Advances in Engineering Education

SUMMER 2011

Service-Learning Integrated throughout a College of Engineering (SLICE)

JOHN DUFFY
University of Massachusetts Lowell

LINDA BARRINGTON
University of Massachusetts Lowell

CHERYL WEST
Massachusetts Bay Community College
Wellesley Hills, Framingham, and Ashland, MA

MANUEL HEREDIA
University of Massachusetts Lowell

and

CAROL BARRY
University of Massachusetts Lowell
Lowell, MA

ABSTRACT

In the fall of 2004 a college began a program to integrate service-learning (S-L) projects into required engineering courses throughout the curriculum, so that students would be exposed to S-L in at least one course in each of eight semesters. The ultimate goal is to graduate better engineers and more engaged citizens and to improve communities, i.e., to engineer the common good. Four of the degree programs have achieved on average one course each semester, with an actual coverage of 103 out of 128 semester courses, or 80% coverage. Of the 32 required courses in the academic year that had an average of 753 students each semester doing S-L projects related to the subject matter of the course, 19 of the courses (60%) were considered engineering science, that is, not explicitly design or first-year introduction courses. More than fifty courses having S-L components have been offered under the program. 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 S-L as one of the reasons for enrolling in engineering at UML, and more than two-thirds of the students reported that S-L helped keep them in engineering. The program represents perhaps the largest experiment with S-L in mainstream engineering courses in terms of courses, students, and faculty. This approach included an inquiry addressing a number of programmatic and research questions, which are posited and "tested" with quantitative and qualitative data.

INTRODUCTION

In 2004 the University of Massachusetts Lowell embarked on a curricular reform of the entire college of engineering. The broad aim was to develop better engineers and better citizens along with improved communities, i.e., to engineer the common good. The strategic goal was to incorporate service-learning (S-L) into enough courses so that on average students would have at least one required course with S-L in each semester in the five undergraduate programs in the college. A secondary goal was to increase recruitment and retention, particularly of underrepresented groups in engineering. The program was named SLICE (Service-Learning Integrated throughout a College of Engineering).

The following sections include the reasons for choosing S-L based on the literature, the strategy used to implement the approach, the results to date, and finally conclusions and advise for individual faculty members wishing to incorporate S-L into an existing course.

SERVICE LEARNING

Service-learning is defined here as a hands-on learning approach in which students achieve academic objectives in a credit-bearing course by meeting real community needs. There are a number of definitions used in the literature (e.g., (Jacoby, 1996), (Bringle & Hatcher, 1995), (Stanton, Giles, & Cruz, 1999), (Learn and Serve America, 2009)); but key elements that appear to be important to researchers and practioners include: projects or placements that meet course academic objectives, the meeting of real community needs, 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 (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). In engineering, the goal is to have students become better professionals and better citizens while the community also benefits.

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, and recruitment of under-represented groups in engineering; it also leads to better retention of students, and citizenship (Eyler & Giles, 1999), as well as helping meet the well-known ABET Criterion 3 (a) - (k) (Accreditation Board for Engineering and Technology [ABET], 2009). Astin *et al.* (2006) found with longitudinal data of 22,000 students that

S-L 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. Eyler and Giles (1999) found S-L 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. 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.

Service-learning is often in general 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)). 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, it was found that S-L projects could be incorporated into existing core courses. For example to meet ABET requirements, having community partners on S-L projects essentially guarantees that students will work on multidisciplinary teams, and that with the correct structure of S-L 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 S-L 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 S-L projects, they are free to do so and should learn more in the process.

Oakes (2004) had a list of 33 universities that had S-L in engineering and described a number of examples of S-L. Perhaps best known is EPICS (Engineering Projects in Community Service), which started at Purdue and includes 18 universities (EPICS, 2009). The program involves elective interdisciplinary S-L courses that students can take from first year to senior year (Coyle, Jamieson, & Sommers, 1997). Tsang (2000) and Lima and Oakes (2006) 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 five years. The University of Vermont Civil and Environmental Engineering Department has integrated S-L into the curriculum with the objective that students have a required course with S-L at least once a year (Dewoolkar, George, Hayden, & Rizzo, 2009), an approach similar to that reported here.

In the current program, the S-L projects 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 the Tsongas History Center that is part of Lowell 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. Juniors in heat transfer courses focused on 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 a 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 the Lowell 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.

METHODS TO INTEGRATE S-L IN EXISTING COURSES

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 (J. Ting) and the five department chairs lent their support in 2004. A workshop for faculty was held in August 2004. Community partners were invited to a S-L fair and were also contacted by university staff for possible projects to meet needs. A part-time staff coordinator started in late fall of 2004. A grant from the National Science Foundation (NSF) under the Departmental Level Reform Program in the Engineering Education Directorate helped support the program from 2005 until 2009.

The following supports were made available to faculty, students, and community partners: A web page was started to help link community partners and faculty (http://slice.uml.edu). Faculty were encouraged to "start small rather than not at all." Biweekly community of practice gatherings have been held roughly every month since 2004 (Wenger, McDermott, & Snyder, 2002). 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 S-L into their courses. A few course releases have been available; a few faculty have taken advantage of small stipends.

