilities for the Lowell's JFK Civic Center and designed drip irrigation systems for a village in Peru.

Material Courses

Plastics Engineering has a four-year history of incorporating service-learning projects in laboratories associated with sophomore-level plastics materials courses. The principle learning outcomes are the ability of students to research polymer materials, to apply their knowledge of polymer materials to a practical problem, to work in groups, and to present their work in professional manner. Over the past three years, sophomores in Plastics Engineering have evaluated the suitability of various transparent plastics sheet for solar lanterns that will be used in Peru (for the Village Empowerment Peru Project); designed and created middle-school-level hands-on activities illustrating polymerization, the oil-to-polymer process, and alternative polymer feedstocks for the National Plastics Center's PlastiVan program; selected materials for and designed the synthetic drain layer for a green roof project proposed by the Merrimack River Watershed Council; evaluated the leeching of low-molecular-weight additives from polyvinyl chloride pipe manufactured in Peru (for the Peru Project); researched background and developed interactive exhibit concepts about synthetic fibers for the American Textile History Museum (Lowell, MA). For these projects, the community partner has presented the organization and the project requirements in an hour-long session with the students. The students have performed the service learning project and then presented their results to the community partner. These projects, which are worth 20% of the course grade, replaced an experiment (and its report) and the final examination for the laboratory.

In a sophomore-level materials course in Mechanical Engineering student teams researched and presented findings to the staff of a local textile history museum to help it begin updating its displays on recent developments in materials, including electrospinning, carbon fibers, biomedical textiles, and textiles in fire fighting. Similarly, chemical engineering students have examined materials in a recycling project, whereas civil engineering students have analyzed of possible materials for alleyways in partnership with the Lawrence Community Works and Groundwork Lawrence. Finally, an optional project for a senior-level mechanical engineering laboratory course was the development of a method to test local playground surface hardness for safety. Table 4 presents the implementation of service-learning projects into materials courses.

Table 4. Service Learning in Materials Courses

	2004-05	2005-06	2006-07	2007-08
Chemical Engineering		●		
Civil Engineering			●	
Electrical Engineering				
Mechanical Engineering	○	○	●○	●○
Plastics Engineering	●	●●	●	●

Statics, Dynamics, and Design Courses

Service-learning projects were also integrated into statics, dynamics, and lower-level design courses (Table 5). Tower design of for water tanks used with village schools in various Peruvian towns have been extra credit (homework) projects for statics courses in mechanical and plastics engineering. The tower design projects have been worth about 10% extra for toward the final course grade. Sophomores in a dynamics course have analyzed the safety of rides at various city playgrounds. These projects have typically been mandatory and have accounted for 20% of the course grade. Each team of two to three students visited and analyzed a different playground. In both courses the selected projects permit the students to apply the concepts learned during the courses to practical problems. The results have been well-received analyses. The students completed analysis of playgrounds in Lowell, MA, and moved onto playgrounds in Lawrence, MA. Electrical engineering students in the sophomore-level Basic EE Lab II have analyzed LEDs in headlamp designs for the Peru Project.

Table 5. Service Learning in Statics, Dynamics, and Lower-level Design Courses

	2004-05	2005-06	2006-07	2007-08
Chemical Engineering				
Civil Engineering				●

Electrical Engineering			●	■
Mechanical Engineering	●	●●●○	●●●○	●○■■
Plastics Engineering		●○	●○	○■

● mandatory; ○ optional; ■ □ planned

Design courses in which the objectives are the learning of design concepts and software packages for solid modeling have been a good fit for service-learning projects, particularly since the courses instructors need new projects for each academic year. Sophomore-level mechanical engineering design courses have tapped the University's assistive technology program to find projects like designing a device to help relative/friend with disability with everyday activities; and designing and manufacturing of assistive technology devices. In similar plastics engineering design courses, students have designed and manufactured rechargeable headlamp casings for the Peru project and animal guards for high voltage transformers for National Grid customers.

