AC 2011-968: ALTRUISTIC ENGINEERING PROJECTS: DO PROJECT-BASED SERVICE-LEARNING DESIGNS IMPACT ATTITUDES IN FIRST-YEAR ENGINEERING STUDENTS?

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Altruistic Engineering Projects: Do project-based service-learning design experiences impact attitudes in first-year engineering students?

Research on knowledge acquisition indicates that engaging students in active learning experiences, such as project-based (PB) and service-learning (SL) instruction, helps them transfer knowledge from the classroom to real-world settings. Combining project-based learning and service-learning (PBSL) has the potential to foster skills needed for a more global engineer, including cultural awareness, community-mindedness, and greater flexibility in defining and solving engineering problems. Practicing engineering in a community context, partnered with a strong emphasis on teamwork and reflection, PBSL programs may be effective approaches to recruit and retain more students, including women and minority students, into engineering programs and the engineering workforce.

One goal of this project is to incorporate PBSL curricula into existing undergraduate engineering design courses. This paper examines student attitudes towards altruistic engineering design experiences versus conventional engineering design experiences when PBSL is incorporated into the first-year undergraduate engineering experience at the University of Colorado Boulder. Using methods informed by current education research, we implemented an experiential, local community client-based PBSL section of First Year Engineering Projects (FYEP) and compared it to a conventional (non-PSBL) section taught by the same instructor. We analyze how the context of altruistic engineering impacts first-year student interest and skills with regard to engineering futures. Our results support the use of PBSL instruction to increase student technical and professional skills preparation. Specifically this paper addresses, *"When compared to conventional design experiences, do PBSL design opportunities significantly increase first-year engineering undergraduate student skills and interest in engineering futures?"*

Why teach project-based service-learning engineering design?

Most research on how people learn in general and, more specifically, how they learn technical subjects has been done in the context of science and math; however, some of the more accepted theories have been recently extended to engineering education. A review of the literature provides strong support for hands-on, project-based engineering design experiences as an instructional method to increase student knowledge and attitudes towards engineering. Research conducted at the University of Colorado Boulder indicates that open-ended, hands-on engineering design courses are a key to recruitment and retention of students in undergraduate engineering[1, 2, 3].

Other research suggests incorporating service-learning components into existing curricula to increase student learning. Service-learning is an educational method through which students actively participate in community service as an integral component of their coursework, fostering both civic responsibility and scholastic abilities through the integration of academic instruction and community-based service. Service-learning courses are evolving in engineering colleges as a mechanism to elevate student communication skills, and provide engineering students with meaningful, community-based learning experiences[4]. Research has found that people involved in service-learning experiences can improve academic learning of material and provide participants with a deeper understanding of the social context of their work[5]. The needs of the community define the service tasks for the students and provide students with the sense of responsibility for being members of a larger community[6]. UCLA's Higher Education Research Institute conducted a longitudinal study of over 22,000 college undergraduates, concluding that the use of service learning pedagogy has significant positive effects on students' academic performance (GPA, writing skills, critical thinking skills), leadership skills, and increased commitment to continued civic participation[7]. 68% of students engaged in the Engineering Projects in Community Service (EPICS) projects from Purdue University reported that participation in service learning positively impacted their determination to continue in engineering[8].

The premise is that engineering design can function as a motivator for learning foundational skills that are necessary precursors to higher level engineering skills[9]. Therefore, the use of developmentally-appropriate engineering curricula that builds on current cognitive research becomes an attractive instructional option. Combining project-based learning and service-learning (PBSL) has the potential to foster greater cultural awareness, community mindedness, and greater flexibility in defining and solving engineering problems.

Research objective

Using a modified engineering design curriculum within a service-learning context enables students to practice technical and professional problem-solving skills while developing new skills associated with local community-based service. The goal of this research is to focus on improving first-year undergraduate student engineering design experiences to address the gap between the teaching practices of engineering education and the learning styles of today's engineering student population, based on current understanding of learning theory.

The PBSL projects for this research are intentionally selected to provide students with engineering design work that results in an improved quality of life or a higher standard of living for targeted local communities. Similar to other service-based programs that serve local communities with social entrepreneurship projects, such as Purdue's EPICS program, our projects follow the emphasis on multidisciplinary teams and start-to-finish design process for local community partners[10,11]. Our program has also woven in rigorous assessment and evaluation of educational outcomes and changes in students' attitudes from inception, with the objective of research — and the dissemination of such — as the foundation of all of our endeavors. The difference from previous studies is that participants are not volunteers. In this study, the engineering students at the University of Colorado Boulder that are required to take FYEP by their departments are unaware of whether the section project is service-based or not, as compared to students self-selecting into a service-based project.

