AC 2010-297: EFFECTS OF SERVICE LEARNING IMPLEMENTED IN AN INTRODUCTORY ENGINEERING COURSE ON STUDENT ATTITUDES AND ABILITIES IN THE CONTEXT OF ABET OUTCOMES

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Effects of Service Learning Implemented in an Introductory Engineering Course on Student Attitudes and Abilities in the Context of ABET Outcomes

Abstract

A semester-long, quasi-experimental study with 119 students enrolled in seven sections of an Introduction to Engineering course at Boise State University was conducted to investigate the effectiveness of using a service learning (SL) method on improving student learning, compared to the effectiveness of using a conventional, non-service-learning (NSL) method. The experimental SL group consisted of two of the seven sections of the course, and the NSL group as a comparison group consisted of the other five sections of the course. Although both SL and NSL groups of students participated in collaborative project-based learning environments to complete given assignments, the types of collaborative learning differed in several ways: 1) The SL students completed one comprehensive project for 7 ½ weeks, whereas the NSL students completed a series of small scale problem-solving projects, 2) The SL students worked with the same members of a team throughout the project, whereas the NSL students worked with different team members for each project (teams of four members worked on the SL project, and teams of three members completed the NSL projects), and 3) Each SL team worked with a client from the community to solve a real problem (i.e., real-world learning experience), whereas NSL teams solved a series of projects based on written directions without input and guidance from real clients (i.e., a lack of real-world learning experience). Results showed that the SL method was significantly more effective than the NSL method in terms of 1) positively influencing students' motivational attitudes toward collaborative project-based learning and 2) improving their self-assessment of engineering abilities measured against ABET Engineering Accreditation Commission program outcomes.

Theoretical Frameworks

What Is Service Learning?

Service learning (SL) is a type of experiential learning method in which students work collaboratively with others, often in a team, applying their knowledge and skills to solve problems in the community. There are numerous potential benefits of using SL in engineering education. SL helps students understand the societal context of engineering by working with clients from the community and solving their problems. SL often uses problem-based approaches to learning, which emphasizes the importance of practical experience in learning and is organized around the investigation of the problem and development of meaningful solutions to the problem.[1]

Engineers are essentially problem solvers; they apply knowledge of math and science to solve the problems for clients or to improve our daily lives. In a traditional educational setting, students are taught foundational analytical skills and scientific concepts through textbooks, lectures and practice with textbook-based theoretical problem solving. By incorporating SL into the classroom, students have an opportunity to apply their knowledge to solve an open-ended, "real world" problem; one for which there are many solutions. Working within the constraints imposed by their client's requirements, project schedule, and budget, they gain practical experience while working through the engineering design process. They practice skills vital to their success as students and professionals, including critical thinking, teamwork, and communication. Understanding the benefit of their work for their client is often a motivating factor causing them to put forth more effort than for a normal class project. Students experience tremendous satisfaction when they are able to see tangible results of their efforts, solve a "real" problem, and see a project through to completion.

How Are Engineering Schools Using Service Learning?

SL, when implemented in engineering curricula, has revealed positive impact on improving student learning. For example, using a dual-team model (a design team and an implementation team), a group of engineering students at Marquette University completed an international SL project using solar-powered water pumping for the Santa Maria de Guadalupe Orphanage in Guatemala. [2] This study confirmed that the SL project not only broadened the social, cultural, and international experience of engineering students, but also helped to reinforce ABET program outcomes.

Students at the University of Tennessee at Chattanooga enrolled in the freshman Introduction to Engineering Design course or juniors and seniors enrolled in an interdisciplinary design course work on designing adaptive or assistive technology solutions for children with special needs. Students report a greater understanding of what engineers do and how they benefit society as a result of their work on these projects.[3]

Engineering students at Cal Poly State University had an opportunity to engage in a year-long project during their first year, which involves SL to design a solar-based hot water heater or an emergency water purification system to meet the needs of local rural residents.[4] This SL experience helped the students develop an appreciation for the relevance of their knowledge in science and mathematics for solving applied engineering problems.

As described in the cases presented above, SL has shown to be effective in producing positive learning outcomes such as improving student motivation in learning, increasing awareness of their roles as engineers and their contributions to the society, while also meeting course objectives and ABET program outcomes.

