AC 2010-2172: STUDENT VOICES: SERVICE-LEARNING IN CORE ENGINEERING COURSES

Cheryl West, UMass Lowell
Research Associate, College of Engineering

John Duffy, University of Massachusetts Lowell
Professor, Mechanical Engineering Department

Manuel Heredia, University of Massachusetts, Lowell
Doctoral Student, Renewable Energy Engineering Program

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

Student Voices: Service-Learning in Core Engineering Courses

Abstract

Undergraduate engineering students were asked about their views of the principal benefits attributable to service-learning (S-L) dispersed through core required courses through surveys, interviews, and focus groups. As S-L continues to become a significant part of the community-engagement movement in higher education, and as more university professors are encouraged to incorporate S-L activities in their course requirements, it is essential that educators build an understanding of what students gain with S-L and that they give students a voice in their own educational process and in the community. The service-learning (S-L) program SLICE (Service-Learning Integrated throughout a College of Engineering), based within the Francis College of Engineering at the University of Massachusetts Lowell, began as a curricular reform initiative designed to sequentially infuse S-L throughout engineering curriculum as a broad approach to promote development of better engineers, more engaged citizens, along with engineering the common good in communities. Chemical, Civil, Electrical, Mechanical, and Plastics Engineering departments within the college integrated S-L activities into 192 course offerings (5 intro, 65 ME, 32 EE, 47 CE, 31 PlE, 12 ChE) across the last five years that involved an average of 753 undergraduate students each semester carrying out S-L projects. Half of the faculty has been involved.

In order to discover student views about S-L activities in engineering courses, and to better understand why students seem more motivated to learn with S-L, administration of 399 pre-S-L surveys and 458 post-S-L surveys were conducted with freshmen students; 526 post S-L student surveys at the end of the 2009 academic year; and 100 interviews, including some focus groups with undergraduate students and 5 alumni in 2009. Based on overall quantitative and qualitative data, students reported that S-L provided an important element of their education that encourages deepened and meaningful learning benefits. The outcomes are based on the total number of participants that responded to surveys across five years, as well as interviews, and focus groups. In short, engineering student voices are calling for more S-L projects integrated into core courses, for more direct community interactions, for meaning to what they are studying, and for empowerment to provide useful service to the community at all levels in their studies.

Keywords: Service-Learning, Diffuse Pedagogies, Qualitative Research

Introduction

As service-learning (S-L) continues to become a significant part of the community-engagement movement in higher education and as more engineering professors incorporate S-L activities into their course requirements, a research window exists for documenting evidence on the impacts of S-L on students. The service-learning (S-L) program SLICE (Service-Learning Integrated throughout a College of Engineering), based within the Francis College of Engineering at the University of Massachusetts Lowell is a National Science Foundation (NSF) funded program that began as a curricular reform initiative designed to infuse S-L sequenced throughout engineering curriculum. The strategic objective was to have at least one course with a S-L project each semester for students in a typical undergraduate degree sequence. This approach has broad goals to promote development of better engineers, more engaged citizens, along with engineering the common good in communities. Extensive integration of S-L into core required engineering courses within five engineering departments: Chemical, Civil, Electrical, Mechanical, and Plastics, has provided various research opportunities to assess impacts of S-L on students.

The SLICE program began in the fall of 2004, at the University of Massachusetts Lowell and has been supported by volunteer efforts of many students, faculty, administrators, and community partners as well as financial support of the National Science Foundation and the university. As a unique feature of the college, the S-L initiative was undertaken in order to provide undergraduate engineering students at least one course containing a S-L experience in each semester throughout their engineering curricula and to assess impacts of S-L experiences on students, as well as faculty, community, administration, and industry. Over the last five years, S-L has been incorporated into 103 out of 128 possible "target" courses to various degrees ranging from 5 to 60% embedment of course learning objectives, and up to 30% of a student's course grade (and 100% in capstone courses). Each semester, 753 students on average were exposed to S-L semester during their engineering program with an overarching goal to graduate better engineers and citizens. Primary S-L research on student impacts conducted through student surveys, interviews, and focus groups are reported in this paper. Additional assessments reported elsewhere (Banzert et al., 2006; Barrington & Duffy, 2007; Bhattacharjee et al., 2008; Burack et al., 2008; Duffy, 2000; Duffy et al., 2008; Duffy, 2008; Kazmer et al., 2006).