Specifically, a treatment (PBSL) section of the FYEP course is compared to a conventional (non-PSBL) section of the same course and instructor, and we investigate if the context of altruistic engineering impacts student technical and professional skills, motivation towards engineering, and intent to continue in engineering. *When compared to conventional design experiences, do PBSL design opportunities significantly increase the skills and interest in engineering futures for a sample of engineering undergraduate student enrolled in an First Year Engineering Projects course? Are these outcomes impacted by gender or ethnicity?"*

Setting for analysis

The University of Colorado Boulder's *First Year Engineering Projects* (FYEP) course has been evolving over the last decade into a successful avenue for increasing the retention of its students in engineering and is the setting for implementing our research question[1]. This course offers students an interdisciplinary, hands-on design-build experience and includes extensive training in teamwork, communication, and time management skills. Student teams design and create engineering products that are displayed and judged at an end-of-semester design expo for their peers and the public. In this experiment, both course sections are taught by the same professor, an award-winning engineering instructor. He had taught the course over a dozen times prior to the start of this study in 2009.

The control section of the FYEP course engaged in non-PBSL design (n=33), and was implemented during the fall 2009 semester. The context for these team projects was the creation of toys, a topic that has been engaging for engineering students of all ages based on the instructor's previous experience. An example of the projects was a car puzzle to help young students with logical reasoning. A PBSL-based section of FYEP was implemented in fall 2010 (n=33) that instead focused projects on altruistic engineering and design for local community clients. Two examples of projects for this section of the course included an egg-transport device for a local elementary school student who was supplementing his family income by selling eggs to teachers at his school, and a "hot box" for growing plants for a community garden that engages youth in urban farming activities to foster responsible decision-making.

To minimize potential instructor bias, the instructor followed identical course timelines and utilized the same grading rubrics to promote consistent project evaluation. The instructor also did not recruit, select, or engage with the clients during the PBSL-based section of the course. The instructor treated the projects between both sections equally, and, when queried, did not think that client-based design would have a greater impact on student learning or attitudes.

Student demographics for both sections (n = 66) are provided in Table 1. Ethnicity was recorded as either students who are underrepresented in engineering (URM) or majority students (MAJ). MAJ students included White and Asian students, while URM students included African American, Hispanic, Native American and Multicultural students.

Table 1. Fall 2009 and 2010 *First-Year Engineering Projects* (FYEP) course demographics, with raw numbers followed by percentage of the whole.

Course	Gender			Ethnicity			Year		
GEEN 1400, fall09, *(conventional)* (1 section, n=33)	M	26	78.8	MAJ	23	69.7	first-yr	27	81.2
	F	7	21.2	URM	10	30.3	other	6	18.2
GEEN 1400, fall10, *(treatment)* (1 section, n= 33)	M	25	75.8	MAJ	23	69.7	first-yr	26	78.8
	F	8	24.2	URM	10	30.3	other	7	21.2

The analysis in this report contains survey data information from 52 first-year engineering students; 11 students were eliminated from the study due to absences during either the pre- or post- survey. Additional data were collected on the cohort of students, including student demographics (gender, ethnicity, grade level), major, academic standing, and GPA.

Measures

Students were given engineering attitude surveys about their semester-long FYEP course experience with choices on a five- or six-point Likert-type scale ranging from "not at all" to "completely," pre- and post-semester, to measure any difference in student skills and interest in engineering futures as a result of exposure to PBSL engineering design.

One survey question borrowed and modified from the Persistence in Engineering (PIE) survey developed as part of the Academic Pathways Study (APS) from the Center for the Advancement of Engineering Education (CAEE) asked the students to provide a self-rating by of their skills preparation by answering the question, "Please rate how well prepared you are to incorporate each of the following items while practicing as an engineer[12]." This survey data contains responses to 20 questions that queried about technical skills preparation (data analysis, math, problem solving) (9 questions) and professional skills preparation (communication, creativity, teamwork) (11 questions). The 1-6 Likert-scale scores were summed separately to get two aggregated scores for technical and professional skills preparation. For example, a higher overall cumulative score for technical skills indicates a student's self-rating that they believe they are prepared to complete technical tasks while practicing as an engineer.

Another section of the survey queried students intention to complete a major in engineering as well as certainty of major choice, with one of the items also borrowed from the PIE survey[12]. These responses followed on a five-point Likert-type scale ranging from "not at all" to "completely certain." Students that did not answer this question were subsequently removed from the analysis of this question.