Course Design with Service Learning

Designing an Introductory Engineering Course with Service Learning to be Aligned with ABET Program Outcomes

The ABET, Inc., Engineering Accreditation Commission (EAC) has been encouraging educational institutions to integrate authentic, meaningful learning experiences into their engineering curricula. Several engineering schools have used SL as a method to achieve ABET EAC program outcomes.[5, 6] The "a through k" 2009-2010 ABET EAC program outcomes that engineering programs must demonstrate that their students attain are listed below: [7]

a. an ability to apply knowledge of mathematics, science and engineering
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.

The College of Engineering at Boise State University has also been paying attention to evaluating the impact of implementing SL in an introductory engineering course as an effort to work toward achieving ABET program outcomes, and we have recently implemented SL in an introductory engineering course to accomplish positive learning outcomes as noted in the previous section. The Introduction to Engineering course is a 3-credit project-based lab course designed to allow students to gain greater insights into the activities and challenges that engineers encounter in their jobs. Students work in teams to design, analyze, and implement solutions to several different open-ended engineering problems which have been selected to give them exposure to the various engineering disciplines. Through a one hour per week lecture and 4 hours per week of lab, the course begins to address the following ABET outcomes:

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

The course contributes to the following ABET outcomes to a lesser degree; however, these learning outcomes are addressed more fully with the addition of the SL curriculum:

a. an ability to apply knowledge of mathematics, science and engineering
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

A comparison of the SL to NSL curriculum is shown in Table 1 below. Note that the SL and NSL curriculum is identical during the first half of the semester. Working through these projects, students hone basic skills, such as gaining familiarity with Microsoft Excel, gathering and presenting data (both written and orally), dimensional analysis, etc., while also getting to know their classmates better, all done in a project-based environment. At midterm, the curriculum diverges.

Table 1. Comparison of SL to NSL Curriculum.

Service Learning Curriculum (SL)	Non Service Learning Curriculum (NSL)
Consumer Product Analysis	Consumer Product Analysis
Manufacturing	Manufacturing
Circuits	Circuits
Service Learning	Composite Beams
	Bridge Building
	Mousetrap Car

For the NSL projects, student teams are comprised of 3 students and are formed by the lab instructor. Teams are changed at the end of each module; this offers students an opportunity to work with many different people and the chance to practice teamwork skills with minimal relationships to manage. Due to the scope of the SL projects and limited time to complete them, SL teams are typically comprised of 4 students per team; these teams remain intact throughout the duration of the SL projects.

The SL projects are carefully screened by the course coordinator and lab instructor to ensure they are of a suitable level of complexity for freshman engineering students and also achievable in the 7 ½ weeks allotted for them. SL students are provided a high-level problem description of the projects assigned to their lab; they are required to "apply" for one of the projects based upon their interest and skills. Additionally, they are asked to suggest potential teammates they work well with. Thus, the course time spent in the first half of the semester working with other classmates provides vital experience in terms of classmate interaction.

It is the goal of the instructors to find adaptive technology design projects where students will modify or adapt equipment for a person with a disability to use. These types of projects have been successfully used with freshman engineering students at other universities. People with adaptive technology needs are able to be very specific about their requirements. They provide students with information on what will and will not work; this feedback is vital in directing the engineering design process. In addition, these projects provide the following opportunities:

- Students solve an adaptive technology problem for their client. These needs are often unique to an individual with a disability; it is likely there is no commercially available solution.
- Students gain hands-on experience developing a solution for their client. They are able to brainstorm ideas, build a prototype and iterate to a final solution; they experience tremendous satisfaction in seeing a project through to completion.
- Students have the opportunity to work with a person with a disability, often a new experience for them. Students quickly move beyond their client's disability and often develop a strong rapport with them.

- There are numerous opportunities for reflection including challenges working through the engineering design process and understanding their client and the challenges their disability creates for them.

The engineering design process is new for most freshman engineering students. They often have little hands-on experience; many of their experiences have been textbook or computer-based. Students are required to brainstorm multiple design options and evaluate them as to which is most likely to meet the project requirements, cost and schedule goals. They are encouraged to develop prototypes using inexpensive, readily available materials including corrugated cardboard, duct tape, PVC pipe and wire. These allow them to better visualize their design than is possible with drawings or sketches; often they are able to conduct some level of functionality testing. The prototypes allow students to refine their product plans and increase the likelihood their final product will work.

Figure 1. Grayson sitting in his chair.

Mentors or consultants are available to guide students through the design process. Students are assigned mentors with backgrounds, skills and experiences appropriate to the problem they are trying to solve. These mentors bring practical experience of what is likely to work; they offer guidance in design options, and materials choices. Assistance ranges from providing subassemblies to complete a design, creating 3D drawings, and part fabrication. They have proved to be an invaluable resource in ensuring the success of these projects.

