AC 2012-3802: K-12 ENGINEERING FOR SERVICE: DO PROJECT-BASED SERVICE-LEARNING DESIGN EXPERIENCES IMPACT ATTITUDES IN HIGH SCHOOL ENGINEERING STUDENTS?

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K-12 Engineering for Service:
Do project-based service-learning design experiences impact attitudes in high school engineering students?

Abstract

Despite well-intentioned efforts, our nation's education system is still not proficiently arming our K-12 students with the tools to succeed and compete in science, technology, engineering, and math (STEM) fields. To help close achievement gaps, engineering in K-12 classrooms offers a real-world application of the fundamental science and math principles that students learn throughout their STEM education.

K-12 engineering efforts are increasing around the nation, often grounded in current research on inquiry- and project-based learning, which has become popular as a result of the research in neuroscience and psychology on cognitive development. The past decade's increase in project-based instructional methods in K-12 education has researchers touting its success as a catalyst for increasing student learning of basic skills, complex problem solving, as well as professional skills and creativity. As a result, the K-12 engineering community has tailored project-based engineering design experiences—or, commonly known as PBL—for K-12 audiences. Project-based service-learning (PBSL) design experiences reportedly offer an added benefit of providing students with meaningful learning experiences in a community-based, (oftentimes local) context. Our analysis supports PBSL engineering design instruction as an intervention to increase high school student attitudes towards engineering and possible persistence into engineering undergraduate enrollment.

This paper examines the impact of PBSL in existing high school engineering design courses. Specifically, we compared one section of a 10th grade *Creative Engineering Design* course at a partner high school course engaged in PBSL projects with two separate sections of the course engaged in non-service learning PBL projects at the same school, during the same semester. Using multiple quantitative data analysis methods informed by current education research, we analyzed how the context of PBSL engineering impacts students' attitudes and efficacy with regard to engineering and community service. We also examined any differential impacts on students by gender and ethnicity. Specifically this research paper addresses, "When compared to conventional design experiences, do PBSL design opportunities significantly increase K-12 student identity and interest in engineering futures, and, if so, are certain groups differentially affected?"

Why Project-Based Service-Learning?

Today's youth want to make a difference. They want to shape the world and see their dreams become reality.[1] Retaining the interest of women and students of color in engineering is reported to improve at the K-12 and undergraduate levels when subject matter is placed in a social context and cooperative, interdisciplinary approaches to problems focus on holistic and global impacts.[2–4]

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 in both K-12 and undergraduate education. Essentially, PBL instruction uses an inquiry process to engage students in learning through exposure to complex, real-world problems, reflecting the environment in which they live and learn.[5] PBL design culminates in a final product, such as a design, model, device, or computer simulation, encouraging collaboration with other students, and using performance-based assessment to evaluate a range of skills and knowledge.[5,6] Currently, only limited research exists on the effectiveness of this method in the classroom, and most of that at the undergraduate engineering level. However, this undergraduate research demonstrates increased conceptual understanding and ability to transfer skills to other situations.[6]

Related research at the undergraduate level suggests that incorporating service-learning into existing engineering curricula increases student learning. In a service context, the needs of the community define the design tasks and provide students with a sense of responsibility for being members of a larger community[7]. This research indicates that instruction in service-learning centered experiences can improve academic learning of material and provide participants with a deeper understanding of the social context of their work, increasing technical, professional, and interpersonal skills.[7–11] The service-learning research at the K-12 level indicates that a service-learning context may be a significant factor in the recruitment of minority and female students into engineering.[12] This positive impact is echoed in undergraduate research on retention of female engineering students.[13]

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. PBSL instructional methods actively engage learners in complex, carefully-designed problems that benefit real communities or clients. Using a method of 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 students of color, into the pipeline of engineering education and the engineering workforce.[10,14]

Background — Skyline High School STEM Academy

Who is Skyline?

Skyline High School appears at first glance to be a below average American high school. Located in Longmont, Colorado, and one of the St. Vrain Valley School District's ten high school options, it is a diverse school with 1,230 students across grades 9-12. Recent composite ACT test scores, required by state mandate to be taken by all 11th grade students, for the Skyline students are 17.7 (2009), 18.9 (2010), and 17.5 (2011), compared to the 2011 district wide and statewide averages of 20.4 and 19.9. Likewise, 45% of Skyline students are from economically disadvantaged families (free and reduced lunch eligible), compared to a high school average in the district of 20% and state of 40%.

However, a closer look shows that Skyline High School is not average at all. In 2009, Skyline began an innovative STEM Academy (http://shs.stvrain.k12.co.us/stem.htm) to help curtail the exodus of academically-oriented students and increase student accomplishment and graduation of students at risk. Believing that the "E" in STEM should not be a silent vowel, the Skyline leadership team partnered with the long-established TEAMS program at the University of Colorado Boulder. One of the goals of the STEM Academy is to mirror the demographics of the school population, ensuring that the program is serving their whole population—including minority youth and girls, both underrepresented in STEM-related fields, and low-income youth from all backgrounds. The Skyline STEM Academy opened in fall 2009 with 80 freshman and 12 sophomores, and grew to 249 students in fall 2011, comprised of 35% female, 35% minority, and 23% free- and reduced-lunch students across grades 9-12.

