What Value Does Service Learning Have on Introductory Engineering Students' Motivation and ABET Program Outcomes?

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Abstract

A quasi-experimental evaluation study was conducted to investigate the effectiveness of using a service learning (SL) method on influencing introductory engineering students' motivation and ABET program outcomes, compared to the effectiveness of using a conventional, non-service-learning (NSL) method. The sample used in the study was 214 students enrolled in an Introduction to Engineering course at a medium-size university in the northwestern region of the U.S. during the fall semester of 2009 and the spring semester of 2010. Sixty-nine students completed SL projects while 145 students completed NSL projects. Both SL and NSL projects were team-based. Using the ARCS model as a framework, students' motivation was measured on attention (interest), relevance, confidence in engineering knowledge, confidence in collaborative learning, and satisfaction. Students' self-assessed engineering abilities were measured on the "a through k" ABET program outcomes. Results showed that the SL method was significantly more effective than the NSL method in terms of positively influencing students' interests, recognition of relevance, and satisfaction in learning and their self-assessed engineering abilities in three out of 11 ABET program outcomes, c, e, and k. Interpretation of the results, application of the results to the course redesign, and recommendations for other engineering educators are provided.

1. Service Learning in Engineering Education

Experiential learning is a pedagogy emphasizing active and meaningful learning processes through direct, concrete experiences (Kolb, 1984; Roger, 1969). Service learning (SL) is a type of experiential learning in which students apply their knowledge and skills to solve problems in the community, often working collaboratively with others as a team. Bringle and Hatcher (1996) define service learning as "a credit-bearing educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility" (p. 222). Service learning has been shown to produce positive personal, social, and learning outcomes, such as improvements on personal identity, spiritual growth, moral development, commitment to service, and analytic and critical thinking skills (Eyler, Giles, Stenson, & Gray, 2001).

There are potential benefits of using a SL strategy in engineering education. Engineers are problem-solvers who apply knowledge of math and science to solve problems or to improve the daily lives of clients. SL helps engineering students understand the environmental and societal context of engineering by working with, rather than working for, clients from the community and solving their problems. Through this reciprocal partnership, both SL students and the community contribute to setting up the goals and receive benefits from the work (Lima & Oakes, 2006). SL also emphasizes the importance of this practical experience in learning through reflection. With SL, students use problem-based approaches to their learning, investigating engineering problems and developing meaningful solutions to the problems (Hmel-Silver, 2004).

A number of research reports describe successful implementation of SL in engineering curricula in the U.S. The SL projects used in the studies vary in scale, ranging from domestic projects dealing with a specific client's or a local community's needs to large-scale international projects involving humanitarian efforts or focusing on community development in developing countries (Ropers-Huilman, Carwile, & Lima, 2005; Padmanabhan & Katti, 2002; Tiryakioğlu, et al., 2009; Wigal, McMahon, & Littleton, 2008; Zhang, Gartner, Gunes, & Ting, 2007; Borg & Zitomer, 2008; Feishman, et al., 2010; Gonzalez, Heisman, & Lucko, 2010). Various SL topics have been used in the studies, including implementation of a solar-powered water pumping system, a solar hot water and water purification system for local rural residents, a disaster-mitigating architectural design, and assistive technology solutions for children with special needs (Borg & Zitomer, 2008; Savage, Chen, & Vanasupa, 2007; Gonzalez, Heisman, & Lucko, 2010; Wigal, McMahon, & Littleton, 2008).

The success of SL projects in engineering education can be measured against various types of potential outcomes including cognitive learning outcomes, motivational outcomes, and ABET program outcomes. In addition to learning analytical skills and scientific concepts through textbooks, lectures, and practice in the classroom, hands-on inquiry-based SL instruction provides students with an opportunity to apply their knowledge and skills to solve real-world problems and to more fully internalize the impact that engineers have in improving people's lives. Recognizing their positive contributions to the client is often a motivating factor causing students to put forth more effort than they would for a typical class project. When students see tangible, positive results of their efforts in solving a "real" problem, they experience tremendous satisfaction, which in turn increases their motivation to pursue engineering careers. SL provides students with opportunities to practice skills vital to their success as engineers, including professional and ethical responsibility, teamwork, and communication, which are emphasized in the ABET criteria for accrediting engineering programs (ABET, 2009). In the following sections, we will discuss more about implementation of SL in engineering curricula for motivational and ABET outcomes.

2. Course Design with Service Learning for Positive Motivational Attitudes

Learning is an emotional process as well as a cognitive process. Student motivation is often an important driver for their learning. To learn new knowledge, students need to develop positive attitudes toward learning and be motivated to learn. Students may lose their motivation to learn when they do not perceive instruction to be interesting or relevant to their goal. They may also lose motivation to learn when they are not confident in learning processes or do not expect to have positive outcomes, and/or they are not satisfied with the instructional processes and actual or potential results. Students likely become or remain motivated or unmotivated to learn depending on their perceptions of their own learning and the learning environment. These aspects of motivation and learning are explained in Weiner's attribution theory and discussed in the ARCS model (Gredler, 1992; Keller, 1987a, 1987b, 1987c). Based on the ARCS model, four factors, Attention, Relevance, Confidence, and Satisfaction (ARCS), can be used to understand student motivation. The following are sample ARCS questions that students might process during their learning:

- Attention - Is this learning interesting to me?
- Relevance - What's in it for me? Will working on this project benefit me now or in the future?
- Confidence - Am I capable of successfully completing this learning task?
- Satisfaction - Do I feel good about this project and what I am learning?