An example of a project completed this semester was a chair for Grayson. He is a 3 year old boy with Lesch Nyhan Syndrome, a metabolic disease which affects his muscle tone. He is unable to sit up without a person sitting behind him to support him under his arms. Grayson's mother wanted students to design a ground-level seat to support him and allow him to play in the grass or sandbox. Additional requirements are that the seat be collapsible, and waterproof.

Grayson is shown sitting in his chair in Figure 1. Students designed the chair using a PVC pipe frame making it collapsible. A wide base and back support were used to provide stability for the chair. Grayson is supported in his chair using nylon leg straps and a wide neoprene band around his abdomen.

Another project completed this semester was a stow-able tray for Tygh. He has spastic cerebral palsy; he uses a power wheelchair and is vision-impaired. His disabilities require that he uses one hand to operate his wheelchair, the other to hold his cane leaving him no hands free to carry additional items. He wanted a tray attached to his wheel chair that he can use when he needs to carry something and stow it when he has no need for it. Additional requirements were that it needed to be easily cleaned, and not increase the width of his wheelchair.

Figure 2. Tygh with finished stow-able tray.

Figure 3. Support structure for stow-able tray.

Students developed a folding tray that slides forward and rotates around a support bar; the final design is shown in Figure 2. Working with one of their consultants, students were able to find a clamp and bar that provided the attachments to the wheelchair and tray. The folding tray was fabricated using cutting board material. A collapsible cup holder was added to allow him to carry drinks while moving. A support structure was added to increase the stability of the tray as shown in Figure 3. Tygh is easily able to open the tray when needed and stow it when not.

Influencing Student Motivational Attitudes on ARCS Factors

To learn new knowledge, students need to develop positive attitudes toward learning and get 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, and/or they are not satisfied with the instructional processes and results. These factors are discussed in John Keller's ARCS model.[8, 9,]

[10] According to the ARCS model, four factors (attention, relevance, confidence and satisfaction) influence the degree of learners' motivation to learn. Learners likely remain motivated or become unmotivated to learn depending on their perceptions of the learning environment – illustrated with several sample questions in Table 2.

Table 2. Motivational ARCS Factors during Learning Processes

Category	**Learners' Perceptions**
Attention	Is the instruction interesting to me? Do I like it? Does it stimulate my curiosity? Is it challenging enough?
Relevance	Does the outcome of learning match my goal? Will I be able to use this knowledge later? How will I use this knowledge? What is it for?
Confidence	Can I successfully complete this task? Can I overcome barriers? Am I capable of accomplishing the goal?
Satisfaction	How am I doing? Am I learning something valuable? Do I feel good about the results? Do I want to do it again?

Therefore, it is critical that instructional strategies be designed to result in positive motivational outcomes as well as learning outcomes. The ARCS model can be served as a theoretical framework to design effective instructional strategies and to evaluate the motivational outcomes, as shown in Figure 4. SL is one of the instructional strategies that have potential to improve students' motivational attitudes on these four ARCS factors. Because both SL and NSL learning environments require effective collaborative team work, the ARCS model is also a helpful framework for evaluating students' motivational attitudes toward collaborative project-based learning environments.