The first four-year STEM Academy cohort to graduate will do so in 2013. Evidence that the STEM Academy is moving students beyond average level of academic preparation are the 2011 school wide CSAP results (Colorado State's NCLB assessment test), which reveal that while the majority of Skyline's 9th and 10th grade students scored only partially proficient in math, writing and science, the average STEM Academy student scored proficient in every one of these content areas.

Skyline's eight feeder elementary and middle schools mirror the demographics of the High School and are a key component in the recruitment and retention of underrepresented populations to the Academy. The TEAMS program was introduced into all feeder school curricula, inspiring shared learning goals between the nine schools.

Persistence in the STEM Academy

A key component of the STEM Academy is the requirement of four full years of math and science for all STEM students, with the prerequisite of completion of Algebra 1 by 9th grade. Because of accelerated math expectations, coupled with a strategic math intervention program, the Algebra 1 failure rate at Skyline High School has been reduced from 38% to 16%. On average, 25% of 9th graders—more than those coming in at the Algebra I level—take Geometry or Algebra 2. Both feeder middle schools now apply the same early intervention strategies with their 7th and 8th grade classes to address holes in math preparation before students get to high school.

Three full years of STEM engineering courses are required to earn a STEM Academy certificate from the high school. Each of the courses has been developed in collaboration with the University of Colorado Boulder's College of Engineering and Applied Science, and provides students with fundamental engineering design principles and experiences, arming them with the resources for a successful first-year engineering program at the college level.

Students typically start the STEM sequence of courses in the 9th grade. As students grow through the varied courses, they are engaged in increasingly complex hands-on design projects that peer into a variety of engineering disciplines. The curriculum uses a modified First-Year Engineering Projects course curricula, as instructed at the University of Colorado Boulder and described by others in "Improving Engineering Student Retention through Hands-On, Team Based, First-Year Design Projects."[15] For example, the 10th grade engineering offering, *Creative Engineering*, engages students in a semester-long design project, with each student team working on a version of the same product. So far, STEM Academy students choose two out of the following Creative

Engineering offerings for the certificate: Assistive Technology, Biotechnology, Sustainable Design, and Structural Design. Their *Senior Design Capstone* course is designed such that students may pick from topics they previously explored in their 10th grade *Creative* or 11th grade *Advanced Engineering* courses. The classes are taught by the high school's experienced science teachers, trained in engineering design through the University's professional development program.

Research Question

The goal of this research is to focus on improving K-12 student experiences in engineering design, based on current understanding of learning theory. Specifically, one PBSL section of a 10th grade semester-long engineering design course is compared to two non-service PBL sections of the same course, and we investigate if the context of PBSL engineering impacts student attitudes towards engineering. When compared to conventional design experiences, do PBSL design opportunities significantly increase K-12 student attitudes for a sample of high school students enrolled in a semester-long, hands-on engineering design course? Are these outcomes impacted by gender or ethnicity?

Methods

Setting for Analysis

A 10th grade engineering design elective course, *Creative Engineering Design*, at Skyline High School in Longmont, Colroado, is the setting for implementing this project's preliminary research. This high school has developed a widely-promoted high school STEM certificate program that began in fall 2009 to bring highly-interactive, hands-on STEM projects into the classroom to capture the attention of students at risk of early school dropout. The students start the STEM engineering sequence in 9th grade, and choose from topics of Assistive Technology, Biotechnology, Sustainable Design, and Structural Design during the more advanced 10th grade *Creative Engineering Design* class. The *Creative Engineering Design* class engages student teams in a semester-long, project-based exploration that follows an engineering design process, beginning with specification of design objectives, research, idea generation, concept refinement, and concluding with development and analysis of a prototype for the chosen solution. Reflection components include a mid-semester focus group discussion, an end-of-semester journal assignment, and open-ended post-survey questions.

Participants

The analysis in this report contains survey data information from 82 engineering students enrolled in three sections of *Creative Engineering Design* during the fall 2010 semester. For this particular semester, three topics of *Creative Engineering Design* were offered: Assistive Technology (Robotics), Structural Design (Cranes), and Biotechnology (service-learning for a local community client). Participants included 26 females (32%) and 56 males (68%). For this analysis, majority students included both female and male Caucasian and Asian students (N=52, 63%), while underrepresented minority (URM) students included female and male African American, Hispanic, Native American and multicultural students (N=30, 37%). Of the students, 68 (83%) are 10th graders in high school, while the remaining 14 students (17%) are juniors and seniors. One section (N=23) of the course was engaged in project–based service-learning (PBSL) projects and the other three sections (N=59) were engaged in non-service PBL projects. All students reported engaging in service opportunities previous to the course, while 20% of students in the non-service PBL and 35% of PBSL students reported actively participating in service 2-4 times per year. Both *Creative Engineering Design* teachers cooperatively developed and implemented the same project schedule, checkpoints, and grading rubrics. During fall 2010, one teacher taught the PBSL section of the course, while the other teacher taught the three non-service PBL sections.