The surveys were separated according to treatment or control group and paired pre- to post- for each individual. Differences in mean scores between PBSL (treatment) and conventional (control) groups were compared, with additional testing for differential impacts by both gender and ethnicity. T-tests were used to determine the significance of pre- to post- matched survey scores for technical and professional preparation in engineering separately. Mean scores are presented in the following tables and have been adjusted to the corresponding Likert-type scale.

Results

Initial data screening generated descriptive statistics that showed seemingly large differences in pre-survey mean scores between the PBSL and conventional groups. Using an independent samples t-test, we determined that the pre-survey means for technical and professional skills preparation were not statistically significant for each analysis. In other words, there is no significant difference between the pre-survey scores in the fall 2009 section and fall 2010 section of First Year Projects in this study. The pre-survey means can be treated as the same, statistically.

Skills preparation

First, a paired-samples t-test was used to analyze the within-person differences in skills score over the course of the semester. The resulting paired sample correlations indicate that students who scored higher on the pre-survey also scored higher on the post-survey. The pre- to post-mean scores of the overall FYEP course (n=52) demonstrate a significant gain from the pre-assessment (mean=3.45) to the post-assessment (mean= 3.62), $p<0.05$, for technical skills preparation, indicating that the pre- to post- gains are likely not due to chance and the course increased *FYEP* student self-reported technical skills. The mean scores of the overall course (n=52) with respect to professional skills demonstrate a gain from the pre-assessment (mean=3.86) to the post-assessment (mean= 3.92). T-test statistical procedures indicate that the gain in professional skills is not statistically significant ($p=0.28$).

Table 2 shows the pre- to post- mean scores of technical and professional skills, divided into PBSL versus conventional groups. Again, the resulting paired sample correlations indicate that students who scored higher on the pre-survey also scored higher on the post-survey for both the PBSL and conventional groups. We compared PBSL and conventional group pre-assessments and found no significant difference in either technical skills (means =3.24, 3.63) or professional skills (mean=3.76, 3.96). Even though the students chose the classes without previous awareness of project topics, the PBSL group showed the greatest gains for both technical and professional skills preparation. The gains in technical and professional skills for the PBSL group are significant at the $p<0.01$ and $p<0.05$ levels respectively, while the gains in technical and professional skills are not significant for the conventional group.

Table 2. R**esults by treatment.** Cell entries contain mean scores of technical and professional skills preparation. A 1-6 Likert-scale adjusted mean is given, pre then post, with gain in parentheses.

FYEP course	**Technical skills preparation** mean score, pre - post	**Professional skills preparation** mean score, pre - post
PBSL (treatment) fall 2010, n=25	3.24 – 3.60* (0.36)	3.76 – 3.93** (0.18)
Conventional (control) fall 2009, n=27	3.63 – 3.65 (0.02)	3.96 -3.92 (-0.04)

*Significant at the $p<0.01$ level, paired t-test
**Significant at the $p<0.05$ level, paired t-test

Further analysis was conducted to determine if differences between PBSL and conventional sections exists with respect to gender. Table 3 shows the pre- to post- mean scores of technical and professional skills, aggregated by treatment and gender. As shown in Table 3, female students in the PBSL group had greater gains in technical and professional skills over the course of the semester than all other subgroups. Also, greater gains in both technical and professional skills were seen for the males in the PBSL group, compared to the males in the conventional group. Only the PBSL group males had a statistically significant increase in technical skills preparation. T-test statistical procedures indicate that all other gains were not significant. One limitation of the data is the small size of the groupings, which can cause non-significant results regardless of experimental impact.

Table 3. **Results by gender.** Cell entries contain mean scores of technical and professional skills preparation aggregated by females and males, PBSL (treatment) and conventional (control) groups. A 1-6 Likert-scale adjusted mean is given, pre then post, with change in parentheses.

FYEP course		Technical skills preparation mean score, pre - post	Professional skills preparation mean score, pre - post
Females	**PBSL (treatment)** n=7/25	**3.22 – 3.59** (0.37)	**3.79 – 4.06** (0.27)
	Conventional (control) n=6/27	**3.33 – 3.31** (-0.02)	**3.47 – 3.58** (0.11)
Males	**PBSL (treatment)** n=18/25	**3.25 – 3.60*** (0.35)	**3.74 – 3.88** (0.14)
	Conventional (control) n= 21/27	**3.72 – 3.75** (0.03)	**4.10 -4.02** (-0.08)

* Significant at the $p<0.01$ level

The data set was also analyzed with respect to students traditionally underrepresented in engineering (URM). For this analysis, majority students included both female and male Caucasian and Asian students, while URM students included female and male African American, Hispanic, Native American and multicultural students. Table 4 displays these mean scores. As shown in Table 4, the URM students in the PBSL group had the greatest gains in both technical and professional skills preparation, and majority gains in the PBSL group were also substantial. These results are significant only for the majority population PBSL students. Again, it should be noted that sample sizes are small.