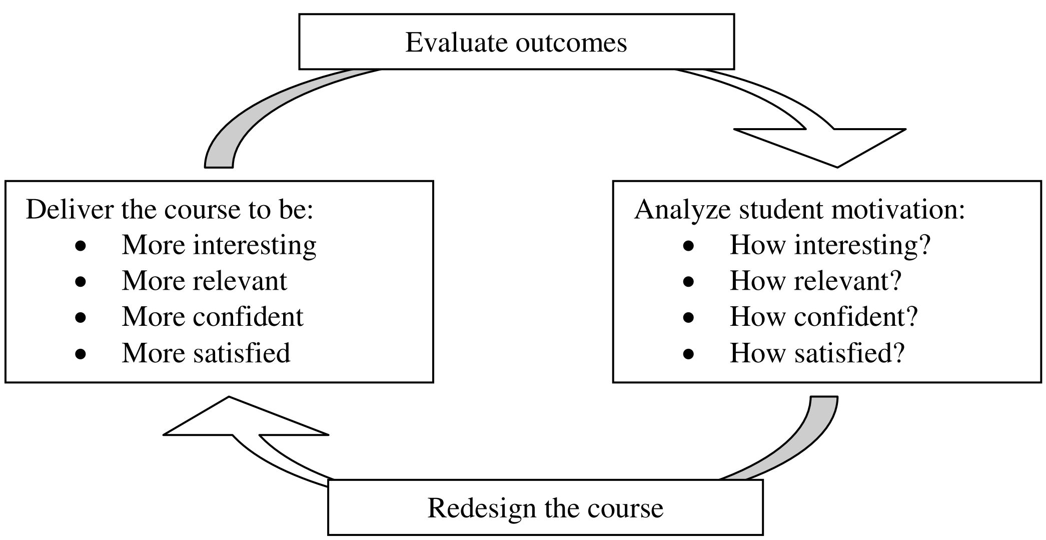

Figure 4. Continuous improvement of course design and outcomes.

Research Method

Research Questions and Hypotheses

The study aimed to answer the following two research questions:

1. How effective is a SL method, compared to a NSL method, on influencing introductory engineering students' motivational attitudes toward collaborative project-based learning measured by four ARCS factors?
2. How effective is a SL method, compared to a NSL method, on improving introductory engineering students' self-assessment on their engineering abilities measured against the ABET "a through k" program outcomes?

The research questions were answered by testing the following null hypotheses:

Ho_1: Students in an introductory engineering class will show no significant difference in terms of their motivational attitudes toward collaborative project-based learning measured by four ARCS factors whether they learn in a SL environment or a NSL environment.

Ho_2: Students in an introductory engineering class will show no significant difference in improving their self-assessment on engineering abilities in any of the ABET "a through k" program outcomes whether they learn in a SL environment or a NSL environment.

Population and Sample

The population of this study is students enrolled in undergraduate introductory engineering classes in the U.S. A sample of students used in this study were 151 students enrolled in seven sections of a 3-credit Introduction to Engineering class offered at Boise State University, a medium-size university in the northwestern region of the U.S. during the fall semester of 2009. Among the 151 students, 131 students (86.75%) voluntarily participated in the study by submitting a consent form; however, 119 of the 131 students (90.83%) submitted complete data sets. Therefore, the following data analysis was conducted on the 119 complete data sets. Ninety-eight students (82.4%) were male, and 21 students (17.6%) were female. The average age of the students was 22.30 (SD = 5.98, *Min.* = 17, and *Max.* = 55). Most students (83.2%) reported that they had not taken any SL-based courses before this course. Only 13 students indicated that they had taken one or two SL-based courses before this class; one student reported having completed 20 SL-based courses; 6 students did not report. Students' majors at the time of the study were Civil Engineering (n = 38), Mechanical Engineering (n = 24), Engineering General (n = 19), Electrical Engineering (n = 17), Materials Science and Engineering (n = 7), Computer Science (n = 4), and other science fields such as Chemistry, Physics, Pre-Med, and Applied Mathematics (n = 10).

Research Design

The independent variable used in this quasi-experimental study was the type of collaborative team projects that students completed during the course – that is, service learning (experimental group) vs. non service learning (comparison group). Students in all seven sections of the course received lecture by the same female instructor or guest lecturer, using the same materials and course topics, but their lab sections were supervised by different instructors. Two of the seven sections of the course were assigned to the experimental condition and the other five sections were assigned to the comparison group.

Research Instruments and Procedure

Post-Project Attitudes Survey: The post-project attitude survey we used in this study was developed based on an existing instrument for evaluating student experience with SL[11]. We modified it for the purpose of our study and developed 19 questions measuring student attitudes toward collaborative project-based learning on a 7-point Likert type scale (1 being 'strongly disagree' and 7 being 'strongly agree'). The attitudes were measured on four factors – attention (3 questions), relevance (5 questions), confidence (8 questions), and satisfaction (3 questions). The survey also contained 3 open-ended questions at the end. Students in both groups submitted the survey at the end of the course (The survey questions and ARCS indicators are presented at http://ipt.boisestate.edu/msensf/ASEE2010ARCSSurvey.htm). Internal reliability of the questions measuring each of the four ARCS factors was an acceptable level. The Cronbach Alpha values for the sets of questions measuring A, R, C, and S were .86, .90, .93, and .89, respectively.

ABET Program Outcomes Pre and Post Surveys: 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 11 ABET program outcomes. The ABET outcomes survey was administered in both groups during the 7th week of the course before the experimental group started service learning, and it was administered again in both groups at the end of the course.

Data Analysis: SPSS 17.0 for Windows was used to analyze the data with descriptive and inferential statistics.[12]

The overall research procedure is illustrated in Figure 5.