Results have been mixed for upper-level design courses. Service-learning projects that meet the technical requirements of chemical engineering and plastics engineering courses have been difficult to find. The most successful product design project in that category has been an evaluation of moldable plastics grave vaults for National Cemetery Association (which was performed by mixed teams of seniors and graduate students).

Electrical and Mechanical Engineering have incorporated a number of projects for upper-level design courses. Electrical engineering students in a junior-level Microprocessors Systems Design I course have used PIC micro controllers to design and build monitors for human voice volume for LifeLinks and have designed and built controllers for the World's Largest Book page-turner. Juniors in Electronics I have designed and built circuits for measuring and displaying the power generation of various water wheels for the Tsongas Industrial History Center. Mechanical engineering students in the senior-level Design of Machine Elements course have designed water towers and motorcycle ambulance connections for the Peru Project; wicket gate mechanism for the National Park Service; and a gym mat roller for the University's Athletics Department.

Capstone Projects

Service-learning capstone projects have been implemented in Electrical and Mechanical Engineering. Electrical Engineering has a long-established assistive technology program[20] in which the first capstone course requires the creation of a business plan to fund the design and development of a product which would be considered an "assistive technology" device for a specific client. In the second capstone course, the students design, test, and deliver a device that would enhance the quality of life for a disadvantaged person. They are required to have direct contact with their client throughout the project.

Mechanical engineering students have a selection of service-learning and industry-based capstone projects. In service-learning projects, the students have designed, build, tested, and re-designed wicket gates for remote lock as well as a large gate hydraulic lock opener for the Lowell National Historical Park; they have also designed and built water supply and purification systems for whole villages, microhydro systems, prosthetic limbs, hand-powered swings and composting solar toilets for the Peru Project.

Civil Engineering capstone students in the Spring 2008 semester are designing an extension of a rail system to connect the Lowell National Park to the north campus of UML.

Students from other disciplines can elect an Intercollegiate Engineering Capstone Design course. These students have designed a WiFi system and biodigestors for Peruvian villages and page turner prototype for World's Largest Book (for Groton Dunstable Regional Middle School).

Students taking additional one-credit Community-based Engineering Design Projects courses have designed a W/C transfer board and trash removers for the Lowell canals.

Other Courses

Service-learning projects have been introduced into other undergraduate courses.

- Civil engineering students in the junior-level Environmental Engineering Laboratory have performed road salt and chemical analyses for the Town of Dunstable. In the next semester's Water Resources Engineering course, the same students used hydrology to gain insight on chloride levels in the Town of Dunstable's wells. These projects were facilitated by a member of Dunstable's Board of Health (which oversees water quality in the wells).
- Students in various engineering statistics courses have performed statistical analyses of a survey data for the SLICE project and have analyzed crime data for the Lowell Police Department as well as health data from medical clinics in which the students have installed raiods, lights, vaccine fridges, and town water supplies.
- In Engineering Ethics, which is required for engineering students, students have examined a number of issues related to Peruvian villages associated with the Peru Project. These issues included whether to provide solar-powered television systems, opportunities for application of nanotechnology, and the pros and cons of nanotechnology applications.

Table 6 lists the service-learning projects incorporated into graduate courses, which can be used as senior electives. The SLICE web site contains more detailed descriptions of 89 different S-L projects along with student handout examples[22]. Also the appendix below has a more complete list of courses into which S-L has been integrated in 2006-07 along with projects. Tables of courses and projects from 2004-05 and 2005-06 are presented in Duffy et al. (2007)[23].