Engineering educators are putting a lot of effort into improving students' motivation to learn by increasing awareness of their roles as engineers and their contributions to the society. SL's motivational impact on such learning outcomes is especially noteworthy because SL is one of the instructional strategies that has the potential to improve students' motivational attitudes on these ARCS factors. Using the motivation theory and the ARCS model as the theoretical framework, engineering educators can implement SL as a strategy to improve student motivation and evaluate the motivational outcomes, as shown in Figure 1. Because SL often requires effective collaborative team work, the ARCS model is also a helpful framework for evaluating students' motivational attitudes toward collaborative project-based learning environments.

Some research has shown positive effects of SL on motivational factors – for example, students found SL to be enjoyable, understood the subject matter better, became more aware of their roles as engineers, and had strong feelings of accomplishment (Zhang, Gartner, Gunes, & Ting, 2007; Tiryakioğlu, et al., 2009; Dukhan, Schumack, & Daniels, 2008; Dewoolkar, George, Hayden, & Neumann, 2009). However, our literature search did not reveal any SL studies that investigated a complete set of ARCS factors as motivational outcomes.

3. Course Design with Service Learning for ABET Program Outcomes

3-1. The ABET Program Outcomes

The Engineering Accreditation Commission (EAC) of ABET, Inc. articulates nine criteria which are "intended to assure quality and to foster the systematic pursuit of improvement in the quality of engineering education that satis-

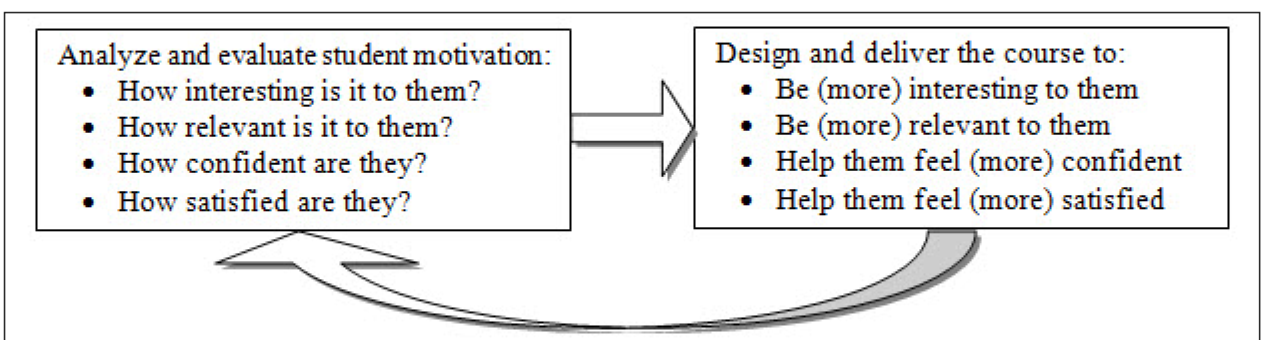

Figure 1. Continuous improvement of course design and outcomes.

fies the needs of constituencies in a dynamic and competitive environment" (ABET, 2009). Engineering programs must demonstrate that their students attain the program outcomes of Criterion 3. These "a through k" 2009-2010 ABET EAC required program outcomes are listed below:

a. an ability to apply knowledge of mathematics, science and engineering to solve engineering problems
b. an ability to design and conduct experiments, as well as to analyze and interpret data
c. an ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability
d. an ability to function on multidisciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

3-2. The Service Learning Curriculum vs. the Non Service Learning Curriculum

The ABET EAC encourages educational institutions to integrate authentic, meaningful learning experiences into their engineering curricula, and requires that programs show evidence of actions to improve their programs (see Criterion 4. Continuous Improvement in ABET, 2009). A few engineering schools have used SL as a method to achieve ABET EAC program outcomes (Borg & Zitomer, 2008; Dewoolkar, George, Hayden, & Neumann, 2009; Ropers-Huilman, Carwile, & Lima, 2005; Zhang, Gartner, Gunes, & Ting, 2007). At our institution, 'Introduction to Engineering' is a three-credit project-based lab course designed to teach freshmen students to understand the overall engineering design process and to allow them to gain insights into the activities and challenges that engineers encounter in their jobs. This freshman course is also critical in terms of recruiting and motivating students to continue to pursue engineering careers. As part of continuous improvement in the introductory engineering course, we recently implemented SL in several sections of the course, while continuing with the conventional non-service learning (NSL) curriculum in other sections of the course. A majority of the coursework in this class is completed by teams of students. Students with both SL and NSL curricula work in teams to design, analyze, and implement solutions to open-ended engineering problems. A difference between SL and NSL curricula lies in the fact that SL projects involve client-based real-world engineering problems whereas NSL project topics are provided by the instructor. A comparison between the SL curriculum and the NSL curriculum is shown in Table 1.