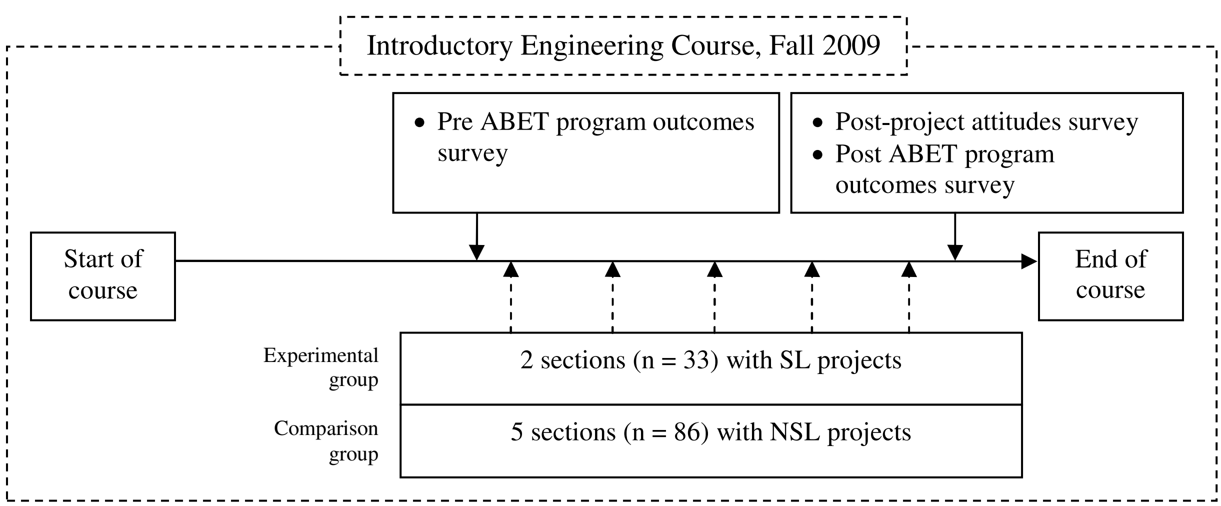

Figure 5. Research procedure.

Results

Students' Motivational Attitudes Measured by ARCS Factors

The data obtained from the post-attitude survey were nonparametric data; therefore, a Mann-Whitney U test was conducted to compare the difference between SL and NSL groups of students in terms of their motivational attitudes toward collaborative project-based learning.[13, 14] As shown in Table 3 and Figure 6, SL students expressed significantly more positive motivational attitudes at a .05 level than NSL students did. Therefore, the first null hypothesis (Ho_1) was rejected. Among the four ARCS factors, attention and relevance factors were significantly different between the SL and NSL groups. When using a conservative Bonferonni method[13], the relevance factor was significantly different between the two groups at a .0125 level (= .05/4).

Table 3. Group Difference on Motivational ARCS Factors.

	Group	*n*	*M*	*Mean Rank*	*Sum of Ranks*	*Mann-Whitney U*	*Z*	*P*
Motivational Attitudes (AVG)	SL	33	5.07	70.42	2324.00	1075.00	-2.042	.041
	NSL	86	4.45	56.00	4816.00			
• Attention	SL	33	4.99	70.48	2326.00	1073.00	-2.061	.039
	NSL	86	4.36	55.98	4814.00			
• Relevance	SL	33	5.01	72.94	2407.00	992.00	-2.539	.011
	NSL	86	4.23	55.03	4733.00			
• Confidence	SL	33	5.04	67.94	2242.00	1157.00	-1.556	.120
	NSL	86	4.54	56.95	4898.00			
• Satisfaction	SL	30	5.30	69.70	2300.00	1099.00	-1.905	.057
	NSL	86	4.69	56.28	4840.00			