The SLICE program defines "service-learning" (S-L) as "a hands-on learning approach in which students achieve academic objectives in a credit bearing course by meeting real community needs." In addition to our S-L program definition, there are a number of definitions used in the literature (Jacoby, 1996; Bringle and Hatcher, 1995; Stanton et al., 1999; Learn and Serve America, 2009). However, key elements that appear to be important to researchers and practitioners include: projects or placements that meet academic objectives in a credit-bearing course, the meeting of real community needs, analysis or reflection on the part of students to relate the service to the subject matter of the course, and reciprocity with the community partner. The approach of S-L, with its roots in experiential learning, is consistent with the theories and empirical research of a number of leading educators and developmental psychologists, as documented by (Jacoby, 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 of S-L is to have students become better professionals and better citizens while the community also benefits.

The following sections summarize benefits of S-L for students reported in recent literature, the purpose of this study, research methodologies employed in this study, assessment findings, and a discussion of implications for educating the workforce of our future engineers.

Service-Learning (S-L) Benefits for Engineering Students

It is generally acknowledged that students engaged in S-L experiences as part of their required coursework are provided with opportunities to gain practical application within real-world settings in ways that have been shown in the past to have a positive effect on students in a wide variety of cognitive and affective measures including critical thinking and tolerance for diversity. Recent literature suggests that S-L leads to better knowledge of course subject matter, cooperative learning, recruitment of underrepresented groups in engineering, retention of students, citizenship as well as the meeting of engineering education criteria (ABET 2000 criteria a-k, well known to engineering educators, (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 that included: 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: personal development, interpersonal development, and community-to-college connections. Students reported working harder, being more curious, connecting learning to personal experience, and demonstrated deeper understanding of subject matter. They found that S-L is more effective over four years and that the messiness inherent in helping solve real community-based problems enhances the positive effects. Messiness also seems to result in positive intellectual development in general, based on several different models, nicely summarized in Chapter 2 of Pascarella and Terenzini (2005). 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.

Models of Service-Learning (S-L) in Engineering Education

Service-learning is often applied in elective courses where instructors have more freedom in the topics that are covered and more freedom to decide on the time that needs to be allotted for each topic (e.g., EPICS, (Coyle, Jamieson, & Sommers, 1997)). However, engineering curricula have numerous requirements, leaving little time for students to take elective courses outside their established programs of study. 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 through the SLICE program 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. The EPICS program involves elective interdisciplinary S-L courses that students can take from first year to senior year. 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 U Mass Lowell has integrated service-learning into many of its core required undergraduate courses over the last five years. In the current program, the S-L projects are intended to replace existing "paper" projects so they do not add more class or homework time for students. Courses and projects include and address a wide range of topics, and require thoughtful and often rigorous application of foundational engineering knowledge and skills. The SLICE model and delivery of S-L disperses and sequences S-L activities within core courses, yet was initiated at the "grass roots" by one faculty member (Duffy J. J., 2000) in ME and two in EE (ATP, 2009) several years earlier. The Dean (John Ting) and five department chairs lent their support, and community partners were approached in 2004. From the beginning, faculty have been encouraged to "start small rather than not at all," and have been supported with biweekly community of practice gatherings.

Examples of S-L projects and courses include junior heat transfer courses focused on analyzing heat loss and developing suggestions for cost effective heating system improvements for a local food pantry, a city hall building, a community health center, as well as for areas of the university. Other examples of S-L integration include sophomore kinematics, sophomore materials, junior fluids, junior circuits, senior microprocessor, senior design of machine elements, senior capstone design, as well as freshmen introduction to engineering courses (Kazmer, Duffy, Barrington, & Perna, 2007) (Kazmer & Johnston, 2008) in which 420 students divided into teams, to design and build energy transformation technology displays for a history center that is part of a national park visited by 60,000 middle school students annually.

