AC 2009-2160: SERVICE-LEARNING IN ENGINEERING SCIENCE COURSES: DOES IT WORK?

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Service-Learning in Engineering Science Courses: Does It Work?

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Abstract

In the fall of 2004 a college with five undergraduate academic programs decided 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 better citizens. 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 over the four years. 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. Eighteen different professors taught these engineering science courses with S-L projects, accounting for from 5 to 20% of the grades of the students. In addition, there were nine other elective courses with an additional 40 students on average per semester doing S-L projects. The goal has essentially been reached in four of the five engineering programs at the University of Massachusetts Lowell with more than fifty courses having S-L components. Over two-thirds of the students and faculty members expressed agreement with the basic idea of SLICE, with about 15% opposed. Some forty-three tenure-track faculty members (including 30% untenured) have integrated S-L into at least one required engineering course, averaging four S-L courses each. Finally, more than two-thirds of the students reported that S-L helped keep them in engineering, and female students reported being significantly more responsive to the S-L projects. This program represents perhaps the largest experiment with S-L in mainstream engineering courses in terms of courses, students, and faculty. This approach is based on a number of hypotheses, which are posited and “tested” with quantitative and qualitative data. Most of the hypotheses are confirmed with data collected to date from this program and literature results.

1. Service Learning

Although there are many definitions of service-learning (1), 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. 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 (1). The approach is also consistent with the recent change in paradigm in education from a focus on teaching to a focus on learning (2). In engineering, the goals 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 (3), as well as helping meet the well-known ABET criteria (a)-(k) (4). Astin et al. (5) 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 (3) 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.

Usually, service-learning is 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. 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, 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) in his article “Service-learning in engineering: A resource guidebook” 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 18 universities. The program involves elective interdisciplinary S-L courses that students can take from first year to senior year (6). Tsang (7) and Lima and Oakes (8) 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 four 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 criteria. In fact, most engineering work involves initial contact with clients (here community partners) to ascertain needs and then follows with design, analysis and manufacturing of a device (or system or study) and finishing with the 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.

In the current program, the S-L projects are designed to not add more class or homework time for students (by replacing existing “paper” projects). As a result 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 to meet with the client, who can sometimes live outside the U.S. 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.

Courses and projects include, for example, a first-year introduction to engineering course in which 420 students, divided into teams, designed and built moving displays illustrating various energy transformation technologies and recycling for 60,000 middle school students that annually visit a history center that is part of a national park. Another example is a sophomore kinematics course in which student teams visited local playgrounds to assess their safety using deceleration, force, and impact equations learned from the course. Junior heat transfer courses focused in analyzing heat loss and making suggestions for heating system savings for a local food pantry, a city hall building, and a community mental health center, as well as for the university itself; these analyses were developed and presented to the stakeholders. Sophomore student teams from the materials course presented findings to the staff of a local textile history museum to help it begin updating its displays on recent developments in materials. Junior fluids, junior circuits, senior microprocessor, senior design of machine elements, and senior capstone design 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.

1. **Hypotheses and Research Questions**

The fundamental hypotheses that SLICE is based upon include the following:

1. Faculty would accept S-L and faculty would develop into practitioners of S-L.
2. Students would accept S-L.
3. Recruitment and retention would increase, particularly among underrepresented groups.
4. Positive cognitive and affective changes would occur in students.
5. Students would learn academic subject matter better.
6. Teamwork, communication skills were increase;
7. Service-learning spread throughout the core curriculum is more effective than one intensive course;
8. A mixture of required and elective service-learning is more effective than either one or the other.
9. Service-learning could result in less coursework time than traditional programs satisfying ABET 2000 criteria.

The basic research then becomes testing these hypotheses. The testing of these hypotheses has been addressed through the following quantitative and qualitative data: straightforward counts of courses, faculty, students; fall “pre” surveys of entering students and spring “post” surveys of all
students; annual surveys of faculty; surveys 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 nine hypotheses is
discussed in section 3.