PROGRAMMATIC AND RESEARCH QUESTIONS

The SLICE program was started with the following questions:

1. Would faculty members accept S-L and develop into practitioners of S-L?
2. Would students accept S-L and benefit from it?
3. Would recruitment and retention increase, particularly among underrepresented groups?
4. Would positive cognitive and affective changes occur in students?
5. Would students learn academic subject matter better?
6. Would teamwork, communication skills increase?
7. Is service-learning spread throughout the core curriculum more effective than in one intensive course?
8. Is a mixture of required and elective service-learning more effective than either one or the other?
9. Could service-learning result in less coursework time than traditional programs satisfying ABET 2000 criteria?
10. Would the local and international community benefit?

Answering these questions has been addressed through the following quantitative and qualitative data: straightforward counts of courses, faculty, students; fall "pre" surveys of entering students, "post" surveys in December of entering students, and spring "post" surveys of all students; annual surveys of faculty; interviews of community partners; interviews of sampled faculty, students, administrators, and community partners. The key instruments and data are presented in the following section. Then how this data addresses the above questions is summarized in section 6.

EVALUATION INSTRUMENTS AND RESULTS

Surveys are given to incoming students in an introduction to engineering course each fall on the first day of class (e.g., n = 399 in 2008) (Appendix A). "Post" surveys are given to the students in introduction to engineering in December and are targeted to all undergraduate students, not just those with S-L project courses, at the end of the academic year in May (n = 458 in 2008, n = 526 in 2009) (Appendix B). Surveys are also given to faculty members once a year (n = 53 out of 76 in May 2008, n = 49 in May 2009) (Appendix C). Also a limited number of comparisons are possible when the students choose to place their ID number on the questionnaire and their responses can be compared over time. Qualitative data was (and continues to be) obtained through in-depth interviews with UML administration, faculty, students, alumni, community partners and industry employers. Student interviews also included use of some focus group discussions. Over a five year period, in-depth interviews were conducted with 6 university administrators, 28 faculty, 117 students, and 15 community partners. A convenience sampling of students and faculty were recruited through flyer distribution, email/phone contacts, and class announcements within each department: Civil, Chemical, Electrical, Mechanical and Plastics Engineering. Surveys, interviews and focus groups were conducted under IRB approval by external and internal evaluators during each year of the S-L project. Surveys were coded to protect participant identity. Each interview and focus group participant was assured confidentiality of their responses with no attribution in reporting. Interview and focus group protocol inquired about each participant's experience with S-L, impacts, challenges and supports associated with S-L program, along with additional comments or recommendations.

Based on continuing analyses of this data, the following results (among many) emerge: two-thirds of both groups agree in principle with combining service and academic coursework and on average that learning, teamwork, interest in subject matter are all improved with S-L. Students are evenly divided as to whether the S-L projects should be mandatory in courses. Two-thirds of the students indicate a positive impact of S-L on their continuing in engineering. Both groups report being more motivated and empowered. One faculty member went so far as to say: "It [S-L] will change the way we think about engineering. It adds an additional dimension." Details follow.

Faculty Impacts

Perhaps the most important outcome of the project so far is that half of the engineering faculty has tried service-learning. In 2003–04, there were one full-time and five part-time faculty members doing S-L. Twenty-five faculty members implemented S-L into at least one of their courses during the 2004-05 academic year. Thirty-two full time faculty members in the 2005-06 academic year tried S-L; there were 68 full-time faculty members at that time, and a couple of S-L faculty were from outside the college but were teaching courses that engineering students could take or were required to take. In 2006–07, 26 tenure-track college faculty members (31 faculty including part-timers) out of 75 had S-L projects in their courses, several in more than one course. Forty-three full-time engineering faculty members have tried S-L so far, more than half the full-time faculty.

Figure 1 summarizes the number of courses offered with S-L in the college over the last five years. The tables in Appendix D list every course with S-L, the S-L project(s), community partner, percent of grade for S-L project, number of students enrolled, number of students completing the S-L project. More detailed descriptions of the projects and community partners are available at http://slice.uml.edu, along with student handout samples and photos (and summaries in Appendix H). The faculty members were motivated enough to integrate S-L into enough courses so that on average in four of the academic programs the strategic goal was met to have at least one course every semester.