Over 100 community partners have been involved with the SLICE projects (http://slice.uml.edu). Some of the community impacts are profound in the areas of the SLICE Program, especially the focus of the capstone EE courses, and the Village Empowerment Program (Duffy J. , 2008) that serves as a source of projects for 27 different courses at UMass Lowell and elsewhere. Lives at the local, state, national and global level are enhanced through student S-L projects. Moreover, participants in our Village Empowerment S-L projects in Peru report, "lives have been saved."

Purpose of the Study

The purpose of this SLICE initiative study was to utilize a mixed method approach of both quantitative and qualitative research methods to gather and assess perspectives regarding experiences and impacts of S-L on undergraduate engineering students. This research began as an examination of benefits and learning outcomes, with a focus on developing a better understanding of the use of S-L as a pedagogical tool from the experience and viewpoint of engineering students. The current study builds upon five years of annual student surveys that investigated some of the principal benefits attributable to S-L experiences from a student perspective.

One of the anticipated findings was that student perspectives and attitudes regarding their S-L experiences would differ by academic level and potentially by engineering discipline, as well as by gender. In general, we expected that the senior and junior students would place more weight upon benefits of S-L than would freshmen and sophomore students. We predicted that engineering alum would provide added insight regarding continued impacts of S-L post graduation. Hence, the authors were interested in whether the S-L experience(s) provided evidence, from a student's and alum's perspective, towards development of academic, professional, personal and interpersonal skills in ways that address ABET criteria (Accreditation Board for Engineering and Technology [ABET], 2009). Key research questions inquired about the impact of S-L on recruitment and retention rates, particularly among underrepresented groups; whether positive cognitive and affective changes would occur in students; impacts on students learning academic subject matter better; whether teamwork, communication skills would increase; if S-L spread throughout core curriculum was more effective than in one intensive course; and if a mixture of required and elective S-L activities were more effective than either one or the other. Answering these questions to various degrees was addressed through methodologies described next. Then how this mixed method data addresses overarching research questions is presented in the findings, and summarized in the discussion and conclusion sections.

Methodology

This study draws upon an engineering student population based in the North Eastern part of the United States and employed a mixed method approach of survey, interview, and focus group, methodologies to research and advance better understanding of S-L impacts on engineering students. In addition, this study seeks to investigate impacts of the SLICE model of and delivery of S-L dispersed and sequenced into core courses. The diffuse nature of this approach presents challenges in assessing and studying its effectiveness. Hence, our mixed method approach includes advantages of qualitative research methods that more deeply probe the "why" behind student responses in relation to their perspectives, opinions, experiences and impacts.

The survey developed for the study was extensively utilized across five years of the SLICE program with perhaps one of the largest cohorts in S-L engineering, was designed to capture impacts of S-L on engineering students. Approximately 2,400 student surveys were administered and analyzed as a part of this study. As an example of the numbers of surveys administered each year, in the recent academic year 2008-09, surveys were given to incoming students in an introduction to engineering course each fall on the first day of class (n = 399 in 2008). "Post" surveys were given to the students in introduction to engineering in December (n = 328 in 2008) and were targeted to all undergraduate students at the end of the academic year in May (n = 526 in 2009). A limited number of comparisons were possible when students chose to place their student ID number on the questionnaire, which enabled comparison of their responses over time.