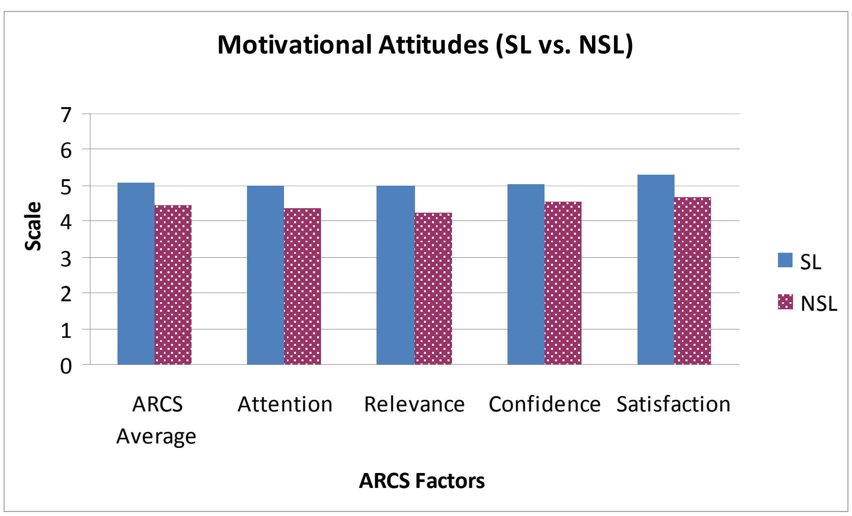

Figure 6. SL and NSL group difference on attitudes toward collaborative project learning.

Students' Self-Assessment of Engineering Abilities Measured Against ABET Program Outcomes

Mann-Whitney U tests and Wilcoxon Signed Ranks tests were conducted to compare the differences between, and improvement of, SL and NSL groups' self-assessment of engineering abilities when measured against ABET program outcomes.

Before the SL group started to use the SL method, SL students' self-assessment of their engineering abilities (M = 4.04, SD = .99) and NSL students' self-assessment of their engineering abilities (M = 3.87, SD = 1.37) were not significantly different from each other.When SL and NSL groups were compared again with the ABET program outcomes post-survey at the end of the course, SL students' self-assessed engineering abilities (M = 4.53, SD = 1.18) were much higher than the NSL students' self-assessed engineering abilities (M = 4.02, SD = 1.54). However, the overall pre-post changes in SL and NSL groups were not significantly different from each other, U = 1118.00, p =.074. When the group differences on pre-post changes were compared on individual ABET program outcomes, significant differences were found on two ABET program outcomes (b and c).

SL students' self-assessed engineering abilities improved from 4.04 to 4.53, and this difference (.49) was a significant improvement, z = -2.85, p = .004, while NSL students' self- assessed engineering abilities improved from 3.87 to 4.02, which was not a significant improvement, z = -1.52, p = .127. When comparing pre and post self-assessment results within each group, SL students' self-assessment of engineering abilities significantly improved on four ABET program outcomes (a, c, d and f), while NSL students' self-assessment of engineering abilities significantly improved on only one ABET program outcome (f). Overall, SL and NSL groups showed significant differences in improving two ABET outcomes, b (p = .034) and c (p = .006). Because SL was significantly more effective than NSL in improving students' self-assessed engineering abilities in at least two ABET program outcomes, the second null hypothesis (Ho_2) was rejected. However, it should be noted that when using a very conservative Bonferonni method, the group differences in improving these two ABET program outcomes were not significant at a .0045 level (= .05/11).

Descriptive and inferential statistics comparing SL and NSL groups' pre and post ABET outcomes survey data are presented in Table 4. Pre-post SL-NSL group differences are illustrated in Figure 7.

Table 4. Group Differences in Pre and Post Self-Assessments of Engineering.