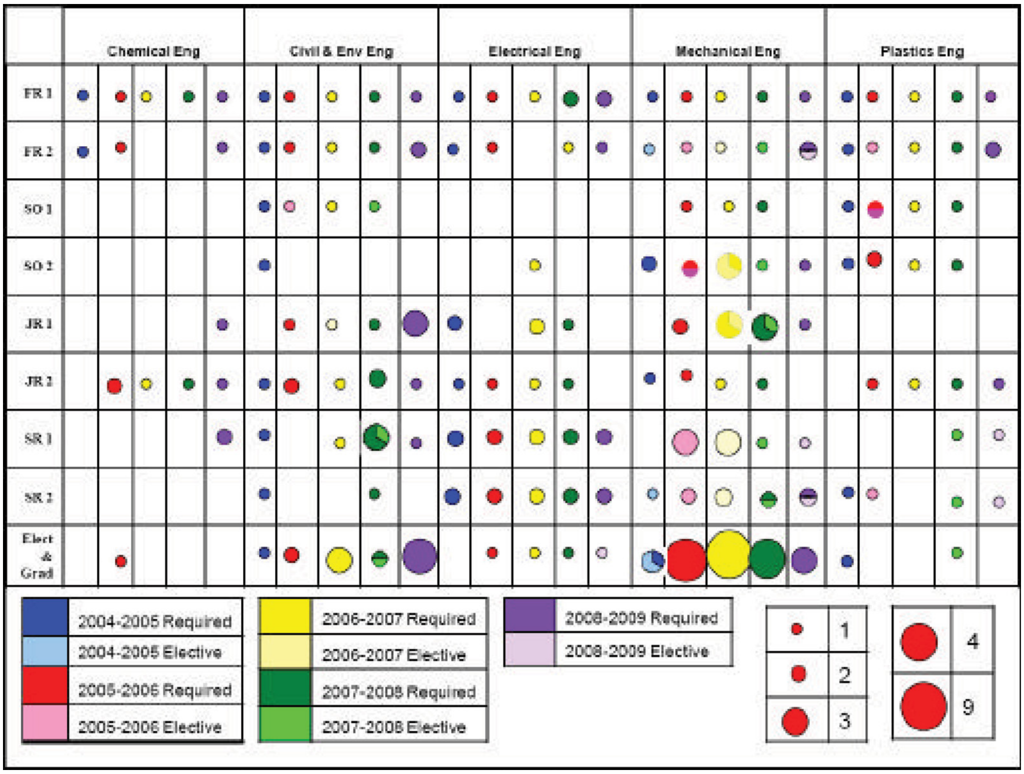

Figure 1. Number of courses with S-L (size of bubbles) by semester (row) in academic program, academic year (color), academic program (columns), and elective or required status (shade).

Obviously, the sophomore year is more challenging to match up as is chemical engineering in general.

In recent literature, a number of factors that motivate faculty use of S-L include frequent encouragement from the department chairperson, dean, or from another faculty member in the department; access to instructional support; and improved learning outcomes (Abes, Jackson, & Jones, 2002) (Hammond, 1994) (Madhumita, 2007). Consistent with the literature, S-L faculty in the qualitative portion of our study indicated the importance of generating positive learning outcomes as being most significant in their decision to incorporate S-L in their teaching, as well as encouragement and internal supports serving as catalysts to attempt S-L. One faculty member asserted that, "*When S-L is done right it has that ability to provide another way of learning*." Another faculty member stated that, "*I received good advice, and my classes have gotten better. S-L fills a gap, it's not boring, and they* [the students] *have an example to practice, with application and everything clicks*."

The written survey questions address the integration of service-learning projects into courses. This survey required reporting on a Likert scale of 1–9, with 1 being "strongly disagree" and 9 being "strongly agree." As shown in the tables in Appendix E, the faculty agreed with all the statements addressing course objectives and community needs, better student learning, and academic rigor of the courses. Two-thirds agree with the goal of SLICE: "I agree in principle with the goal of having at least one service-learning course available every semester for every undergraduate in our college of engineering." These results were significantly (5% level in a t-test) different from neutral (as indicated by the asterisk). The t-tests were corrected for finite population since over half the population was sampled. The one statement with the mean agreement being neutral (until 2009) was: "It is possible to integrate service-learning into existing engineering courses without adding to the overall workload of students by replacing existing homework, projects, lab experiments, lectures, etc. with similar activities solving real problems in the community." Faculty are now shifting to the belief that it is possible to not increase student workload with S-L.

In the surveys, faculty who incorporated service learning into their courses found that the projects "*provide students an opportunity to deal with open-ended real-word problems and allow them to use their creativity to solve problems*." In addition, service learning projects "*allow students to deal with socially responsible issues and to provide a social benefit to the community*." International projects engaged "*students in understanding human needs and engineering problems/solutions at a level different than that commonly encountered in the US;*" these projects forced students to "*(a) look for alternative solutions, (b) consider cost and equipment as a major limiting factor, and (c) make decisions on what can be done and not what ideally should be done*." Overall, the S-L projects showed students that "*engineers do things that benefit society*." These faculty members also felt that their students were engaged, motivated, and learned more than they would have with conventional instruction methods. The reasons given for not trying S-L were content, time, and finding acceptable projects. Many faculty members mentioned in the surveys and interviews that lack of time in the course and in their individual schedules as the major reason for not incorporating service-learning. One faculty member stated that he tried service-learning "*because it helps the community*," but "*it is a lot of extra work*."

The attitude toward service-learning and perceived impact on teaching differed significantly between male and female faculty members in the surveys, as indicated in the tables in Appendix E. Many of the means were 2 whole points different from female to male. These differences may be attributed to gender-based attitudes towards the societal impacts of engineering, but also reflect the relative seniority of the female faculty. The faculty in the College of Engineering is 17% female, but only one of those women members was on the faculty before 1996. In contrast, several men have been faculty for 30 to 40 years. The untenured faculty tended to be more enthusiastic about implementing S-L projects as a group (Appendix E). Thirty percent of those implementing S-L in 2004-09 were untenured. There were significant differences (5% significance level with t-tests) in the mean responses to a many of the statements in the survey by gender, tenure status, and department.