Student comments included at the end of post S-L surveys additionally supplemented qualitative data, primarily obtained through semi-structured in-depth interviews and focus groups with 100 U Mass Lowell undergraduate engineering students and 5 alumni. A convenience sampling of students were recruited for interviews and focus groups through flyer distribution and class announcements within each department of Civil, Chemical, Electrical, Mechanical and Plastics Engineering. A total of 78 males and 28 females (39 seniors, 33 juniors, 6 sophomore, and 22 freshmen) volunteered for the interview and focus group portion of the study, with undergraduate students indicating that they were 11 chemical, 22 civil, 15 electrical, 23 mechanical, and 28 plastics engineering students. In addition, a convenience sampling of 5 U Mass Lowell engineering alum employment recruiters were enlisted for voluntary interviews during an Engineering & Technical Career Day Fair in April 2009. Alum recruits were comprised of 3 male and 2 female engineering graduates employed in various engineering related industry roles (domestic-international). Over a five-month period during April to August 2009, in-depth interviews and focus groups were conducted utilizing the same protocol and inquired about each participant's S-L experiences and associated impacts on their perspectives, learning and future career roles, along with additional comments or recommendations.

Surveys, interviews and focus groups were conducted under U Mass Lowell Institutional Review Board (IRB) approval by external and internal evaluators during each year of the S-L project. Surveys and interviews were coded to protect participant identity. Each interview and focus group participant was assured confidentiality of his or her responses, with no attribution in reporting. Key results and broad findings are presented in the following section.

Results

Student Survey Findings

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 first year students represented 33% of the sample, sophomore 18%, juniors 26%, and seniors 23%. The engineering total student population for 2008-09 was 1169 (institutional research office).

The mean responses for attitudes towards S-L, teamwork, communication, hands-on learning, commitment toward helping communities that were tabulated from the pre and post surveys from

2009 going back to 2004 can be viewed online (http://slice.uml.edu). In general, student surveys gathered and analyzed across five years indicated that students strongly agreed that they enjoyed learning, learned more from hands-on activities, and used what they learned in their lives. They reported a preference for working in groups. The students agreed that social problems are not easily solved and required everyone's input. 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 were 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 U Mass Lowell.

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. As an illustration, Figure 1 shows the difference in mean Likert scale responses for male and female students responding to the question: To what extent have the service-learning projects this year had an effect on "the likelihood that I would continue in engineering."

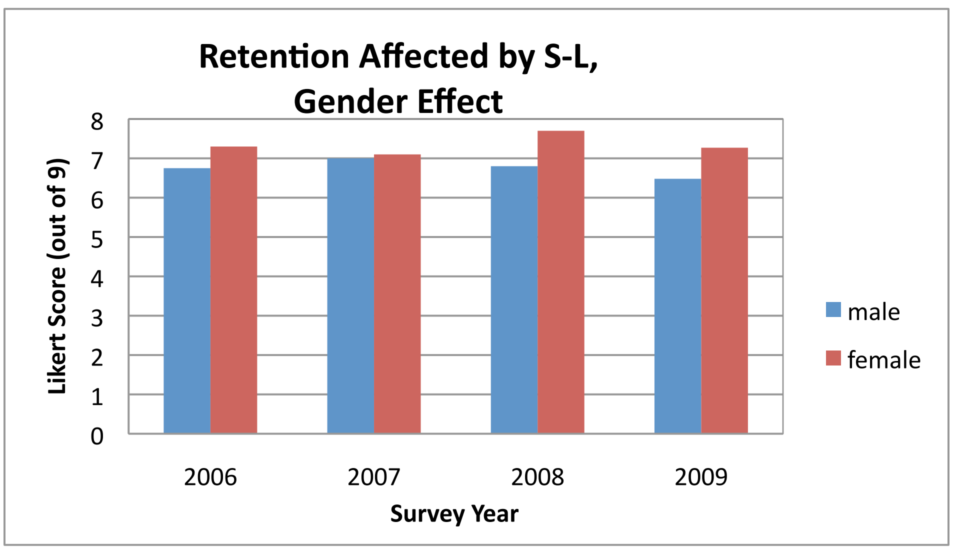

Figure 1. Mean response to retention effect by gender over four years of student surveys.