Note that three identical modules (1. Consumer Product Analysis, 2. Manufacturing, and 3. Circuits) are used in both the SL and NSL curricula during the first half of the semester. Working through these modules, students hone basic skills, such as gaining familiarity with Microsoft Excel, gathering, analyzing, and presenting data

	SL Curriculum	**NSL Curriculum**
Modules	1. Consumer Product Analysis	
	2. Manufacturing	
	3. Circuits	
	4. One SL Project (Week 8- Week 15)	4. Three NSL projects 1. Composite Beams (Week 8 – Week 9) 2. Bridge Building (Week 10 – Week 12) 3. Mousetrap Cars (Week 13 – Week 15)
ABET Outcomes Specific to SL	a, c, e, and k	-
ABET Outcomes Common to Both SL and NSL	b, d, f, g, and h	

Table 1. Comparison of SL Curriculum to NSL Curriculum

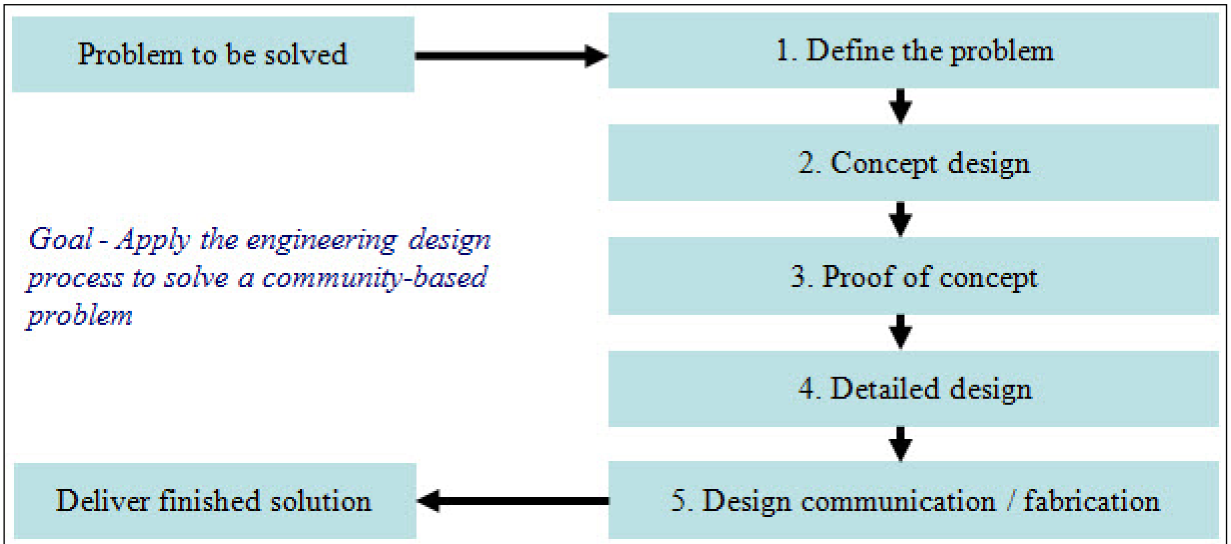

Figure 2. Engineering design process.

(both written and orally), dimensional analysis, etc., while working in teams with their classmates, all done in a project-based environment. Teams are re-assigned at the start of each new module. These frequently changing teams provide students with the chance to interact with their classmates and gain experience with people with different learning styles, ideas, and personalities.

As the curriculum diverges into SL and NSL projects at midterm (Week 8), this familiarity with their peers is of great benefit as students are allowed to request teammates to work with for the SL projects. The instructor takes these teammate requests under consideration and forms the teams in a way that will help ensure the success of each project. Larger teams are used for SL projects since they tend to be more complex than NSL projects. SL projects have four students per team and NSL projects have three students per team. As shown in Table 1, while teams of NSL students complete three NSL projects (composite beams, bridge building, and mousetrap car) guided by specifications provided by the instructor, each team of SL students completes one SL project for 7 1/2 weeks, working directly with their client.

While the course (both SL and NSL curricula) touches on many of the ABET outcomes, it was designed to address outcomes b, d, f, g, and h. Four additional ABET outcomes, a, c, e, and k, are addressed in the SL curriculum as the SL module is designed to allow students to gain more in-depth experience applying the engineering design process, a methodical approach to problem solving, by designing a solution to a community-based problem. Although there are many versions of the engineering design process, the five-step process shown in Figure 2 is used in this course.

The technical focus of both SL and NSL projects is for students to understand and apply the engineering design process and perform the design, modeling, and analysis tasks which are an integral part of the engineering design process.

SL projects used in this class are primarily adaptive design projects, where students modify or create a device for a person with a disability. Several critical factors for successful completion of these projects have been identified as follows:

- The instructor carefully screens the prospective projects and potential clients to assess whether the project is of an appropriate level of complexity for freshman students, can be accomplished in the allotted time, and whether students will be able to develop a rapport with their client.
- Clients are heavily involved in the problem definition and design process. Students meet with their client as frequently as necessary; initial client meetings are imperative in ensuring students have a good understanding of the problem they are trying to solve. Clients are required to approve of the team's work at each step in the design process and to participate in testing prototypes and verifying the final solution.
- Students are required to create a prototype of their design during the proof of concept phase, ideally a working model, so they are better able to visualize their design and begin to validate that it will solve their client's problem as they envisioned.

- Students are required to submit documentation of their work in completing the steps in the design process at regular intervals. This helps ensure that students continue to make adequate progress in meeting their goal and have a record of all design options in case they need to be revisited.
- Students are asked to reflect on their work during the design process including challenges they encounter and new insights they gain as a result of working on these projects.
- Mentors or consultants from the university and community assist student teams as needed. They are able to guide students through the process with design advice, material selection, and part fabrication expertise.

NSL projects are also design projects, and students follow the same engineering design process illustrated in Figure 2. However, during the first step, Define the Problem, students are provided with design specification defined by the instructor. Students follow the remaining steps in the design process and deliver the final solution to the instructor.

3-3. Service Learning Project Example 1 - Door Opener

An example of an SL project completed in the introductory engineering course was a door opener device for Josiah. Josiah uses a power wheelchair and has limited use of his hands and arms. He wanted a device to allow his service dog, Sabrina, to be able to open doors for him; particularly those where there is no accessible door opener switch.