2. Evaluation Instruments and Results

Surveys are given to incoming students in an introduction to engineering course each fall on the
first day of class (n = 399 in 2008). “Post” surveys are given to the students in introduction to
engineering in December and are targeted to all undergraduate students at the end of the
academic year in May (n = 458 in 2008). Surveys are also given to faculty members once a year
(n = 53 out of 76 in May 2008). A limited number of interviews also have been undertaken with
faculty (n = 16 in 2007) with an experienced independent researcher(9). Also a limited number
of comparisons are possible when the students choose to place their ID number on the
questionnaire and their responses can compared over time. 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 pointed out a possible long-term outcome: “It [S-L] will
change the way we think about engineering. It adds an additional dimension.”

3.1 Faculty Impacts

Perhaps the most important outcome of the project so far is that almost half of the engineering
faculty has tried service-learning. In 2003-04, there was 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 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, just about half
the faculty.

Tables 1-3 present the results of the 2008 faculty survey. The 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 Table 1, the faculty
agreed with the three statements addressing course objectives and community needs, better
student learning, and academic rigor of the courses. These results were significantly (5% level in
a t-test) different from neutral (as indicated by the asterisk).

Table 1. Results of 2008 Faculty Survey, Part 1

<table>
<thead>
<tr>
<th>Question</th>
<th>N</th>
<th>Mean</th>
<th>Sig.</th>
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<tbody>
<tr>
<td></td>
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</table>

With service learning, it is possible to meet course learning objectives in a credit-bearing course while also meeting real community needs.  

<table>
<thead>
<tr>
<th>Statement</th>
<th>Mean Score</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>When service-learning is done well, students learn the subject matter better than in a traditional classroom.</td>
<td>6.68</td>
<td>*</td>
</tr>
<tr>
<td>Service-learning courses can be academically rigorous.</td>
<td>6.40</td>
<td>*</td>
</tr>
</tbody>
</table>

1= Strongly Disagree, 5=Neutral or don’t know, 9=Strongly Agree

Faculty who incorporated service learning into their courses found that, “when well integrated, the service learning can strengthen the course curriculum.” 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. Faculty reported these projects “benefit students as well as client” and “show the students their learning can have immediate impact to the community.”

The reasons given for not trying S-L were content, time, and finding acceptable projects. One faculty member summarized this content issue as: “the academic semester is so tight it is hard enough just to cover the academic content of the course. If service learning is added, then something important will need to be dropped -- that’s not acceptable.” Another group cited the need for fundamentals before service-learning; for example, “the course I am teaching is a very fundamental course [that] the students have to learn before they start service.” Other cited that service-learning was “not relevant,” particularly given that they were teaching graduate courses.

Many faculty members mentioned 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.” Other faculty felt that they lacked time in their schedules for development of service-learning curricula. For example, one professor said that you “can’t do it all” – i.e., adding S-L plus having “a full teaching load, running multi-million dollar lab, and having full research schedule (with no support staff).” Although there was a small stipend associated with developing service-learning curricula, some faculty felt that stipend was not a measure of the time required to implement S-L projects. Junior and senior faculty who implemented S-L did so because such projects benefited their students. Thus, service-learning was a labor of love.

Other faculty cited the inability to find a relevant project. This issue has been significant for design and process courses in some disciplines because the course product, such as a tooling or
process design, is more industrially relevant. Moreover, for some courses, it has also been “difficult to find projects that can involve S-L and also [meet] time limitations.” In some cases, S-L projects have been split into smaller sections to enable students to complete a section within a homework assignment or semester-long project. This approach, however, does not work with all projects.

The progress of the service-learning initiative has been presented to the entire faculty of the College of Engineering each semester at the faculty retreat. As indicated in Table 2, the faculty agreed that “in principle, service-learning would be beneficial to the students in the courses I teach” and “in principle with the goal of having at least one service-learning course available every semester for every undergraduate in our college of engineering.” There is still no consensus over whether “it is possible to integrate service-learning into existing engineering courses without adding to the overall workload of students by replacing existing overall workload of students by replacing existing homework, projects, lab experiments, lectures, etc. with similar activities solving real problems in the community.” The faculty also agreed that “with service-learning, students become better citizens” (6.42) and that “service-learning can be an effective way to increase the involvement of women and other underrepresented groups in engineering (5.91).