Table 6: Service-learning Projects in Graduate Courses

	Title	Example Projects
CE	Water Resources Assessment	Water resource analysis for the National College of Forestry in Honduras and El Hormiguero, Nicaragua (for Mesoamerican Development Institute)
	Wastewater Treatment & Storm Water Management	Wastewater technology evaluation for application in developing countries
	Civil Eng Lab	Initial analysis of historical footbridge design for the Architectural Heritage Foundation (Lowell, MA)

EE	Intro to Biosensors	Lowell HS education modules and mentoring.
	Adv. Computer Architecture	Deployment and monitoring of real-time sensors for energy used reduction project of UML Facilities staff.
ME	Energy Engineering Workshop	Green building upgrades for North American Indian Center of Boston; solar water pumping system design and installation for Laguna, Peru; green building designs for Habitat for Humanity.
	Energy Systems Design	Feasibility study of photovoltaics and green building improvement for Lowell Technical High School
	Solar Fundamentals	Estimate solar irradiation and optimal tilt for a solar collector and install Peru; design a solar hot water batch collector for a village biogas system; design and build a solar herb crop dryer for Peru; analysis of monitored weather data for design of solar systems for villages in Peru; solar PV array with optimized layout for Lowell Tech HS feasibility study; solar hot water systems for Indian reservation AZ.
	Solar Systems Engineering	Carbon displacement credit assessment of PV systems in Peruvian villages; solar water pumping system data acquisition design and installation for Peru; green building and solar designs for local teen center.

Student and Faculty Acceptance

Surveys of students and faculty have been administered in the last three academic years, 2004-07 and the instruments themselves along with results are presented in some detail in Duffy et al. (2007)[23]. Of relevance is the extent to which the projects described here have been accepted by students and faculty. Two-thirds of both groups agree in principle that service and academic coursework should be combined (i.e., service-learning). They also agree on average that learning, teamwork, interest in subject matter, motivation to continue in engineering are all improved with S-L.

Conclusions

Although service-learning projects that meet real community needs and that help students achieve academic objectives in the courses are difficult to create, the college of engineering at UML has integrated service-learning into 35 different undergraduate core courses over the last four years. Initial projects were built on the foundation of two existing service-learning projects: the Village Empowerment Peru Project which provides systems to remote Andean villages, and the Assistive Technology program, which improves the lives of disabled individuals. New partners have been found in public schools, museums, local municipalities, and a range of community groups. Many of the projects are low-cost and can be implemented by individual faculty members without the requirement of a formal institutional program. Repeated surveys of students and faculty indicate that two-thirds of both groups agree in principle with combining service and academic coursework and agree on average that learning, teamwork, interest in subject matter, motivation to continue in engineering are all improved with S-L.

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Appendix

Service-Learning in Courses 2006-2007								
Yr	**Course #**	**F, S**	**Cr**	**Course Title**	**Professor**	**Activities**	**S-L stu**	**# stu**
Common First Year Course								
Fr	25.107	F 06	2	Intro. to Engineering I	Dave Kazmer	Tsongas Industrial History Center exhibits for K-12 illustrating "energy around us" principles of engineering;	354	354
CORE REQUIRED COURSES								
CHEMICAL ENGINEERING								
Jr	10.304	S 07	3	Heat Transfer	Al Donatelli	Winter heat loss/alterations analysis for Mental Health Assoc of Greater Lowell (MHA)	18	18
CIVIL ENGINEERING								
Fr	25.108	S 07	2	Intro. To Eng. II - CEE	Jackie Zhang	Parking lot re-design: UML Smith & Eames	35	35
So	14.286	F 06	3	Probability & Statistics for Engineers	Oz Gunes	Statistical analysis of water samples from Town of Dunstable wells	21	35
Jr	14.310	F 06	3	Engineering Materials	Krishna Vedula	Analysis of possible materials for Lawrence alleyways with Lawrence Community Works (LCW) and Groundwork Lawrence (GL)	10	31
Jr	14.332	S 07	3	Environmental Eng. Lab	Cliff Bruell	Town of Dunstable road salt/chem analysis	27	27
Sr	14.460	F 06	3	Water Resources Engineering	Jackie Zhang	Follow up on spring soils project: Using hydrology to gain insight on chloride levels in the Town of Dunstable wells	39	39