The SL team of students found several hooks at a local hardware store and tested them as the basis for the door opener device. A rope with knots tied at varying heights provides Sabrina with a location to pull from depending on the type of door to be opened. Once Sabrina pulls the door open, Josiah blocks the door open with his wheelchair, retrieves the device and stores it on his wheelchair for easy access (see Figures 3 and 4).

Figure 3. Sabrina using the door opener device.

Figure 4. Door successfully opened.

3-4. Service Learning Project Example 2 – Education Assistant

Another SL project was an education assistant for Maddie. Maddie is a student at a local high school; she has cognitive disabilities and is easily distracted. Her teacher wanted an educational environment that would keep her interest and minimize distractions from other students in her class.

Using a desk found on Craig's List as the basis for their design, the team of students modified it to allow Maddie to pull up to it in her wheelchair as shown in Figure 5. The team designed and built a collapsible carrel-type enclosure to help Maddie focus on her learning materials. The walls of the enclosure feature a whiteboard surface for additional activities as shown in Figure 6.

3-5. Additional Service Learning Project Examples

Other SL projects included a stow-able tray with a collapsible cup holder attached to a wheelchair for a vision-impaired person with spastic cerebral palsy, and a ground-level, collapsible, and waterproof chair for a 3-year old child with Lesch Nyhan Syndrome, both of which are described in our preliminary report presented based on Fall 2009 semester data (Sevier, Chyung, Schrader, & Callahan, 2010).

4. Evaluation Methodology

4-1. Research Variables, Research Questions, and Hypotheses

During the curriculum redesign, we conducted an evaluation study with a quasi-experimental design to investigate the effectiveness of using a SL method on influencing introductory engineering students' motivation and attainment of ABET program outcomes, compared to the effectiveness of using a conventional, NSL method. The independent variable used in this study was the type of team projects that students completed during the course – that is, SL (experimental group) vs. NSL (comparison group). The dependent variables were students' motivational attitudes toward learning measured by the ARCS factors, and their self-assessed engineering abilities measured against the ABET "a through k" program outcomes. With the independent and dependent variables of the study, we aimed to answer the following research questions:

1. How does a SL method affect introductory engineering students' motivational attitudes toward learning measured by the ARCS factors, compared to a NSL method?
2. How does a SL method influence introductory engineering students' self-assessment on their engineering abilities measured against the ABET program outcomes, compared to a NSL method?

We answered the research questions by testing the following null hypotheses. Because both SL and NSL conditions used collaborative team projects, we measured two types of student confidence – confidence in their engineering knowledge and confidence in collaborative learning.

Ho_1 – Ho_5: Introductory engineering students who learn in a SL environment and introductory engineering students who learn in a NSL environment will show no significant difference in terms of the motivational attitudes such as:

Ho_1: their interest in learning engineering
Ho_2: their recognition in relevance of learning
Ho_3: their confidence in engineering knowledge
Ho_4: their confidence in collaborative learning
Ho_5: their satisfaction in learning

Figure 5. Students with the education assistant they designed.

Figure 6. Maddie using her education assistant.

Ho_6 – Ho_{16}: Introductory engineering students who learn in a SL environment and introductory engineering students who learn in a NSL environment will show no significant difference in their self-assessed engineering abilities in:

Ho_6: the ABET program outcome 'a'
Ho_7: the ABET program outcome 'b'
Ho_8: the ABET program outcome 'c'
Ho_9: the ABET program outcome 'd'
Ho_{10}: the ABET program outcome 'e'
Ho_{11}: the ABET program outcome 'f'
Ho_{12}: the ABET program outcome 'g'
Ho_{13}: the ABET program outcome 'h'
Ho_{14}: the ABET program outcome 'i'

Ho_{15}: the ABET program outcome 'j'
Ho_{16}: the ABET program outcome 'k'

4-2. Participants

The population of this study is students enrolled in undergraduate introductory engineering classes in the U.S. We used a convenience sample of 254 students enrolled in a three-credit Introduction to Engineering class offered at our institution, a medium-size university in the northwestern region of the U.S., during the fall semester of 2009 and the spring semester of 2010. Among the 254 students, 234 students (92.12%) voluntarily participated in the study by submitting a consent form; however, 214 of the 234 students (91.45%) submitted complete data sets. Therefore, we conducted the following data analysis on the 214 complete data sets. One hundred and seventy-two students (80.37%) were male, and 42 students (19.63%) were female. The average age of the students was 22.27 (SD = 5.69, *Min.* = 17, and *Max.* = 55). Students' majors at the time of the study were Civil Engineering (n = 56), Mechanical Engineering (n = 50), Electrical Engineering (n= 33), Engineering General (n = 31), Materials Science and Engineering (n = 13), Computer Science (n = 6), and other science fields such as Chemistry, Physics, Pre-Med, and Applied Mathematics (n = 25). Most students (80.80%) reported that they had not taken any SL-based courses before this course. Eighteen students indicated that they had taken one SL-based course, 10 students said two SL-based courses, and only two students said they had taken more than three SL-based courses before this class; 11 students did not report.

4-3. Research Instruments and Procedure

Introductory Engineering Course: Students in all sections of the course in both semesters received lecture by the same female instructor, using the same materials and course topics, but their lab sections were supervised by different instructors. Students enrolled in a section of the course that best fits their class schedule when they registered for the course. The SL sections were selected by the program coordinator; students signed up for their lab section without knowing whether their section would be a SL or NSL group. Two of the seven sections of the class during the fall 2009 semester and two of the five sections during the spring '10 semester were assigned to the experimental SL condition (a total of 69 students) and the remaining eight sections were assigned to the comparison NSL group (a total of 145 students). A total of 22 SL projects were completed during the 2009 – 2010 academic year, with 12 projects completed during the fall 2009 semester and 10 projects completed during the spring 2010 semester.