<table>
<thead>
<tr>
<th>Question</th>
<th>N</th>
<th>Mean</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>In principle, service-learning would be beneficial to the students in the courses I teach</td>
<td>53</td>
<td>6.57</td>
<td>*</td>
</tr>
<tr>
<td>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.</td>
<td>53</td>
<td>6.57</td>
<td>*</td>
</tr>
<tr>
<td>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.</td>
<td>53</td>
<td>5.02</td>
<td></td>
</tr>
<tr>
<td>With service-learning, students become better citizens.</td>
<td>53</td>
<td>6.42</td>
<td>*</td>
</tr>
<tr>
<td>Service-learning can be an effective way to increase the involvement of women and other underrepresented groups in engineering.</td>
<td>53</td>
<td>5.91</td>
<td>*</td>
</tr>
</tbody>
</table>

1= Strongly Disagree, 5=Neutral or don’t know, 9=Strongly Agree

Overall, most faculty felt that service-learning enhanced student learning. One faculty stated that:
“[The] program is great. It is a form of active learning that provides client interaction and real human needs. The primary limitation is the formation of a project around the required content of the course. An "academic" project can be better targeted, though the [S-L] projects provide a different set of learning outcomes.”

Another faculty member reported that:

“Students are highly motivated by engaging project work and I always feel that projects improve the quality of education. [The S-L program] has done a great job supporting project initiatives and assisting in the development of new projects. My firm belief in the benefits of projects coupled with the support of [the S-L program] has been the main reason why I incorporate [S-L] projects. “

The effect of department/discipline on the survey’s answers was studied using a comparison between the answers obtained from mechanical department; the department that has the biggest number of S-L involved courses, with other departments. The results of this survey are shown in Figure 1. In general, the faculty agreed that (a) “with service learning, it is possible to meet course learning objectives in a credit-bearing course while also meeting real community needs,” (b) “when service-learning is done well, students learn the subject matter better than in a traditional classroom,” (c) “service-learning courses can be academically rigorous,” and (c) with service-learning, students become better citizens. There was greater agreement from mechanical and civil engineering faculty, probably because service-learning projects have fit more easily into a wider range of courses in these disciplines. In electrical and computer engineering, service-learning is generally tied to assistive technology projects – although new projects have recently been added – and with chemical and plastics engineering, appropriate service learning projects are hard to find. This department-specific difference in the integration of service-learning is more significantly reflected in last two statements. For statement (f) “in principle, service-learning would be beneficial to the students in the courses I teach,” the level of agreement decreased as civil, mechanical, electrical, and plastics engineering, with chemical engineering faculty being neutral on statement. Faculty in chemical and plastics engineering also disagreed with statement (h) “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.”
Figure 1. Faculty attitudes by department - from the 2008 survey – with the questions being:
(a) with service learning, it is possible to meet course learning objectives in a credit-bearing course while also meeting real community needs,
(b) when service-learning is done well, students learn the subject matter better than in a traditional classroom,
(c) with service-learning, students become better citizens,
(d) service-learning can be an effective way to increase the involvement of women and other underrepresented groups in engineering,
(e) service-learning courses can be academically rigorous,
(f) in principle, service-learning would be beneficial to the students in the courses I teach, and
(h) 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.

The attitude toward service-learning differed significantly between male and female faculty members (Figure 2). Female faculty strongly agreed with statements (a) to (c), and (f) to (g) while male faculty members were in agreement, but were less enthusiastic. Overall, female faculty members scored the statements at 8 whereas their male colleagues provided an overall score of about 6. Moreover, female faculty agreed with the last statement - “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;” overall, their male colleagues disagreed with this statement. These differences may be attributed to gender-based attitudes towards the societal impacts of engineering, but more probably 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, many men have been faculty
for 30 to 40 years. As discussed next, the younger faculty tended to be more enthusiastic about implementing S-L projects.

![Bar chart showing faculty attitudes by gender](image)

**Figure 2.** Faculty attitudes by gender - from the 2008 survey – with the questions being:

(a) with service learning, it is possible to meet course learning objectives in a credit-bearing course while also meeting real community needs,

(b) when service-learning is done well, students learn the subject matter better than in a traditional classroom,

(c) with service-learning, students become better citizens,

(d) service-learning can be an effective way to increase the involvement of women and other underrepresented groups in engineering,

(f) in principle, service-learning would be beneficial to the students in the courses I teach,

(g) 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, and

(h) 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.