ELECTRICAL ENGINEERING								
So	16.208	S 07	3	Basic EE Lab II	Alan Rux	LED analysis for headlamp design for Peru	36	36
Jr	16.317	F 06	3	Microprocessors Systems Design I	Yan Luo	PIC micro controllers to build monitors for human voice volume for LifeLinks (North Chelmsford)	33	33
Jr	16.317	S 07	3	Microprocessors Systems Design I	Yan Luo	World's Largest Book page-turner control design for Groton-Dunstable Regional Middle School	44	44
Jr	16.365	F 06	3	Electronics I	Joel Therrien	Designed and built circuits for measuring and displaying the power generation of various water wheels for the Tsongas Industrial History Center	50	50
Sr	16.399	F 06	3	Capstone I (Proposal)	Alan Rux, Donn Clark, Senait Haileselassie	Develop a business plan to fund the design and development of a product which would be considered an "Assistive Technology" device. Students work with a specific client and identify Capstone Assistive Technology project to be accomplished in 16.499.	44	44
Sr	16.399	S 07	3	Capstone I (Proposal)	Donn Clark	Business plan to fund the design & development of Assistive Technology device; incl. client	20	20
Sr	16.499	F 06	3	Capstone II (Project)	Alan Rux	Students are required to design, test and deliver a device that would enhance the quality of life for a disadvantaged person. Students are required to have direct contact with their client throughout the project.	41	41
Sr	16.499	S 07	3	Capstone II (Project)	Alan Rux, Jay Fu, Senait Haileselassie, Chuck Maffeo	Design, test and deliver a device that would enhance the quality of life for a disadvantaged person; including direct contact with client	50	50
MECHANICAL ENGINEERING								
Fr	25.108	S 07	2	Intro. To Eng. II - ME	Sammy Shina	Renewable energy application for Greater Lowell Technical HS (GLTHS)	9	108
So	22.202	S 07	2	Design Lab II	Bob Parkin, Byungki Kim	Design/manufacture of assistive tech devices - for the Bill Kelly Assistive Technology center at the Hogan Regional Center, Hathorne, MA	53	60
So	22.213	S 07	3	Dynamics	Faize Jamil	Analyze playgrounds for City of Lawrence, Department of Parks and Recreation (and other playgrounds)	24	43
So	22.296	S 07	3	Mechanical Behavior of Materials	Emmanuelle Reynaud	Mounted posters and annotated bibliographies for the American Textile History Museum (ATHM)	18	18

Jr	22.341	S 07	3	Conduction & Radiation	Hongwei Sun	Winter heat loss/alterations analysis for the JFK Civic Center, City of Lowell, Division of Planning and Development	48	48
S r	22.342	F 06	3	Convective Processes	Gene Niemi	Piping design of water supply system for Yanacaca village, Peru	47	47
Jr	22.361	F 06	3	Mathematical Methods for Mechanical Engineers	John McKellige t	statistical analysis of Company survey for SLICE	61	61
Jr	22.381	F 06	3	Fluids	Majid Charmchi	Canal locks wicket gate - hydrostatic analysis for NPS	11	48
S r	22.403	F 06	3	Mechanical Engineering Lab II: Measurement Engineering	Majid Charmchi	playground materials analysis for safety	10	43
S r	22.423	F 06	3	Capstone	Sammy Shina	Design, build, test, re-design wicket gates for remote lock for the Lowell National Historical Park (LNHP).	2	3
S r	22.423	S 07	3	Capstone	John Duffy	2 groups for Village Empowerment Peru project: Hand-powered swing (3) and Composting solar toilet (2)	5	5
S r	22.423	S 07	3	Capstone	Sammy Shina	Large gate hydraulic lock opener	4	39
S r	22.425	F 06	3	Design of Machine Elements	Chris Niezrecki	Water tower designs (2) and motorcycle ambulance connection for Peru; wicket gate mechanism for the NPS; gym mat roller for UML Athletics Dept.	19	49
S r	22.441	S 07	3	Analysis of Thermo-Fluid Processes	Majid Charmchi	Analyze heat exchanger possibilities for the JFK Civic Center, City of Lowell, Division of Planning and Development	7	48
PLASTICS ENGINEERING								
F r	25.108	S 07	2	Intro. To Eng. II - PE	Carol Barry, Nick Schott	Teaching modules for CHN Outreach program in Lowell schools	28	28
S o	26.215	F 06	1	Plastics Process Lab I	Carol Barry	Plasticizer leaching from PVC testing for Peru	21	21
S o	26.218	S 07	2	Intro. to Design	Steve Orroth, Nick Schott	Design and manufacture of animal guards for high voltage transformers for National Grid customers	22	22
Jr	26.348	S 07	3	Heat Transfer	"Jim" Jan Chan Huang	Plastic insulation analysis for Mental Health Assoc of Greater Lowell (MHA)	21	21
ELECTIVE/GRADUATE COURSES								
CIVIL ENGINEERING								
G r S	14.570	S 07	3	Water Resources Assessment	Bill Moeller	Water resource analysis for the National College of Forestry in Honduras for the Mesoamerican	3	3