Table 4. **Results by ethnicity**. Cell entries contain underrepresented minorities' mean scores of technical and professional skills preparation divided by majority and URM students, PBSL (treatment) and conventional (control) groups. A 1-6 Likert-scale adjusted mean is given, pre then post, with change in parentheses.

FYEP course		Technical skills preparation mean score, pre - post	Professional skills preparation mean score, pre - post
URM	**PBSL (treatment)** n=7/25	**3.20 – 3.78** (0.58)	**3.84 – 4.09** (0.25)
	Conventional (control) n=6/27	**3.58 – 3.56** (-0.02)	**3.86 - 3.84** (-0.02)
Majority	**PBSL (treatment)** n=18/25	**3.26 – 3.55**** (0.29)	**3.74 – 3.90** (0.16)
	Conventional (control) n= 21/27	**3.66 – 3.70** (0.04)	**4.01 - 3.96** (-0.05)

** Significant at the $p<0.05$ level

Intention and certainty of engineering major

The Likert-adjusted pre- to post-mean scores of the overall FYEP course (n=51) demonstrate a decrease from the pre-assessment (mean=4.57) to the post-assessment (mean= 4.33), for intent to complete a major in engineering. The mean scores of the overall course (n=50) with respect to how certain the students are about their major choice within engineering show a gain from the pre-assessment (mean=3.44) to the post-assessment (mean= 3.56). T-test statistical procedures indicate that neither of these differences is statistically significant.

Table 5 gives the mean scores for both questions, divided into PBSL versus conventional groups. None of the gains for either group are significant. However, the PBSL group showed greater relative gains for both intent to complete a major in engineering and certainty about their choice of major.

Table 5. R**esults by treatment.** Cell entries contain mean scores of technical and professional skills preparation. A 1-6 Likert-scale adjusted mean is given, pre then post, with gain in parentheses.

FYEP course	**Intent to complete major in engr** pre - post	**Certainty of major choice in engr** pre - post
PBSL (treatment) fall 2010, n=27	4.52 – 4.48 (-0.04)	3.28 – 3.64 (0.36)
Conventional (control) fall 2009, n=28	4.62 – 4.19 (-0.42)	3.60 -3.48 (-0.12)

Discussion and future work

The research is clear: hands-on design project courses are beneficial to engineering students. Longitudinal studies of FYEP students at the University of Colorado Boulder demonstrate a higher retention through the seventh academic semester in engineering studies for those who complete the course than those who do not[1,2]. Multiple sections of the course are offered each semester and projects range from assistive technology innovations, interactive learning exhibits for youngsters, Lego robots, and Rube Goldberg devices. Several departments already require completion of the team-based, multidisciplinary, three-credit projects course for graduation.

This analysis was intended to determine if a PBSL context significantly increases the self-reported skills and interest in engineering futures for a sample of engineering undergraduate student enrolled in a FYEP course. Overall, we found statistically significant gains in self-reported technical and professional skills for the PBSL treatment group in comparison with the conventional, or control, group. We also found that the intent to complete a major in engineering and certainty about their choice of engineering major of the students in the PBSL group was greater than the intent and certainty of their control group counterparts. This distinction, though not statistically significant for the small sample size in this analysis, is relevant when placed in the context of the PIE survey finding that students who do not persist in engineering are less certain of their intention to complete a major in engineering in the first year of college[13].

With respect to gender and ethnicity, female students in the FYEP PBSL group demonstrated greater gains in technical and professional skills over the course of the semester than all other subgroups. However, t-test statistical procedures indicate that these gains were not significant, likely due to small sample size of female in this section of the course (n=7). The URM students in the PBSL group also had the greatest gains in both technical and professional skills preparation as compared to their majority counterparts. Again, the sample size of the group (n=7) was relatively small. Collection of more data is needed to address the low sample sizes of female and URM students and to determine if these gains persist.

Future research of FYEP will include a more in-depth look at other constructs, including motivation, ability ratings compared with peers in their class, performance in the class, and post-survey reported awareness of professional skills needed in the engineering workforce. A multilevel linear model will be used to estimate the variance between teams of students.

This exploratory study supports future research on PBSL engineering design instruction as an intervention to increase first-year engineering student skills and attitudes about engineering. Analyzing any future data could inform the broader engineering community on the usefulness of PBSL instructional practices for narrowing the gap between the teaching practices of engineering education and the learning styles of today's engineering student population.

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