As illustrated in Figure 3, untenured faculty exhibited a one-point greater agreement with the statements (a) “with service learning, it is possible to meet course learning objectives in a credit-bearing course while also meeting real community needs,” (c) “with service-learning, students become better citizens,” and (f) “in principle, service-learning would be beneficial to the students in the courses I teach.” They also showed a half-point greater agreement with the statements (b) “when service-learning is done well, students learn the subject matter better than in a traditional classroom,” (e) “service-learning courses can be academically rigorous,” and (g) “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.” Interestingly, both tenured and untenured tenured faculty showed similar (and lesser) agreement with the last statement “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.” Overall, the untenured faculty members have been willing to try service-learning projects in many of their undergraduate courses. Although not all these projects have been 100% successful, fewer untenured faculty members have refused to even consider incorporating S-L into appropriate courses.

Figure 3. Faculty attitudes by on tenure status - from the 2008 survey – with the questions being:
(a) with service learning, it is possible to meet course learning objectives in a credit-bearing course while also meeting real community needs,
(b) when service-learning is done well, students learn the subject matter better than in a traditional classroom,
(c) with service-learning, students become better citizens,
(e) service-learning courses can be academically rigorous,
(f) in principle, service-learning would be beneficial to the students in the courses I teach,
(g) 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, and
(h) 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.

3.2 Impact on Faculty Teaching

The faculty were asked how S-L affected the following series of statements: (a) my knowledge of issues and resources in the community, (b) my emphasis on community issue/problems in my class or program, (c) my use of community issues and resources in my class or program, (d) my use of information about Lowell in teaching about community issues in my class, (e) my emphasis on the importance of examining public policy in teaching about community issues in
my class, (f) my use of student-led projects in my teaching, (g) amount of discussion of 
controversial/ community issues, (h) amount of time I spend lecturing, (i), my belief that students 
can make a difference in their communities, (j) my personal commitment to improving the 
community, (k) my enjoyment or satisfaction with teaching, (l) my ability to address ABET 
outcomes in my teaching, (m), my day-to-day workload, (n) my access to resources and people, 
(o) the existence of partnerships between my College or program and other organizations in the 
community, (p), the use of community issues in the class or program by other faculty in the 
College or community organization, (q) my role as a resource for colleagues in my College or 
program, (r) my connections with other engineers who share my interests and ideals, (s) my 

sense that I am confident and capable as an educator, and (t) my sense of pride and satisfaction 
with the UML engineering program. This survey required reporting on a Likert scale of 1-9, 
with 1 being “strongly disagree” and 9 being “strongly agree.”

Figure 4 presents this impact by discipline. The responses for statements (a), (c), (f), (i) to (m), 
(o) and (s) exhibited the same trend. Faculty from civil and mechanical engineering more 
strongly agreed with these statements; they were followed by electrical engineering, plastics 
engineering, and chemical engineering faculty. Often the responses engineering, and chemical 
engineering faculty were disagreement with the statements. These responses reflected the ability 
to incorporate S-L projects and the type of S-L projected employed in these disciplines. 
Mechanical and civil engineering projects tended to examine community infrastructure, both 
locally and globally. Electrical engineering projects were often based on assistive technology. 
Projects selected for chemical and plastics, engineering, however, were more diverse and 
sometimes more abstract.

A different response was observed for statements (d) “my use of information about Lowell in 
teaching about community issues in my class” and (e) “my emphasis on the importance of 
examining public policy in teaching about community issues in my class.” Civil engineering 
faculty more strongly agreed with these statements. Electrical, mechanical, and plastics 
engineering faculty gave neutral responses, whereas chemical engineering faculty disagreed with 
statements. This pattern again reflects the level of S-L integration and the type of S-L projects. 
Many civil engineering projects involved local community partners.
Figure 4. Impact of service-learning on faculty teaching: (a) my knowledge of issues and resources in the community, (b) my emphasis on community issue/problems in my class or program, (c) my use of community issues and resources in my class or program, (d) my use of information about Lowell in teaching about community issues in my class, (e) my emphasis on the importance of examining public policy in teaching about community issues in my class, (f) my use of student-led projects in my teaching, (g) amount of discussion of controversial/community issues, (h) amount of time I spend lecturing, (i), my belief that students can make a difference in their communities, (j) my personal commitment to improving the community, (k) my enjoyment or satisfaction with teaching, (l) my ability to address ABET outcomes in my teaching, (m), my day-to-day workload, (n) my access to resources and people, (o) the existence of partnerships between my College or program and other organizations in the community, (p), the use of community issues in the class or program by other faculty in the College or community organization, (q) my role as a resource for colleagues in my College or program, (r) my connections with other engineers who share my interests and ideals, (s) my sense that I am confident and capable as an educator, and (t) my sense of pride and satisfaction with the UML engineering program