Student Impacts

The post-questionnaire surveyed 458 students in the College of Engineering in the spring of 2008. Of the 2008 students in the sample, 86.9% were identified as male, 74.2% were Caucasian, and 3.9% were international students. In contrast to most student populations, only 60.5% of the students were between 18 to 21 years old; most of the remaining were older. The composition of the survey was 26.6% freshmen, 21.2% sophomores, 25.1%, juniors, and 19.4%, seniors. Due to differences in class sizes and courses incorporating S-L projects, there was a some uneven distribution of disciplines; of the students taking the spring 2008 survey, 19.4% were civil engineers, 9.4% were chemical engineers, 9.0% were electrical engineers, 27.3% were mechanical engineers, and 27.3% were plastics engineers. These students had taken as many as 19 previous courses with a S-L component. In 2009, the sample size was 526, 12% female, 13% Asian, 4% black, 2% American Indian/Hawaiian; 9% Hispanic, 91% non-Hispanic; 2% international. The department breakdown was: 70 from Chemical; 122, Civil; 62, Electrical; 182, Mechanical; 67, Plastic.

The mean responses for attitudes towards S-L, teamwork, communication, hands-on learning, commitment toward helping communities are tabulated in the tables in Appendix F for the pre and post surveys from 2009 going back to 2004. For example, the students strongly agreed that they enjoyed learning, learned more from hand-on activities, and used what they learned in their lives. They reported a preference for working in groups. The students agreed that social problems not easily solved and required everyone's input. They students agreed that "it is important to be involved", "service and academic coursework should be integrated", "engineers should use their skills to solve social problems", and "it is important to have a career that involves people." The students also felt that they could impact problems on a local and international level, but interestingly, did not agree on the need to influence the political structure. Students are evenly divided as to whether the S-L projects should be mandatory in courses.

One important consistent tabulation from the first year student surveys (fall post surveys), however, is that 21% to 24% of first year students agreed to the statement that S-L was one of the reasons for coming to UML.

As with the faculty, female students responded more positively (at the 5% level) to service-related work than male students. Generally, the differences were typically 0.5 to 1.0 points on the Likert scale.

The mean student responses were analyzed by performing t-tests between the mean responses and neutral (5 on the Likert scale) and between post spring 2009 results and all previous surveys. Note that the pre surveys are given only to first year students as are the fall post surveys. The spring surveys are given to all levels of students, even though the majority of the samples were from juniors and seniors, whether they had S-L in courses or not. The results are summarized in the table in Appendix F. Note that the comparisons over time are not from the same populations, but they do give some insight into changes over time. Note that the farther back in time one goes the more significant differences in mean responses are observed between the spring 09 cohort and previous samples. Thus, changes in attitude and outlook seem to take time, which is no surprise.

Matching ID number results were compared over time also; that is, one student is tracked over time. The difficulty was that there were not that many matches; for example, 32 from the pre fall 06 to spring 09 surveys. The only significant differences in this sample were in response to the statements: “I feel well prepared for my future career,” and “I have a close working relationship with at least one faculty member at this institution.” The issue seems to be with the small sample. There are more matches over shorter time periods. Previous studies compared by ID before and after surveys in the introduction to engineering course, which has had high numbers. Some significant changes in attitudes were encountered in the one semester (Kazmer, Duffy, & Perna, 2006) (Kazmer, Duffy, Barrington, & Perna, 2007). It appears that future tracking this larger number of students now with IDs will pay off in subsequent years.

In interviews, students reported S-L as being an important part of their educational experience at UML, which they also commented on as a significant approach to prepare them for “*a real world, and to think outside the box*,” and that S-L “*gives projects a purpose, rather than just a grade*.” In general, students interviewed for this study reported being motivated and changed through their S-L experiences. Students readily talked about “*working harder*,” and that S-L was “*more applicable than learning from a book*.” For the most part, S-L was and is accepted by the majority of students within the engineering programs. However, both faculty and students reported that, “*Not all the students wanted to do S-L, some complained*.” Nevertheless, the majority of students viewed S-L positively and talked about, “*being more engaged and more excited with S-L*.”

Institutional Impacts

One of the objectives of the project is to satisfy ABET objectives without having to add extra courses to the curriculum. The college had an ABET visit in the fall of 2006. Two of the findings are relevant here (ABET, “Final Statement University of Massachusetts Lowell College of Engineering Accreditation Cycle 2006–2007”). One “Institutional Observation” was “The service learning program currently in the Department of Electrical and Computer Engineering is unique, and it would be beneficial to both the students and the surrounding community if it were expanded across the college." (p. 3) SLICE would appear to be precisely the program to adapt and expand S-L across the college in ways appropriate for each department and to carry out this recommendation from ABET. Under the Mechanical Engineering Program a "strength" was cited: "The integration of design-build-test experience, service learning experiences, and well designed laboratory experiences throughout the curriculum produces an innovative program that is unusually rich in hands-on experiences and broad in scope." The ME Program has the most S-L courses and the highest number of faculty (12 out of 13 at the time) involved with SLICE. Thus, the ABET accrediting visitors seem to commend the service-learning efforts undertaken so far and encourage the spreading of them throughout the college.

Other institutional benefits include the recruitment and retention of students discussed below, and satisfaction of faculty. Other expected outcomes include positive community relations, more satisfied alumni, alumni more inclined toward community service, employers seeking alumni. Data to address these expected outcomes is being collected. An indicator of institutional commitment toward the program is the permanent position of service-learning coordinator for the college. The University also was awarded by the Carnegie Foundation the designation "Community Engagement," in large measure due to the SLICE program.