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. The pre surveys were given only to first year students, as were the fall post surveys. The spring surveys were given to all levels of students, even though the majority of the samples were from juniors and seniors. Note that the comparisons over time were not from the same populations except for post to post 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 were observed between the spring 2009 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, students were individually tracked over time. However, there were not that many matches; students were not required to give their ID numbers (nor to take the survey at all), in accordance with IRB guidelines. For example, 32 matches were made from the pre fall 2006 to spring 2009 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." Some significant changes occur in other matching between years, but no consistency is shown except for the faculty member relationship question. The issue seems to be with the small sample or the short interval. There were more matches over shorter time periods, for example, matching pre and post surveys in the same class, introduction to engineering. There were 128 matches in the fall of 2007. A few more differences were seen, such as, more agreement with the statements that "engineers should use their skills to solve social problems" and that "it is important to me personally to have a career that involves helping people." It appears that future tracking of the larger number of students now with IDs will pay off in subsequent years. A number of voluntary student comments and suggestions included at the end of post S-L surveys indicated that S-L had provided many learning opportunities and motivation for participants to continue in their engineering education and field.

Student Interview and Focus Group Findings

Overall, students reported S-L as being an important part of their educational experience at U Mass Lowell, which they commented on as a significant approach to prepare them for the *"real world, and to think outside the box,"* and that S-L "*gives projects a purpose, rather than just a grade*." In general, students expressed being more motivated to learn, work harder, and changed through their S-L experiences. For the most part, S-L was and is accepted by the majority of students within the engineering programs. Engineering alum reported being changed by their S-L experience, continued to integrate service as a part of their professional roles, and recommended that S-L be required for all engineering students.

An overview of 100 student participant interviews and focus groups resulted in the following S-L impacts and benefits reported by students in regards to their S-L experiences:

- 82% reported being more motivated and working harder;
- 73% experienced deeper subject matter learning;
- 68% indicated gains in critical thinking, problem solving, teamwork, and communication skills;
- 59% stated enhanced belief in their abilities to make a difference and be productive;
- 32% reported résumé and potential occupational enhancements; and
- 29% described their coursework as more interesting and engaging with S-L.

In terms of being more motivated and working harder, students discussed elements of S-L that dynamically provided: a sense of purpose; a catalyst to do more research and ask more questions than usual; as well relevant, creative, and useful learning opportunities that were personally rewarding. Students related that S-L motivation resulted in their increased interest in conducting more research and information gathering for S-L assignments and projects, as well as being more creative in their approaches and feeling that their efforts may be useful for a community partner. In regards to deeper learning experiences, students described the contextual application of their course learning through S-L as providing an engaging challenge that "*pushed their thinking*," and enhanced the speed and depth of their learning. Gains in critical thinking, problem solving, teamwork and communication skills were expressed by students as valued skill sets, that were deemed transferrable to other courses and future work settings. Students conversed about an enhanced belief in their ability to make a difference and be productive members of society due to an increased awareness of developing engineering solutions within a societal and global context requiring a sense of ethics and civic engagement. Overall, students pointed to the benefit of using S-L experiences and projects as concrete and "*tangible*" ways to present their levels of knowledge and skills on resumes and during actual and potential employment interviews. Students often commented on their coursework with S-L as bring more fun, engaging, interesting, and "*cool*" educational activities.

Student Interview and Focus Group Reports of S-L Challenges and Suggestions

Students also discussed their challenges with S-L experiences, and suggested possible solutions:

- 52% experienced the timing of S-L as challenging;
- 47% stated that there was not enough community interaction;
- 38% expressed disappointment in the rigor of some S-L experiences,
- 32% felt uncertain about their level of academic capacity to do S-L; and
- 25% discussed teamwork as having challenging elements.