For all statements, female faculty again showed greater agreement with the male faculty (Figure 5). In addition, the untenured faculty was also more impacted by service-learning (Figure 6).
3.3 Student Impacts

The analyzed post-questionnaire surveyed 458 students in the College of Engineering in the spring of 2008. Of these students, 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. As shown in Figure 7, these students had taken as many as 19 previous courses with a S-L component.

Figure 7. Courses with S-L projects previously taken by students surveyed in spring 2008.

Table 3 presents the results of the spring 2008 student survey. These 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.

Table 3. Results of the Spring 2008 Student Survey

<table>
<thead>
<tr>
<th>Statement</th>
<th>Spring 2008 Student Survey</th>
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<tbody>
<tr>
<td>I enjoy learning</td>
<td>448</td>
<td>7.81</td>
<td>*</td>
</tr>
<tr>
<td>I learn more when courses contain hands-on activities</td>
<td>448</td>
<td>7.89</td>
<td>*</td>
</tr>
<tr>
<td>The things I learn are useful in my life</td>
<td>448</td>
<td>7.03</td>
<td>*</td>
</tr>
<tr>
<td>Social problems are not my concern</td>
<td>446</td>
<td>3.80</td>
<td>*</td>
</tr>
<tr>
<td>People who receive social services largely have only themselves to blame for needing services</td>
<td>444</td>
<td>4.25</td>
<td>*</td>
</tr>
<tr>
<td>Most social problems are easy to solve</td>
<td>445</td>
<td>3.77</td>
<td>*</td>
</tr>
<tr>
<td>I plan to do something to improve my community in the near future</td>
<td>445</td>
<td>6.25</td>
<td>*</td>
</tr>
<tr>
<td>It is important to be involved</td>
<td>442</td>
<td>6.30</td>
<td>*</td>
</tr>
<tr>
<td>It is not necessary to volunteer</td>
<td>439</td>
<td>4.25</td>
<td>*</td>
</tr>
<tr>
<td>I am concerned about community issues</td>
<td>442</td>
<td>6.06</td>
<td>*</td>
</tr>
</tbody>
</table>
These students agreed that social problems not easily solved and required everyone’s input. They students felt agreed that “it is important to be involved” (6.30), “service and academic coursework should be integrated” (6.44), “engineers should use their skills to solve social problems” (6.74), and “it is important to have a career that involves people (6.25). 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. Overall, they agreed with statements “I have a realistic understanding of the daily responsibilities” and “I feel well prepared for my future career.” Students are evenly divided as to whether the S-L projects should be mandatory in courses. One important tabulation from the December 2006 first year student survey, however, is that 21% of first year students agreed to the statement that S-L was one of the reasons for coming to UML (n = 208).

The orientation of students to service was also examined for students in the five engineering disciplines (Figure 8). Students in engineering disciplines agree that they can have an impact of solving problems; that it is important to be involved; and that having a career that involves people is important. In these aspects, the electrical engineering students agreed less strongly than students in the other disciplines. Most students were neutral with respect to the importance of influencing the political structure. Students in all disciplines agreed that they were prepared for their future career.
Figure 8. Effect of discipline on students’ responses to selected survey statements.
As illustrated in Figure 9, the students’ status had limited impact on their desire to perform service. Freshman, sophomores, juniors, and seniors agreed equally that service and academic coursework are important, that engineers should use their skills to benefit humanity, and that it is important to be involved; they also felt that working in teams was not a waste. Seniors, however, agreed more strongly with the statements “I have a realistic understanding of the daily responsibilities,” “I feel well prepared for my future career,” and “I have a close working relationship with faculty.” These responses may have been due to the student’s involvement in capstone design projects, which typically provide the student greater interaction with individual faculty and more control of their project.
Figure 9. Effect of student status on their responses to the 2008 survey.

As with the faculty, female students responded more positively (at the 5% level) to service-related work than male students (Figure 10). Generally, the differences were typically 0.5 to 1.0 points on the Likert scale.