Motivational Attitudes Survey: We developed the motivational attitudes survey based on an existing instrument used at the Service Learning Office in our institution (Boise State University, 2010). We modified it for the purpose of our study and developed 19 questions measuring student motivational attitudes toward collaborative project-based learning on a 7-point Likert-type scale (1 being 'strongly disagree' and 7 being 'strongly agree'). The motivational attitudes were measured on the ARCS factors – attention (three questions), relevance (five questions), confidence-knowledge (three questions), confidence-collaboration (five questions), and satisfaction (three questions). The survey also contained three open-ended questions at the end (see Table 2). Students in both SL and NSL groups submitted the survey at the end of the course. We reviewed the Cronbach Alpha level to check internal reliability of the questions measuring each of the ARCS factors. The Cronbach Alpha values for the sets of questions measuring attention, relevance, confidence-knowledge, confidence-collaboration, and satisfaction were .85, .88, .82, .89, and .88, respectively, which were acceptable levels.

ABET Program Outcomes Survey: As shown in Appendix A, the ABET program outcomes survey asked students to rate on a 7-point scale (1 being 'no improvement' and 7 being 'a lot of improvement') how much they thought participating in class project-based activities helped them improve each of the 11 ABET program outcomes. We administered the ABET outcomes survey in both SL and NSL groups at the end of the course.

Limitations of the Study: There were a few limitations of the study. First, it was a quasi-experimental study, using a convenience sample rather than a sample randomly selected from its population. Also, it was a post-measure only design, in which we assumed non-significance in the pre-conditions of experimental and comparison groups. Because of those limitations, the generalizability of the study results would be limited to the context that is similar to the study setting. Another limitation of the study was the unequal sample sizes used in SL and NSL groups. Each SL team of students was provided with $200 for purchasing items and

Survey Question	ARCS Factors
1. This class helped me become more interested in helping solve community problems.	Attention
2. The project activities helped me see how course concepts can be applied to solving real problems.	Relevance
3. Through the project, I gained practical experience that will appeal to employers, graduate schools, and/or scholarship reviewers.	Relevance
4. Because of the project I completed, I will be able to recall and use the information better in the future.	Confidence-Knowledge
5. The project activities have helped me improve my communication skills.	Confidence-Collaboration
6. The project activities helped me understand the basic concepts and theories of the subject.	Confidence-Knowledge
7. The project activities helped me analyze issues about citizenship or my responsibility in the community.	Relevance
8. The project activities I performed in this class made me feel more interested in attending class.	Attention
9. The project activities helped me develop collaboration skills.	Confidence-Collaboration
10. The project activities fostered personal insights and growth.	Relevance
11. After having completed the project activities, I feel confident in my decision to pursue an engineering degree.	Confidence-Knowledge
12. The project activities helped me feel good about being able to solve engineering problems.	Satisfaction
13. In future projects, I would be able to deal with difficult group members better, as a result of this project experience.	Confidence-Collaboration
14. The project activities made the engineering subject more interesting.	Attention
15. I would recommend providing this type of project activities to other students who will be taking this class in the future.	Satisfaction
16. I would like to participate in this type of team project activity in my future courses.	Satisfaction
17. I feel confident in completing team projects in the future.	Confidence-Collaboration
18. As a result of the project activities that I completed, I am more comfortable in my dealings with people of diverse backgrounds.	Confidence-Collaboration
19. The project activities helped me appreciate the importance of working in a team when solving engineering problems.	Relevance
20. Service learning involves working with actual clients from the community to help solve their real problems. Prior to this semester, how many service learning based courses have you taken? (NOT including this semester)	(Open-ended Questions)
21. What suggestions do you have for the instructor to help improve the overall experience during the project activities?	
22. As you reflect on your experience, describe the most meaningful part of the project for you. Describe ways it has changed your behavior or way of thinking.	

Table 2. Motivational Attitudes Survey Questions and ARCS Factors

	Group	n	M	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	P
Attention	SL	69	5.13	124.63	8599.50	3820.50	-2.80	.005
	NSL	145	4.54	99.35	15505.50			
Relevance	SL	69	5.08	126.02	8695.50	3724.50	-3.02	.003
	NSL	145	4.46	98.69	14309.50			
Confidence-Knowledge	SL	69	5.00	115.48	7968.00	4452.00	-1.30	.192
	NSL	145	4.71	103.70	15037.00			
Confidence-Collaboration	SL	69	5.08	115.44	7965.50	4454.50	-1.29	.195
	NSL	145	4.84	103.72	15039.50			
Satisfaction	SL	69	5.28	120.46	8311.50	4108.50	-2.11	.034
	NSL	145	4.85	101.33	14883.00			

Table 3. Group Differences on Motivational Attitudes

services necessary to complete their SL project. Because of the limited funding, only two of the lab sections of the introductory engineering class during each semester were able to participate in service learning, which caused the unequal sizes of the experimental and comparison groups.

5. Results

5-1. Students' Motivational Attitudes

We conducted Mann-Whitney U tests on non-parametric data obtained from the motivational attitudes survey to compare the difference between SL and NSL groups of students in terms of their motivational attitudes toward collaborative project-based learning (Green, & Salkind, 2008; Morgan, Leech, Gloeckner, & Barrett, 2007). The results are shown in Table 3 and Figure 7. SL students' attention, relevance, and satisfaction scores were significantly higher at a .05 level than NSL students' scores were; therefore, the null hypotheses, Ho_1, Ho_2, and Ho_5, were rejected. SL students' confidence levels in their engineering knowledge and collaborative learning were higher than NSL students' confidence levels, but the differences were not statistically significant. Therefore, the null hypotheses, Ho_3 and Ho_4, were retained.