The timing of S-L was articulated by students interviewed as a challenge when S-L was presented late in the semester, which did not allow enough time for students to plan, prepare, and at times complete a S-L assignment or project. Students also commented on concerns about S-L being offered too early within their academic experience due an interest in gaining "*basic engineering skills*." Students expressed concern over a lack of community interaction that could help to inform and provide feedback on their S-L project efforts and overall experience. In addition, if S-L projects were perceived as being "*too easy,*" or *"not enough challenge,"* students stated that this was not a useful experience and did not provide enough academic rigor. Nonetheless, students also reported being uncertain about their academic capacity to engage in S-L experiences or projects if they felt "*overwhelmed*," *"unprepared,"* or lacking in academic readiness. Teamwork dynamics were described by a fourth of the students as being a challenge due to some students not contributing to the S-L team or at times taking over the team in terms of control and decision-making processes.

Students provided recommendations regarding each of the S-L challenges described above. In terms of timing and pacing of S-L activities, students suggested that S-L assignments and or projects be introduced at the beginning of and spread across the semester, as well as completed prior to final exams. Students expressed great interest in being provided with further opportunities to discuss, problem solve and collaborate with community partners as well as receive feedback. Students suggested that community partners could meet and interact during class time. A few students recognized the challenges of organizing community partner interactions, and suggested that such interactions could be simulated through groups of student's role-playing community partner interactions, which could provide a simulated interactive S-L experience. Engineering undergraduates also recommended that sufficient and appropriate academic rigor be included in S-L opportunities, as well as balancing the S-L experience with enough academic background and support. Students with positive S-L team experience suggested that ground rules for teamwork were helpful and should be a part of the S-L framework.

Discussion

This study investigated the impact of S-L experiences on undergraduate engineering students. As the results indicate, student perceptions of the benefits of S-L tend to be highly correlated between findings resulting from our mixed method approach of student surveys, interviews, and focus groups. Comparison of survey, interview, and focus group findings indicate primarily the following themes with major outcomes associated with S-L experiences, students reported that they:

- agree in principle with combining academic subject matter with service
- are more motivated to learn subject matter and work harder with S-L
- achieve more research/ information gathering and learning more with S-L
- experience a preference for and gains in soft skills while working as S-L teams
- are more engaged with learning due to S-L
- like the benefits of a mix of required to optional S-L experiences

Additional findings emerging from qualitative interview and focus group data suggest further insight as to why students reported beneficial S-L impacts. Students remarked on being changed by their S-L experience, with one student nicely summing this theme by stating that, "*We care now with S-L, and without S-L, we don't care.*" In addition, senior and junior students commented on the usefulness of S-L experiences as a concrete speaking point and example used in their employment interviews and résumés. Even though students have been known to complain about additional coursework, the majority of students interviewed voiced a preference for complex and challenging S-L activities as having a greater "*impact on our learning*."

The interview question that sparked the most enthusiastic responses by students inquired about roles of engineers. Student and alum attitudes and opinions regarding the importance of engineering roles and values that contribute to solving community problems were discussed with students often emphatically stating that, *"It's 100% important!"* or, "*That is the role of an engineer*!" In general, students described pivotal societal roles played by engineers, with one student summarizing the significance by stating that this "*ranks among the highest and first criteria for engineers.*" In terms of evaluating long-term effects of S-L experiences on students' attitudes, behaviors, and activities, students discussed and pointed to a key difference between other forms of experiential learning and S-L as being the integral element of service. Students talked about the service aspect of S-L in ways that that emphasized the personal significance of doing projects "*that matter versus just homework,"* as well as "why not help others?" Students also talked about learning from each other through collaborative S-L activities that provided increased opportunities to increase their problem solving and critical thinking skills.

Overall, 72% of the students interviewed were male engineering students, with female engineering students comprising 28% of the total sample. Despite these gender percentages, approximately 8% of the total College of Engineering student population was comprised of female engineering students at the time of this study. So, a higher percentage of females were recruited for interviews than exist within the engineering college student population. With a program emphasis on increasing recruitment and retention of females through S-L opportunities, it was important to recruit as many female engineering students as possible to participate in this study. In addition, an emphasis on recruiting junior and senior students resulted in 72% of the students interviewed. Junior and senior students have experienced S-L within their coursework to a greater degree than freshmen and sophomore students, which provided research opportunities to more deeply examine and learn from their experiences. Nevertheless, freshmen and sophomore students provided a lens to view and compare student attitudes, affect and cognition regarding S-L experiences from academic levels and departments.