Community Impacts

A coequal objective of S-L is the meeting of real community needs in the process of meeting student academic needs and course objectives. Over 100 community partners have been involved with SLICE projects. These are listed at http://slice.uml.edu. Some of the community impacts are profound in the areas of the Assistive Technology Program (ATP, 2009), the focus of the capstone EE courses, and Village Empowerment Program (Duffy J., 2008) (short video at: http://library.uml.edu/media/peru/peru.html and additional information at http://energy.caeds.eng.uml.edu/peru-07/), which serves as a source of projects for 27 different courses at UML and elsewhere. Lives are literally saved through student projects.

The assessment of community impacts is important and ongoing, and a report from independent evaluators Cathy Burack and Alan Melchior at Brandeis University is given in Appendix G. Ten community partners in the region were interviewed in the fall 2008. The report concludes:

> Overall, two broad findings emerge from the interviews with community partners. The first is the strong belief that participation in SLICE has major benefits for the partner organizations in terms of the specific project work, as well as increased awareness of the agencies and their missions. At the same time, there continue to be ways to strengthen

the partner experience for both students and partners. Most of these depend on building stronger, more reliable channels of communication between SLICE, participating faculty, and the agencies being served. It is anticipated that as communications improve, the projects will become more relevant, learning will improve, and the ability to identify new opportunities to collaborate will grow.

ANSWERS TO PROGRAMMATIC AND RESEARCH QUESTIONS

Briefly summarized below, in answer to the questions posed in Section 2, are the results above and other results to date that have been reported in other papers (Banzaert, Duffy, & Wallace, 2006) (Barrington & Duffy, 2007) (Bhattacharjee, Lin, Williams, & Duffy, 2008) (Burack, Duffy, Melchior, & Morgan, 2008) (Duffy J. J., 2000) (Duffy, et al., 2008) (Duffy, et al., 2007) (Duffy, et al., 2007) (Duffy, et al., 2007) (Duffy J., 2008) (Kazmer, Duffy, & Perna, 2006) (Kazmer, Duffy, Barrington, & Perna, 2007) (Zhang, Gartner, Gunez, & Ting, 2007) (Kazmer & Johnston, 2008) (Duffy, Barrington, & Heredia, 2009) (Duffy, Barrington, & Heredia, 2009).

1. *Would faculty accept S-L*? Forty-eight faculty members have integrated S-L into an average of 4 courses each in the engineering curriculum. Thirty-five core required courses have had S-L. Four of the undergraduate programs (ME, EE, CE, and Plastics E) have essentially reached the objective of one course every semester. The remaining program (ChE) in the fall 2008 semester had four courses and is getting close to the objective. Of these 48 faculty members, 6 are female, 5 are part-time, 30% are not-tenured of the tenure track faculty (43). There are 78 full time faculty members in the college; approximately 5 teach only graduate courses. So well over half of the faculty has tried S-L. Female and non-tenured faculty members have significantly higher positive attitudes toward S-L on questionnaires. Thirty-four faculty members have committed to continue using S-L in 2009-2010; the actual number of faculty to use S-L is expected to be higher.
2. *Would students accept S-L*? Two-thirds of the students consistently agree in principle with combining academic subject matter with service. On every single survey question, the students have averaged higher than neutral on a 9 point Likert scale (except the desire for political involvement). Thirty-seven percent agreed S-L projects should be required, not optional in courses; 26% disagreed. Female students score significantly higher than males on ranking helping others as a reason for entering engineering and other key questions.
3. *Would recruitment and retention increase, particularly among underrepresented groups*? The number of entering students has increased 50% in the five years SLICE has been in existence

(UML institutional research data). Twenty-three percent of incoming students over the last three years report that S-L was one of the reasons for their choosing the college. Advertising for the college lists among the ten reasons for choosing the college, the number two as S-L (the first is low cost). The percentage of entering females has not increased, disappointingly. However, the number of Hispanic students enrolled increased 50%. It may take some time for the reputation of the S-L program to reach high schools. Students indicated that S-L had a positive impact on the likelihood of their **continuing in engineering** (1-9 scale). In Spring 2008, 64% of 369 agreed (25% strongly); 3% disagreed; the rest neutral. In Spring 2009 62% agreed. These results are discussed in more detail in (Duffy, Barrington, & Heredia, 2009) (Duffy, Barrington, & Heredia, 2009) and (Barrington & Duffy, 2007). Future plans call for assessing whether S-L affects the retention of underrepresented groups.

4. *With S-L, would students be more motivated to learn subject matter; would certain attitudes change*? On the surveys, students do report being more motivated to learn and spending more time voluntarily on S-L projects (compared to neutral on a Likert scale). Attitudes are significantly positive toward S-L and civic engagement. Faculty in interviews also report students being more motivated. One faculty member reports getting much higher teacher evaluations from students with S-L than without.
5. *Would students learn academic subject matter better*. There are positive results of indirect measures of subject matter comprehension. Dave Kazmer compared the grades of students in the introduction to engineering course he had taught for two years before he introduced service-learning and then two years after. The grades increased (Kazmer, Duffy, & Perna, 2006) (Kazmer, Duffy, Barrington, & Perna, 2007).