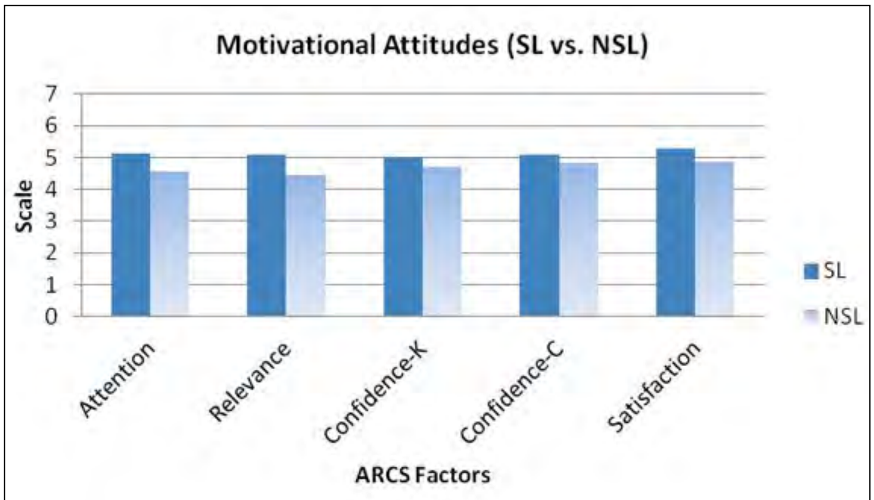

Figure 7. SL and NSL group differences on motivational attitudes.

5-2. Students' Self-Assessment of ABET Engineering Abilities

We conducted Mann-Whitney U tests to compare the differences between SL and NSL groups in terms of their self-assessed engineering abilities when measured against individual ABET program outcomes. SL students' self-assessed engineering abilities were higher than the NSL students' self-assessed engineering abilities in all (except 'a') of the ABET program outcomes. The group differences in three ABET program outcomes, c (Ho_8), e (Ho_{10}), and k (Ho_{16}), were found to be statistically significant at a .05 level. Therefore, the three null hypotheses, Ho_8, Ho_{10}, and Ho_{16}, were rejected and other null hypotheses were retained. Descriptive and inferential statistics comparing SL and NSL groups' self-assessed abilities of the ABET program outcomes are presented in Table 4. The SL-NSL group differences are illustrated in Figure 8.

5-3. Students' Comments on the Most Meaningful Part of the Project

An open-ended question was asked to both SL and NSL students to describe the most meaningful part of the project(s) they had completed. Students' comments support the quantitative results. While most comments by the NSL students were about working in teams or on specific projects (e.g., build breadboard cir-

ABET Program Outcomes	SL		NSL		U	Z	p
	M	SD	M	SD			
a. Ability to apply knowledge of mathematics, science and engineering to solve engineering problems	4.13	1.64	4.19	1.67	4896.00	-.256	.798
b. Ability to design and conduct experiments, as well as to analyze and interpret data	4.64	1.49	4.50	1.58	4685.50	-.766	.444
c. Ability to design a system, component or process to meet desired needs	5.10	1.36	4.55	1.63	4037.50	-2.333	.020
d. Ability to function on multidisciplinary teams	4.90	1.48	4.66	1.63	4599.50	-.975	.330
e. Ability to identify, formulate, and solve engineering problems	4.93	1.52	4.50	1.59	4157.50	-2.046	.041
f. Understanding of professional and ethical responsibility	4.86	1.50	4.54	1.83	4626.00	-.905	.365
g. Ability to communicate effectively	4.54	1.63	4.25	1.79	4564.00	-1.053	.292
h. Broad education necessary to understand the impact of engineering solutions in a global and societal context	4.52	1.57	4.27	1.76	4660.00	-.823	.411
i. Recognition of the need for and ability to engage in life-long learning	4.59	1.83	4.25	1.88	4456.50	-1.309	.190
j. Knowledge of contemporary issues	3.94	1.68	3.74	1.69	4578.00	-1.020	.308
k. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	4.64	1.64	4.09	1.69	4060.00	-2.271	.023

Table 4. Group Differences in Self-Assessed Engineering Abilities

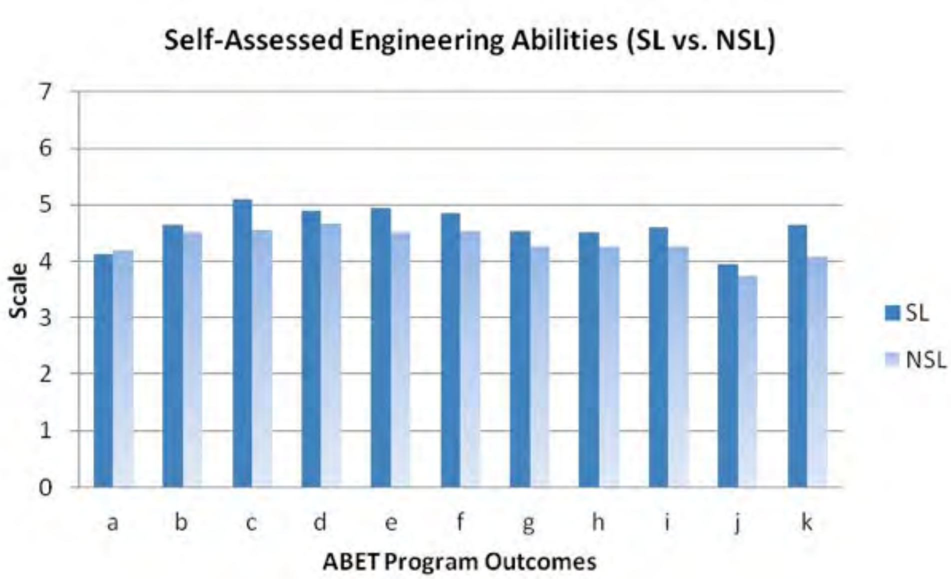

Figure 8. Self-assessed engineering abilities between SL and NSL groups.