The impact of service-learning is presented in Table 4. Overall, the students felt that S-L improved their ability to make a difference in their communities, their communication skills, their teamwork and project skills, and their interest in engineering.
Figure 10. The effect of gender on student responses to the 2008 survey.

Table 4. The Impact of S-L on Students (from Spring 2008 Survey)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Spring 2008 Student Survey</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>Sig.</td>
</tr>
<tr>
<td>a) I can make difference in the community</td>
<td>368</td>
<td>6.15</td>
<td>*</td>
</tr>
<tr>
<td>b) My interest in learning</td>
<td>369</td>
<td>6.40</td>
<td>*</td>
</tr>
<tr>
<td>c) Involved in community issues</td>
<td>367</td>
<td>6.32</td>
<td>*</td>
</tr>
<tr>
<td>d) Ability to write and speak about comm.</td>
<td>367</td>
<td>6.29</td>
<td>*</td>
</tr>
<tr>
<td>e) My ability to find information</td>
<td>367</td>
<td>6.23</td>
<td>*</td>
</tr>
<tr>
<td>f) My ability to evaluate information</td>
<td>367</td>
<td>6.44</td>
<td>*</td>
</tr>
<tr>
<td>g) My decision-making skills</td>
<td>368</td>
<td>6.68</td>
<td>*</td>
</tr>
<tr>
<td>h) My leadership skills</td>
<td>368</td>
<td>6.59</td>
<td>*</td>
</tr>
<tr>
<td>i) My understanding of value of teamwork</td>
<td>368</td>
<td>6.55</td>
<td>*</td>
</tr>
<tr>
<td>j) My ability to carry out a project</td>
<td>364</td>
<td>6.47</td>
<td>*</td>
</tr>
<tr>
<td>k) Interest in volunteering</td>
<td>367</td>
<td>5.98</td>
<td>*</td>
</tr>
<tr>
<td>l) My school pride</td>
<td>368</td>
<td>5.80</td>
<td>*</td>
</tr>
<tr>
<td>m) Continue in engineering</td>
<td>369</td>
<td>6.82</td>
<td>*</td>
</tr>
</tbody>
</table>

Mean responses to Likert scale of 1 (disagree) to 5 (neutral) to 9 (agree)

2.4 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 above, 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.

2.5 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 (10), the focus of the capstone EE courses, and Village Empowerment Program (11), which serves as a source of projects for 20 different courses at UML. The assessment of community impacts is important and ongoing, but its reporting is beyond the scope of this paper.

3. Summary of Results and Hypotheses Tested

Briefly summarized below in answer to the hypotheses posed in Section 2 are the results above and other results to date that have been reported in other papers (12) (13) (14) (9) (15) (16) (17) (11) (18) (19) (20).

1. Faculty would 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 the future; the actual number of faculty to use S-L is expected to be higher.

2. Students would 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. **Recruitment and retention would increase, particularly among underrepresented groups.** The number of entering students has increased 50% in the four years SLICE has been in existence. Twenty-three percent of incoming students report that S-L was one of the reasons for 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 number 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. These results are discussed in more detail in a companion paper in this proceedings.

4. **With S-L students would be more motivated to learn subject matter; certain attitudes would change with S-L.** 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. **Students would 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 (18)(19). Students in SLICE surveys discussed above reported voluntarily spending more time on S-L tasks and being more motivated to learn the subject matter. Faculty agree 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 (8). 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.

6. **Teamwork, communication skills would 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.

7. **Service-learning spread throughout the core curriculum is more effective than one intensive course.** Although there is some evidence to support this hypothesis in the literature (3) 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. This approach is what we are in the process of doing 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.

8. **A mixture of required and elective service-learning is 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 (3) or not (23). 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. **Service-learning could result in less coursework time than traditional programs satisfying ABET 2009 criteria.** The response to the infamous a-k outcome requirements of ABET 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.

In short there is no data upon which to reject any of these hypotheses. There are quantitative and qualitative data upon which to accept the hypotheses presented next.

4. **Conclusions**

Again, the data suggest the following conclusions:
- half the faculty and essentially all 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 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 the only 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 and hypothesis tests, particularly the fifth, seventh, and eighth hypotheses 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.
5. **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. 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.

6. **References**