Group	SL (*n* = 33)			NSL (*n* = 86)			SL vs. NSL (n =119)
	Pre	**Post**	**Diff**	**Pre**	**Post**	**Diff**	**Diff**
ABET Program Outcomes	*M* *(SD)*	*M* *(SD)*	*Z** *(p)*	*M* *(SD)*	*M* *(SD)*	*Z** *(p)*	*U*** *(p)*
Self-Assessment of ABET Program Outcomes (AVG)	4.04 (.99)	4.53 (1.18)	-2.85 (.004)	3.87 (1.37)	4.02 (1.54)	-1.52 (.127)	1118.00 (.074)
a. Ability to apply knowledge of mathematics, science and engineering to solve engineering problems	3.45 (1.46)	4.15 (1.77)	-2.04 (.041)	3.55 (1.53)	3.88 (1.73)	-1.72 (.085)	1176.00 (.240)
b. Ability to design and conduct experiments, as well as to analyze and interpret data	4.15 (1.37)	4.70 (1.53)	-1.57 (.116)	4.41 (1.56)	4.21 (1.70)	-1.06 (.289)	1070.50 (.034)
c. Ability to design a system, component or process to meet desired needs	4.52 (1.39)	5.21 (1.31)	-2.48 (.013)	4.40 (1.59)	4.26 (1.66)	-0.90 (.368)	950.00 (.006)
d. Ability to function on multidisciplinary teams	4.15 (1.60)	4.79 (1.38)	-1.98 (.047)	4.19 (1.62)	4.41 (1.76)	-1.70 (.089)	1282.50 (.407)
e. Ability to identify, formulate, and solve engineering problems	4.30 (1.35)	4.88 (1.55)	-1.87 (.061)	3.98 (1.73)	4.14 (1.69)	-1.25 (.208)	1124.00 (.270)
f. Understanding of professional and ethical responsibility	3.61 (1.34)	4.79 (1.51)	-2.79 (.005)	3.38 (1.78)	4.22 (1.97)	-4.01 (.000)	1238.00 (.274)
g. Ability to communicate effectively	4.00 (1.52)	4.48 (1.73)	-1.73 (.083)	4.08 (1.63)	3.98 (1.83)	-0.32 (.742)	1140.50 (.108)
h. Broad education necessary to understand the impact of engineering solutions in a global and societal context	4.18 (1.53)	4.52 (1.43)	-1.29 (.229)	3.81 (1.70)	3.93 (1.88)	-0.84 (.400)	1267.00 (.407)
i. Recognition of the need for and ability to engage in life-long learning	4.18 (1.48)	4.24 (1.93)	-0.48 (.629)	3.89 (1.89)	3.92 (1.97)	-0.47 (.636)	1323.00 (.628)
j. Knowledge of contemporary issues	3.55 (1.30)	3.58 (1.78)	-0.61 (.541)	3.29 (1.67)	3.53 (1.71)	-1.61 (.106)	1406.50 (.937)
k. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	4.36 (1.55)	4.52 (1.67)	-0.60 (.547)	3.70 (1.72)	3.83 (1.75)	-0.93 (.349)	1407.00 (.942)

* Wilcoxon Signed Ranks Test
** Mann-Whitney U-Test

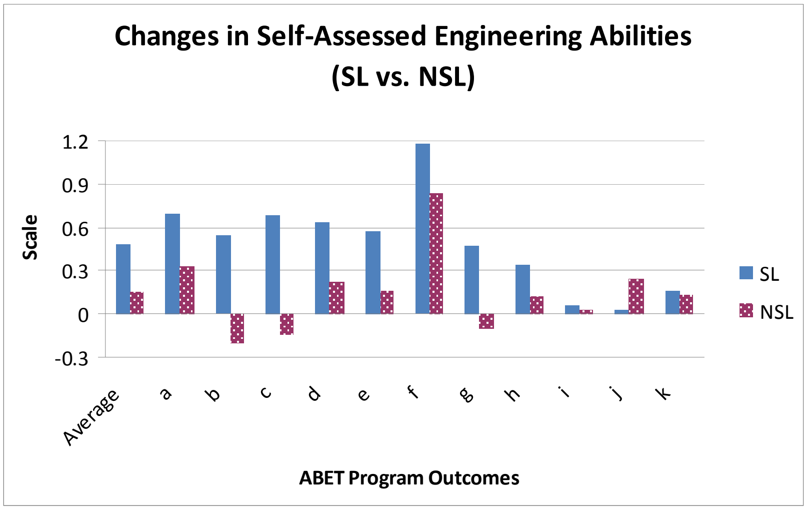

Figure 7. SL and NSL groups' changes in self-assessed engineering abilities.

Conclusions

Discussion

This study has revealed that a SL method is significantly more effective than a NSL method in terms of improving introductory engineering students' 1. motivational attitudes toward collaborative project-based learning measured by four ARCS factors and 2. self-assessment on their engineering abilities when measured against the 11 ABET "a through k" program outcomes.

The SL method used in an introductory engineering class was particularly effective on influencing motivational attitudes toward collaborative learning on the attention and relevance factors. The most positive outcome was that SL helped students realize that they could contribute to the community by using their engineering abilities to solve clients' needs (relevance).

SL is also proven to be an effective instructional method for contributing to the ABET program outcomes. While NSL students perceived themselves to be only slightly changed in terms of their engineering abilities measured against the ABET program outcomes, SL students perceived that they significantly improved their engineering abilities after having participated in SL in the introductory engineering course. Not only did the SL students improve their self-assessed ABET abilities in *each* of the 11 ABET program outcomes (satisfying both the overall course objectives of addressing the ABET outcomes, b, d, f, g, and h, and the SL-specific course objectives of addressing the ABET outcomes, a, c, e, and k), but SL was significantly more effective than NSL in improving two of the ABET program outcomes:

b. Ability to design and conduct experiments, as well as to analyze and interpret data (an overall course objective), and

c. Ability to design a system, component or process to meet desired needs (a SL-specific course objective)

Two ABET program outcomes that SL rated highest were:

c. Ability to design a system, component or process to meet desired needs ($M = 5.21$), and
e. Ability to identify, formulate, and solve engineering problems ($M = 4.88$).