SL	NSL
"The most meaningful part was actually having the chance to help someone in the community have a better way of life. It may widen my involvement and interest in the community." "It is meaningful that I am able to use my field to help others, and not just benefit myself." "I really loved getting to know my client. It really is rewarding to try to figure out the best possible solution to a problem that will affect someone so much. It really made me appreciate my health and even that I chose this class to be in to change someone's life." "I learned a lot more about different machining possibilities. I think this project really will benefit all engineering students." "The service project helped me grasp onto what engineers really do, help people, and it is cool."	"I'm not afraid of mechanics now. I was worried I would not do well because I did not know how to wire things, or how motors and things work but it was fun and I learned a lot." "I actually enjoyed working in different groups and bouncing ideas off of each other. Constructive communication." "I feel the lectures about the different opportunities that engineers get, and also the presentation [of] the different aspects of each engineering career field help broaden my knowledge." "During the bridge design, when we saw our design hold an enormous amount of weight, I then thought I could do this. I grew with confidence." "I liked be(ing) able to have a taste of each type of engineering because it gave me an even firmer grasp of what I wanted to do."

Table 5. SL and NSL Groups' Comments about the Most Meaningful Part of the Project

cuits, or bridge projects) being interesting, SL students' comments were much more specific and related to the ABET program outcomes, especially c and e, as well as A, R, and S factors. Table 5 presents a few examples of student comments.

6. Conclusions

6-1. Discussion

Our study has revealed that a SL method is significantly more effective than a NSL method in influencing introductory engineering students' interests, recognition of relevance, and satisfaction in learning, and their self-assessed engineering abilities in three out of 11 ABET program outcomes, c, e, and k. The ABET results from our study are partially supported by several other studies. Ropers-Huilman, Carwile, and Lima's (2005) study revealed that the participating students strongly perceived that SL enhanced their ability to master the ABET outcomes, c, d, e, and g. In a study by Borg and Zitomer (2008), students gave the highest average scores to questions about ABET outcomes, a, c, e, h, and i. We emphasize that SL has shown positive effects on the ABET outcomes 'c' and 'e' in these two studies as well as ours.

However, the literature also shows results contradictory to our study's results; for example, Borg and Zitomer's (2008) study involving an international SL project showed that students' perceptions toward the ABET outcome 'k' dramatically decreased upon completion of a SL project because of their frustrations during the implementation of the project at the worksite in a foreign country. On the contrary, the SL students who participated in our study did not experience such frustrations and rated the ABET program outcome 'k' high. It implies that the effectiveness of SL is context-sensitive in that various factors such as the course subject, the scale of the project, or access to the client / project site could influence students' self-assessment of ABET outcomes.

Nevertheless, when triangulating the results from the ARCS analysis and the results from the ABET program outcome analysis, supported by other studies, it is apparent that the SL method is significantly more effective than the NSL method in improving students' understanding about how their knowledge and skills could help solve engineering problems in the community and how they as engineers would make important contributions to society, as stated in ABET program outcomes, c and e:

c. an ability to design a system, component or process to meet desired needs
e. an ability to identify, formulate, and solve engineering problems

6-2. Evidence-Based Course Outcomes

The instructor of the introductory engineering course designed the SL curriculum with four ABET program outcomes (a, c, e, and k) as its SL-specific course outcomes:

a. an ability to apply knowledge of mathematics, science and engineering to solve engineering problems
c. an ability to design a system, component or process to meet desired needs
e. an ability to identify, formulate, and solve engineering problems
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Our study has shown SL's significant impact on three of the four SL-specific outcomes of this introductory engineering course (see Table 6). The SL group of students also ranked two SL-specific ABET program outcomes, c and e, as their top two engineering abilities. It validates the selection of the three SL-specific course outcomes for the introductory engineering course with SL. However, our study did not show the ABET program outcome "(a) 'Ability to apply knowledge of mathematics, science and engineering to solve engineering problems" to be a strong SL-specific outcome. In retrospect, the "Introduction to Engineering" course is not designed to teach students new math and science skills. Instead, this course is designed to help students apply the engineering design process and to see the 'relevance' of such capabilities in solving engineering problems and feel 'motivated' while completing a client-based engineering project. This outcome seems to fall better into "(k) 'Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice." Based on this finding, the course instructor decided to remove the ABET outcome 'a' from the list of the main SL-specific outcomes in the future syllabus of this introductory engineering course.