Students in SLICE surveys reported voluntarily spending more time on S-L tasks and being more motivated to learn the subject matter. Faculty agree in surveys with the statement that students learn course subject matter better with S-L. Traditionally S-L is focused on achieving academic objectives in a course and meeting real community needs. It appears that most other applications of S-L in engineering are in courses that have academic objectives of teamwork, communication, and/or design (Lima & Oakes, 2006). In SLICE, however, in core courses the subject matter involves mainline engineering theory, methods, and skills, such as, heat transfer, fluids, circuits, and dynamics. This represents an area that presents a unique subject pool and an opportunity for basic research that is planned to continue.

Qualitative assessment based on student interview and focus group responses relative to improved learning revealed that students were in general agreement that enhanced learning of engineering concepts, development of teamwork and leadership skills, improved communication and problem solving skills, and increased awareness of engineering roles and responsibilities, all resulted from S-L projects.

6. *Would teamwork, communication skills improve?* Since the students invariably undertake team projects for S-L (even if a community partner is the only other team member as in assistive technology capstone projects) and have to communicate the results to the community partner, teamwork and communication are inherent in S-L. Students are asked about teamwork and communication in the surveys, and they self report that they improve in both areas as a result of S-L activities. This is an area that S-L courses in other engineering schools are more focused on (Mathews, Ferguson, Huyek, & Pamulaparthy, 2006).

   Based on the evidence from faculty interviews and recent literature, S-L provides a platform for students to gain competencies of collaboration and communication skills as well as a deeper comprehension of the social context related to challenges they are solving through development of critical thinking and problem solving skills along with a greater awareness of ethical standards (Lima & Oakes, 2006) (Oakes, 2004) (Swa09). Faculty participating in SLICE projects reported a mix of teamwork methods in which students self select, while others assigned team members based on complexity of project and numbers of students enrolled in courses. Both faculty and students reported a mix of teamwork outcomes. Some teams were very effective and productive, while others struggled with the balance of equitable roles, participation, and delivery of reports and project deliverables. On the other hand, students that did not have the opportunity to work on S-L teams viewed that as a loss to their potential professional development and quality of end products or project deliverables.

7. *Is service-learning spread throughout the core curriculum more effective than one intensive course?* Although there is some evidence to support this hypothesis in the literature (Eyler & Giles, 1999) and in general is intuitively consistent with general education principles, this is a challenging hypothesis to test. One needs to track students through the four years and compare changes in measures of key outcomes of S-L compared to changes with just one course or one semester. This approach is being pursued by collecting the baseline data through questionnaires with identification numbers of students so tracking becomes possible. We have two years of high numbers of entering student surveys with ID numbers. We have made a preliminary analysis of this effect by comparing survey results of electrical engineering students who have a required set of two capstone courses involving assistive technology S-L projects to students who have had a distributed sequence of a higher number of S-L courses over the curriculum, mainly mechanical engineering students with S-L capstone projects elective. Comparison of means with t-tests (5%) were performed. For the post surveys in 2008, for example, 24 ME student responses were compared to 20 EE responses. The ME were higher in almost all categories on the survey, with a few significantly higher mean responses in items on, for example, interest in volunteering,

influencing the political structure, helping the community, and believing in the value of teamwork (EE students do not work in teams in their assistive technology capstone projects).

8. *Is a mixture of required and elective service-learning more effective than either one or the other?* Students in surveys are divided as to whether to require S-L activities in courses, with 36% being in favor of requiring S-L projects, 24% disagreeing, the rest neutral (n = 458, spring 2008). There are differences in the literature about whether to require S-L (Eyler & Giles, 1999) or not (Werner, 1998) . ABET guidelines require the same curricular features be available to all students. So it does appear that some required S-L components are necessary for ABET recognition and that a mix is more defensible and consistent with student views.
9. *Could service-learning result in less coursework time than traditional programs satisfying ABET 2009 criteri?*. The response to the infamous a-k outcome requirements of ABET (Accreditation Board for Engineering and Technology [ABET], 2009) here is to integrate the ABET outcomes into existing courses (as opposed to adding new courses) to meet, for example, outcome h: the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. The institutional ABET visit was positive in this regard.
10. *Would the community really benefit*. There is little question of the community benefit of two long-standing programs now included in the SLICE program (Assistive Technology and Village Empowerment). The other partnerships are growing. In interviews local partners discussed positive benefits and suggest that more communication will lead to even better results.

In short the answers to these questions seem positive at this stage of development of the SLICE program.

For convenience Table 1 summarizes the above questions and the research tools used to help answer them.

PRACTICAL STRATEGIES AND SUGGESTIONS FOR FACULTY IMPLEMENTERS

For those wishing to incorporate S-L into existing courses, some concrete suggestions are offered to minimize the work and to avoid some pitfalls. See the SLICE website http://slice.uml.edu for more details on project ideas and related community partners for specific engineering subjects.