Based on continuing analyses of this data, results emerging from written surveys indicated that two-thirds of the students reported a positive impact of S-L on their continuing in engineering, as well as one third of students reporting that S-L was a recruitment factor. In contrast to survey findings, S-L opportunities at U Mass Lowell were not reported by students interviewed as a recruitment factor. However, students were not directly asked if they selected U Mass Lowell due to S-L activities, yet students did comment that they, "*would recommend the program"* due to S-L opportunities. In addition, students specifically talked about useful gains in problem solving skills, analytic skills, people skills, practical application of theory, self-learning, and benefits of learning through mistakes. For the most part, S-L was and is accepted by the majority of students within the engineering programs. However, both 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."* Alums suggested that S-L should be required of engineering students since, "*the S-L problem [project] is the motivation to learn, and provides a way to apply what they have learned*."

This research was somewhat limited by the relatively small number of alum interviews. A larger and more representative sample of alumni interview responses would have improved the reliability of the data and the generalizabilty of the analysis in terms of evaluating long-term impacts of S-L experiences. Nevertheless, a large cohort of undergraduate engineering students participated in a longitudinal survey study complemented by a large representative sampling of student interviews. Hence, while the authors believe there is validity for accepting results of the study, in addition, much of what was learned could be used to lay the foundation for comparisons to future studies. By and large, one of the most important findings from the current study appears to be numerous S-L benefits voiced by students.

Conclusions and Recommendations for Future Research

This research highlights the importance of service-learning (S-L) benefits for engineering students. Although S-L is a useful approach to meet many of the ABET requirements, it is not generally incorporated into engineering curricula. Traditional academic programs prepare students for examinations in specific areas. While such academic grounding is needed for foundations of engineering curriculum, S-L opportunities allow for concurrent development of technical engineering and professional skills (communications, ethics, societal awareness and sensitivity, among many others), along with a context for reflection and development of adaptability to a world of changing conditions. S-L provides a more complete context in which technical engineering skills are applied, and deepens the quality and long-term impacts of engineering education. Furthermore, practical experiences gained during S-L activities provide broad reinforcement and enhancement of engineering competencies while inspiring engineering students to apply their knowledge as an integral part of tomorrow's society. They see the profession as including service to others in the community, that is, engineering the common good.

In general, the educational challenges and benefits derived from S-L experiences were reported by students as significant and meaningful opportunities to struggle with uncertainty and develop creative solutions in ways that have the capacity to achieve and surpass ABET criteria. Service-learning (S-L) provides a natural complement to relevant course work thus providing motivation for students to gain and apply a diversity of new skills, as well as foundations of engineering principles presented in their coursework. S-L is an educational tool to inspire development of a socially engaged engineering workforce to engineer common good. Yet, quantifying benefits of S-L can be complex. Nevertheless, findings reported by student voices in this study indicate a wide range of benefits that include development of technical skills while also developing sets of professional skills.

This study supports an expanded view on how students reportedly deepen their learning experiences through active construction of knowledge motivated by integration of S-L within core course curricula. There are a number of compelling reasons to support adoption of S-L into engineering curricula. Additionally, there are a number of ways that individual faculty members or whole institutions could begin to implement this model of S-L, so that more engineering students would experience the opportunity to apply their engineering skills in partnership with local to global communities while gaining and achieving academic credit. In many cases, modifying current courses with a start small approach that replaces a homework or lab assignment with a S-L activity can provide seamless course relevance and coherence. Given perceived benefits voiced by students as derived from S-L experiences, there is a need to further investigate and to quantify beneficial impacts on students in ways that more clearly identify and measure areas of development and gains in skill sets. A number of factors in student S-L experiences were identified which were seen to correlate with factors reported in recent literature, and these insights should be helpful to those involved in development of S-L experiences in engineering. Future work should be pursued to evaluate more deeply the application of S-L engineering curricula.

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