r						Development Institute (MDI)		
G r	14.733	S 07	3	MS Project in Civil Eng Lab	Susan Faraji	Initial analysis of historical footbridge design for the Architectural Heritage Foundation site at 165 Jackson St. Lowell, MA	1	1
G r	18.584	S 07	3	Sustainable Infrastructure Practicum	Bill Moeller	Coffee waste composting for organic farmers in Honduras with MDI	1	1
ELECTRICAL ENGINEERING								
G r S r	16.541	S 07	3	Introduction to Biosensors	Xingwei Wang	Lowell HS education modules, presentation and mentoring.	8	8
MECHANICAL ENGINEERING								
G r	22.504	F 06	3	Energy Engineering Workshop	John Duffy	Green building upgrades for North American Indian Coalition of Boston	3	3
G r	22.504	S 07	3	Energy Engineering Workshop	John Duffy	Solar water pumping system design and installation for Laguna, Peru	2	2
G r S r	22.521	F 06	3	Solar Fundamentals	John Duffy	Estimate solar irradiation and optimal tilt for a solar collector and install in Yanacaca in Peru; design a solar hot water batch collector for a village biogas system; design and build for Yanacaca a solar herb crop dryer.	10	10
G r S r	22.527	S 07	3	Solar Systems Engineering	John Duffy	Carbon displacement credit assessment of PV systems in Peruvian villages with Staples; solar water pumping system data acquisition design and installation for Huayash, Peru	8	8
INTERCOLLEGIATE ENGINEERING								
Jr	25.300	S 07	1	Community-based Engineering Design Project II	Bob Parkin	W/C transfer board	1	1
Jr	25.300	F 06	1	Community-based Engineering Design Project II	John Duffy	Lowell canals trash remover	1	1
S r	25.400	S 07	1	Community-based Engineering Design Project III	John Duffy	Lowell canals trash remover	1	1
S r	25.401	S 07	3	Intercollegiate Engineering Capstone Design Project	John Duffy	WiFi system design for Huarmey Valley village in the dept. of Ancash, Peru	1	1
S r	25.401	S 07	3	Intercollegiate Engineering Capstone Design	Jim Sherwood	Page turner prototype for World's Largest Book for Groton Dunstable Regional Middle School	4	4

				Project				
						2006-07 Total S-L Student-Courses:	1276	1613
						Total enrollment full time (ABET report) [2]:		2154
						Total full-time regular faculty with S-L:	26	
						Total faculty with S-L incl part-time:	31	
						Total faculty full-time who have ever tried S-L:	37	
						Total full-time faculty in entire college:	78	
						Total courses with students engaged in S-L :	46	
						Total required courses with S-L (unique, not counting sections):	28	