1. "Start small rather than not at all." It is much better to start off with a relatively small well-defined community problem to be solved and have the project be successful, 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

Research Question	Data Collection Methods
1. Would faculty members accept S-L and develop into practitioners of S-L?	Faculty surveys and interviews Tracking number of S-L courses Tracking faculty participation Community of Practice discussions
2. Would students accept S-L and benefit from it?	Faculty surveys and interviews Student surveys and interviews Alum interviews
3. Would recruitment and retention increase, particularly among underrepresented groups?	Faculty surveys Student surveys Institutional research data College of Engineering data
4. Would positive cognitive and affective change occur in students?	Faculty surveys and interviews Student surveys and interviews Alum interviews Student evaluations of faculty
5. Would students learn subject matter better?	Faculty surveys and interviews Student surveys and interviews Alum interviews Tracking change in student grades (Intro to Engineering)
6. Would teamwork and communication skills increase?	Faculty surveys and interviews Student surveys and interviews Alum interviews ABET Report 2006–07
7. Is S-L spread throughout the core curriculum more effective than in one intensive course?	Student surveys and interviews
8. Is a mixture of required and elective S-L more effective than either one or the other?	Faculty interviews Student surveys and interviews Alum interviews
9. Could the S-L result in less coursework time than traditional programs satisfying ABET criteria?	Faculty interviews Student surveys and interviews Alum interviews ABET Report 2006–07
10. Would the local and international community benefit?	Community interviews Faculty surveys and interviews Student surveys and interviews Alum interviews ABET Report 2006–07 Tracking number of community partners Tracking number of S-L projects Community Engagement Award, Carnegie Foundation

Table 1. Evaluation methods for each research question posed.

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 choose 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. Three aspects of reflection include: linking the S-L project with the subject matter, developing a broader appreciation of the discipline, and an enhancing a sense of civic responsibility (Bringle & Hatcher, 1995). 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 struc-

tured 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 (Kolb, 1984). 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.

CONCLUSIONS

The data from this study and literature suggest the following conclusions:

- Half of the full-time faculty and most of the students have carried out S-L in core courses;
- Recruitment and retention are aided (based on self-reporting); underrepresented groups already in engineering indicate more positive attitudes toward S-L;
- Student attitudes toward the notion of citizen engineer are positive;
- Faculty and students report students being more motivated to learn basic course subject matter and spending more time voluntarily on S-L projects that reinforce subject matter;
- Indirect measures indicate subject matter comprehension is increasing, as for example, more time reported on course material; grades have increased in one large course with S-L;
- S-L projects generally require teamwork and communication; students and faculty report positive influences of S-L on these skills;
- The principle of "If some is good, then more is better," seems to hold in this case, at least based on past research; it appears that integration throughout the curriculum is a good way to achieve a wholesale change in attitude about the nature of the engineering profession, one that says that service and helping is a given, a part of the profession;

- A mixture of required and elective projects within required courses appears to reasonable, especially with elective projects in capstone courses where intrinsic motivation is very important;
- No additional coursework is added to incorporate S-L and to meet ABET objectives.

Longitudinal studies are under way to get more definitive answers to these research questions, particularly the fifth, seventh, and eighth questions above.

In closing, a unique program has been implemented to incorporate service-learning components into existing courses throughout an engineering curriculum so that every student on average has at least one course a semester with S-L available. The courses include 35 core required engineering science courses as well as design and introductory courses. This strategic objective has been met in four of five academic programs in the college with the fifth coming close this academic year of 2008–2009. That the outcomes of any pedagogy would be compelling enough for half of the faculty members in a relatively large college to adapt their teaching approach is a testament in itself to the experience here of S-L in core engineering science courses and is perhaps the most significant result to date. Thirty-four faculty members have committed to continuing using S-L in at least one of their courses; the college continues to provide a full-time S-L coordinator. So the prospects for sustainability of the program look good. The nature of the integration of S-L into existing courses makes this approach very easy to adapt by a single faculty member, a department, a college, or a university without a huge outlay of resources. Students are continuing to report coming and staying as a result of S-L to engage in engineering the common good.

ACKNOWLEDGMENT

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 UML. Thanks to all the faculty members in engineering and other colleges who have tried S-L in their courses as part of this program (they are all listed in the table in Appendix D. 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. We acknowledge also the assistance of evaluators Dwight Giles of U Mass Boston and Cathy Burack and Alan Melchior of Brandeis University.

REFERENCES

Abes, E. S., Jackson, G., & Jones, S. (2002). Factors that motivate and deter faculty use of service-learning. *Michigan Journal of Community Service Learning, 9* (1), pp. 5–17.

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

Astin, A., 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.* Retrieved 2009 5-February from Higher Education Research Institute, UCLA: http://www.gseis.ucla.edu/heri/PDFs/pubs/reports/UnderstandingTheEffectsOfServiceLearning_FinalReport.pdf

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

Banzaert, A., Duffy, J., & Wallace, D. (2006). Integration of service-learning into engineering core at U Mass Lowell and MIT. *American Society of Engineering Education 2006 Annual Conference Proceedings.*

Barrington, L., & Duffy, J. (2007). Attracting underrepresented groups to engineering with service-learning. *Proceedings American Socierty of Engineering Educatioin Annual Conference.* http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F14%2FAC%25202007Full2871.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Bhattacharjee, U., Lin, C., Williams, R., & Duffy, J. (2008). Solar energy education with service-learning: Case study of a freshman engineering course. *Proceedings Annual Meeting American Solar Energy Society (peer reviewed section).*

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

Bringle, R. G., Hatcher, J. A., & Games, R. (1996). Implementing service-learning in higher education. *The Journal of Higher Education, 67*, 221–239.

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.

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

Dewoolkar, M. M., George, L. A., Hayden, N. J., & Rizzo, D. M. (2009). Vertical integration of service-learning into civil and environmental engineering curricula. *International Journal of Engineering Education, 56* (6), 1257–1269.