When triangulating the results from the ARCS factor analysis and the results from the ABET program outcome analysis, it is apparent that the SL method is significantly more effective than the NSL method in improving students' understanding about how relevant to the societal needs their learning is and how important contributions to the society they as engineers make.

Although this study revealed positive effectiveness of using a SL method on improving students' motivational attitudes and self-assessment of engineering abilities, there is still room for improvement. The students' overall motivational attitudes (mean values) were 5.07 for the SL group and 4.45 for the NSL group on a 7-point scale. While these mean values are on the positive side from the scale's mid-point (4), there remains potential for improving students' motivational attitudes further up the scale into the 6 to 7 range. Similarly, the mean ratings of students' self-assessment of their engineering abilities measured on a 7-point scale against the 11 ABET program outcomes ranged from 3.58 (the ABET program outcome 'j') to 5.21 (the ABET program outcome 'c') for the SL group and from 3.53 (the ABET program outcome 'j') to 4.41 (the ABET program outcome'd') for the NSL group. Although one course cannot make significant positive changes in all 11 ABET program outcomes, there is still potential for improving students' perceptions of their engineering abilities up to the 5 to 7 range, especially for those ABET outcomes to which the course objectives are closely related.

Limitations of the Study

Several limitations of the study should be noted. First, it was a quasi-experimental study, using a convenience sample rather than a randomly selected sample from its population. 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 services necessary to complete the SL project. Due to the limited funding, only two of the seven sections of the introductory engineering class were able to participate in service learning.

Another limitation of the study was that because this study was conducted in a normal educational setting, students were likely aware of SL vs. NSL conditions. Therefore, it is possible that some students in the NSL group might have felt dissatisfied with the fact that they were assigned to the NSL group, which could have influenced their responses to the surveys. This is evidenced by comments provided by a couple of students from the NSL group - "Make them all service learning lab sections" and "Service learning would make this course much more useful and worthwhile."

Recommendations

Based on our experience of implementing a SL method in an introductory engineering course, we provide the following recommendations to other educators in the engineering community:

- Implement SL early in the engineering curriculum via introductory engineering courses. Traditionally, senior-level students experience a SL type of project-based learning in their capstone courses. This study has shown that engineering students can not only complete SL projects successfully in their introductory course but also significantly benefit by SL in terms of improving motivational attitudes toward collaborative teamwork and self-evaluation of engineering abilities.
- Seek funding to support SL in engineering courses. As discussed in this report, a lack of funding for the projects was a limitation of the study and is a possible barrier to continuous implementation of the SL method in engineering classrooms.
- Integration of SL into a curriculum requires careful planning.[15] Before implementing SL in a curriculum, assess needs of the local community while establishing positive rapport with the community, 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.
- Finding adequate projects suitable for freshman engineering students to complete can be a limiting factor. The client problems need to be of an appropriate scope and level of complexity; freshman engineering students have little to no experience with electronic design, 3D drawing and the engineering design process.
- Conduct educational research to assess effectiveness of the SL method (or other types of project-based learning) and redesign the curriculum to improve the motivational appeal. Effectiveness of instruction improves through a cycle of continuous assessment and redesign of the curriculum. The Post-Project Attitudes Survey questionnaire presented in Table 3 can be used as a summative evaluation instrument to assess students' motivational attitudes toward collaborative project-based learning, and the data can be used to redesign the course to be more interesting and more relevant to students, and to help them more confident in and satisfied with their learning.
- Study the impact of a SL method on student learning and retention. This study investigated students' motivational attitudes and self-assessment of engineering abilities. It is hypothesized that positive motivational attitudes and self-assessment of abilities would result in deeper understandings of engineering and continuous motivation to pursue engineering as a career. More research should be conducted to test the hypothesis.
- Design engineering curricula with instructional strategies such as SL that contribute to meeting ABET program outcomes. As shown in the literature review, engineering educators have successfully designed and implemented SL in their curricula to achieve ABET program outcomes. This study also has shown positive results of incorporating SL into an engineering curriculum toward producing positive ABET program outcomes. We strongly encourage other engineering educators to apply similar approaches to their curriculum design to help achieve ABET program outcomes.

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