The study results also support that the course's overall outcomes have been met by both SL and NSL groups (see Table 6). The instructor set five ABET program outcomes (b, d, f, g, and h) as its overall course outcomes and both SL and NSL groups ranked three of them (b, d, and f) as among the top five. The other two outcomes (g and h) are also met, as the students in both groups self-assessed their engineering abilities to be 4.25 or higher (on a 7-point scale). Therefore, the course instructor decided to keep the five overall course outcomes as is:

b. an ability to design and conduct experiments, as well as to analyze and interpret data
d. an ability to function on multidisciplinary teams
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively (both written and oral formats)
h. the broad education necessary to understand the impact of engineering solutions in a global and societal context

6-3. Recommendations

It was our understanding during the study that one introductory engineering course would not and could not make significant contributions to improving students' self-assessed abilities in all 11 ABET program outcomes. Nonetheless, this study has shown how we could start facilitating the development of ABET program outcomes, even in an introductory engineering course, using an effective instructional strategy such as SL. Based on our experience, we provide a few recommendations for other engineering educators.

First, we emphasize the importance of the continuous instructional design process, including the design of a course with clearly targeted ABET program outcomes as its outcomes, the evaluation of the outcomes, and the confirmation or adjustment of the course outcomes, based on the evidence obtained from the evaluation.

We recommend engineering educators design their curricula with instructional strategies that facilitate ongoing developments of ABET program outcomes. For example, as shown in the literature and this study, SL is an effective method for producing ABET program outcomes. However, ABET program outcomes are results of accumulative efforts throughout the engineering degree curriculum. Therefore, we strongly encourage other engineering educators to use a survey such as the one shown in Appendix A to measure students' self-assessment of their ABET outcomes in each of their classes as part of their curriculum evaluation methods.

SL				NSL	
Rank-Order	**ABET Program Outcomes**	***M***		**ABET Program Outcomes**	***M***
1	**c. Ability to design a system, component or process to meet desired needs**	**5.10***		*d. Ability to function on multidisciplinary teams*	*4.66*
2	**e. Ability to identify, formulate, and solve engineering problems**	**4.93***		**c. Ability to design a system, component or process to meet desired needs**	**4.55***
3	*d. Ability to function on multidisciplinary teams*	*4.90*		*f. Understanding of professional and ethical responsibility*	*4.54*
4	*f. Understanding of professional and ethical responsibility*	*4.86*		*b. Ability to design and conduct experiments, as well as to analyze and interpret data*	*4.50*
5	*b. Ability to design and conduct experiments, as well as to analyze and interpret data*	*4.64*		**e. Ability to identify, formulate, and solve engineering problems**	**4.50***
6	**k. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice**	**4.64***		*h. Broad education necessary to understand the impact of engineering solutions in a global and societal context*	*4.27*
7	i. Recognition of the need for and ability to engage in life-long learning	4.59		*g. Ability to communicate effectively*	*4.25*
8	*g. Ability to communicate effectively*	*4.54*		i. Recognition of the need for and ability to engage in life-long learning	4.25
9	*h. Broad education necessary to understand the impact of engineering solutions in a global and societal context*	*4.52*		**a. Ability to apply knowledge of mathematics, science and engineering to solve engineering problems**	**4.19**
10	**a. Ability to apply knowledge of mathematics, science and engineering to solve engineering problems**	**4.13**		**k. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice**	**4.09***
11	j. Knowledge of contemporary issues	3.94		j. Knowledge of contemporary issues	3.74

Bold – SL-specific course outcomes
Italic – Overall course outcomes
* - A significant difference between SL and NSL

Table 6. Rank-Ordered ABET Program Outcomes by SL and NSL Groups

We emphasize that integration of SL into a curriculum requires careful planning (Ghannam, 2007). Before implementing SL in an engineering curriculum, the instructor should assess needs of the local community while establishing positive rapport with the community and its potential clients, plan for overcoming potential challenges to be faced during the application of SL, and estimate resources required to successfully integrate SL into teaching and learning. This includes seeking funding to support SL projects.

It is common that a SL-type of project-based learning strategy is implemented in senior-level capstone courses. Our study has shown that engineering students can complete SL projects successfully in their introductory course and significantly benefit by SL. The SL projects do not need to be large-scaled international projects with high budgets. In fact, introductory engineering students can learn better through specific SL projects from the local community, which include frequent interactions with their client to understand their needs, and design and test a solution to their problem.

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Appendix A. ABET Program Outcome Self-Assessment Survey

Your Name: ____________________________________ Section: ______________________

Now that you have completed the project activities, please provide your thoughts on the following items. Remember there are no right or wrong answers. Select a number on the scale that best describes your thoughts.

1. Ability to apply knowledge of mathematics, science and engineering to solve engineering problems	No improvement 1 2 3 4 5 6 7 A lot of improvement
2. Ability to design and conduct experiments, as well as to analyze and interpret data	No improvement 1 2 3 4 5 6 7 A lot of improvement
3. Ability to design a system, component or process to meet desired needs	No improvement 1 2 3 4 5 6 7 A lot of improvement
4. Ability to function on multidisciplinary teams	No improvement 1 2 3 4 5 6 7 A lot of improvement
5. Ability to identify, formulate, and solve engineering problems	No improvement 1 2 3 4 5 6 7 A lot of improvement
6. Understanding of professional and ethical responsibility	No improvement 1 2 3 4 5 6 7 A lot of improvement
7. Ability to communicate effectively	No improvement 1 2 3 4 5 6 7 A lot of improvement
8. Broad education necessary to understand the impact of engineering solutions in a global and societal context	No improvement 1 2 3 4 5 6 7 A lot of improvement
9. Recognition of the need for and ability to engage in life-long learning	No improvement 1 2 3 4 5 6 7 A lot of improvement
10. Knowledge of contemporary issues	No improvement 1 2 3 4 5 6 7 A lot of improvement
11. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	No improvement 1 2 3 4 5 6 7 A lot of improvement