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. http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F17%2FAC%25202008Full1163.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Duffy, J., Barrington, L., Moeller, W., Barry, C., Kazmer, D., West, C., et al. (2008). Service-learning projects in core undergraduate engineering courses. *International Journal of Service-Learning in Engineering,* Vol. 3, No. 2, pp. 18–41.

Duffy, J., Barrington, L., West, C., McKelliget, J., Niemi, E., Shina, S., et al. (2007). Service-learning in core courses throughout a mechanical engineering curriculum. *American Society of Engineering Education Annual Conference Proceedings.* http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F14-%2FAC%25202007Full2621.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2-Fpdf&charset=

Duffy, J., Kazmer, D., Barrington, L., Ting, J., Barry, C., Zhang, Z., et al. (2007). Service-learning integrated into existing core courses throughout a college of engineering. *Proceedings American Society of Engineering Education Annual Conference* (p. CD). Washington, DC: American Society of Engineering Education. http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F14%2FAC%25202007Full2639.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

EPICS. (2009). *EPICS/University*. Retrieved 2009 31-July from https://engineering.purdue.edu/EPICSU/

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

Hammond, C. (1994). Faculty motivation and satisfaction in Michigan higher education. *Michigan Journal of Community Service Learning, 1*, 42–49.

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

Kazmer, D., & Johnston, S. (2008). Lions and tigers and freshmen. *Proceedings of the Society of Plastics Engineers Annual Technical Conference.* SPE.

Kazmer, D., Duffy, J., & Perna, B. (2006). Learning through service: Analysis of a first college wide service-learning course. *American Society of Engineering Education Annual Conference Proceedings.* ASEE. http://search.asee.org/search/fetch?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F12%2F2006Full824.pdf&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Kazmer, D., Duffy, J., Barrington, L., & Perna, B. (2007). Introduction to engineering through service-learning. *ASME 2007 International Design Engineering Technical Conference Proceedings*, *IDETC/DEC-34491.*

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

Learn and Serve America. (2009). *Characteristics of Service-Learning*. Retrieved 2009 31-July from http://www.servicelearning.org/what_is_service-learning/characteristics/index.php

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

Madhumita, B. &. (2007). Faculty use of service-learning: perceptions, motivations, and impediments for the human sciences. *Michigan Journal of Community Service Learning, 14* (1).

Mathews, J., Ferguson, D., Huyek, M., & Pamulaparthy, A. (2006). Work in progress: Assessing student acquisition of knowledge of learning objectives for an interprofessional projects program. *Frontiers in Education Conference, 36th Annual* (pp. 7-8). San Deigo: IEEE. http://fie-conference.org/fie2006/papers/1720.pdf

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

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

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.

Zhang, X., Gartner, N., Gunez, O., & Ting, J. (2007). Integrating service-learning projects into civil engineering courses. *International Journal for Service Learning in Engineering, 2*, 44.

AUTHORS

John Duffy, Professor in the Mechanical Engineering Department and the Coordinator for the Solar Engineering Graduate Program at the University of Massachusetts Lowell. He is the faculty coordinator of the service-learning program in the college. He also leads the Village Empowerment program focusing service-learning projects in remote areas of the Peruvian Andes and in the Tohono O'odham Nation in Arizona.

Linda Barrington, Engineering Service-Learning Coordinator at the Francis College of Engineering, University of Massachusetts Lowell, holds BS degrees in Natural Science and Mathematics, Psychology and Mechanical Engineering, a Masters in Business Administration and a Graduate Certificate in Sustainable Infrastructure for Developing Nations. She worked for over twenty years administrating programs for community service agencies prior to joining academia.

Cheryl West, directs and provides oversight of grant development at Massachusetts Bay Community College based in Wellesley Hills, Framingham, and Ashland. Dr. West has conducted research in the areas of service-learning pedagogy, work environment, cleaner production, community-based needs, and trauma related resilience. Her program assessments have included engineering service-learning, wellness programs for healthcare workers in nursing homes, computer-based hazardous waste training, court-based child care, and special needs educational programs. Dr. West has a wide range of expertise in program development in STEM

programs, workforce development, environmental and public health initiatives, higher education partnerships, organizational dynamics, and conflict resolution among diverse cultural communities and organizations.

Manuel Heredia received his bachelor's degree in Mechanical Engineering from the National University of Engineering (Peru) and his master's of science in Energy Engineering from the University of Masachusetts Lowell (UML). Mr. Heredia is currently pursuing the Ph.D. degree in Solar Energy at UML. Since 2005, he has been Research Assistant for the Service-Learning Integrated throughout the College of Engineering project (SLICE).

Carol Barry is a Professor of Plastics Engineering at the University of Massachusetts Lowell. She is also an Associate Director of the NSF Center for High-rate Nanomanufacturing, a collaboration between Northeastern University, the University of Massachusetts Lowell, and the University of New Hampshire. In this capacity she oversees a three-University STEM education and outreach program which includes the "REU Site: Incorporating Ethical Decisions into Nanomanufacturing Research." Prof. Barry's research focuses on polymer manufacturing, specifically directed assembly of polymers and nanoparticles into nanoscale patterns, injection molding and nanoimprint lithography of nano and microstructured surfaces, extrusion of multilayered films, and compounding and forming of nanocomposites.