Instrument Design

Students were given an online engineering attitude survey during class in the first and final weeks of the fall 2010 semester, with choices on a five-point Likert-type scale for each survey question ranging from “not at all” to “definitely.” The survey objective was to measure any change in student attitudes towards engineering as a result of exposure to the 10^{th} grade *Creative Engineering Design* course. Students typically completed the survey instrument within ~20 minutes. Several existing surveys from the literature around undergraduate engineering were integrated into the high school survey, including the Community Service Attitudes Scale (validated), which assesses the degree of participants’ attitudes regarding community service (15 items).[16] Other items originated from the Academic Pathways Study (APS) and the Assessing Women and Men in Engineering Project (AWE), designed to examine how student attitudes, skills, and efficacy change over time.[17,18]

In addition, demographic data such as gender, ethnicity, and year/grade, were collected with missing values retrieved from the high school student database.

Surveys and focus groups for all participating students are conducted under the large public University of Colorado Boulder’s Institutional Review Board (IRB) approval, reviewed annually by external and internal evaluators. Student responses are coded to protect participant identity.

Validity of the Instrument

Our instrument was examined to gather evidence of validity by analyzing how well the items measure the constructs that we intended. A Principal Components Analysis (PCA) was performed on the sample to analyze the theoretical constructs represented by the sets of response items related to attitudes towards community service (Community Service), efficacy with engineering skills (Efficacy), and awareness that there are needs that can be met by engineering (Awareness). The number of factors was determined by examining the total variance explained as well as a Cattell’s Scree test, which suggested that there was a five- or six-component solution. PCA was re-run using both five and six dimensionalities, and the results were compared. Very little explanatory power was added by including a sixth dimension, so a five-factor solution was chosen. PCA also suggested that attitudes towards community service may correlate significantly with students’ awareness of needs that can be met by engineering, though not very strongly. The average of the items that loaded on a given factor is used as independent variables in the remainder of this analysis.

Variables in Analysis

The dependent variables in this paper, to potentially explain differences in attitudes and perceptions between groups of students, were selected on the basis of research on service-learning and hands-on projects and confirmed through factor analysis. The three out of five factors that are examined in this paper include students' self-estimates of their attitudes towards community service (Community Service), efficacy with engineering skills (Efficacy), and awareness that there are needs that can be met by engineering (Awareness). The remaining two factors will be discussed in future papers. Selected survey items for each factor are presented in Table 1. Other variables collected for this analysis include the demographic variables of gender and ethnicity.

Table 1. Factors, Related Questions and Constituent Items for the *Creative Engineering* Survey

Factor, Question, and selected constituent items
Community Service (13 items)[16]
Pretend you are going to volunteer for community service sometime in the next year. Rate how you feel about the following.
Improving communities is important to maintaining a quality society.
I am responsible for doing something about improving the community.
It's my responsibility to take some real measures to help others in need.
I will seek out the opportunity to do community service in the next year.
Efficacy (11 items)
How much do you agree with the following statements?
I can succeed in an engineering curriculum.
I am good at designing things.
I know what an engineer does.
I am interested in taking more engineering courses.
Awareness (10 items)
How much do you agree with the following statements?
I think engineers create things for the benefit of society.
I understand the impacts of engineering design on the local community.
There are people in the community who need help.
There are needs in the community.

Statistical Analysis

Each survey was scored by taking the average of the 1-5 Likert-scale responses for each factor; average response to questions results in a composite score for each student. For example, a higher average of the nine pre-survey item scores for Awareness indicates a student's greater initial overall perception of their awareness that there are needs in the community that can be met by engineering. Next, each set of survey responses was paired pre- to post- for each individual.

First, we analyzed the data for missing values and data entry errors. We excluded five students who did not complete either a pre- or post-survey from the data set prior to analysis. Any missing values were examined for patterns, and no student skipped more than one or two items in each administration of the survey. Missing survey data was handled during subsequent analyses with list-wise deletion. Missing demographic data was retrieved from the high school student database.

Paired sample t-tests were used with each analysis to determine mean, standard deviation, correlations, and paired differences. Repeated measures of analysis of variance (ANOVA) were used when appropriate to examine within-person and between-groups relationships for analysis. Effect sizes were calculated for the paper to measure the practical significance of the relationship between pre- and post-assessment independent of the statistical analyses. For all analyses in the paper, IBM SPSS statistical software package (version 20) was used.

Results

The survey results reported in this paper are from matched pre- to post-surveys of 82 students enrolled in three sections of 10th grade *Creative Engineering Design* during the fall 2010 semester. Initial data screening generated descriptive statistics on each of the factors that showed trends for the overall cohort of students in Table 2. A paired-samples t-test was used to analyze the within-person differences in factor scores 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 10th grade students in Table 2 demonstrate a significant gain from the pre-assessment to post-assessment in self-rated attitudes towards Community Service and Efficacy. The paired sample means also demonstrate no change in Awareness. This cohort of Academy students displays a relatively high initial level of response for all three factors.

Table 2. **Overall Results**.
Cell entries contain mean scores, (standard deviations), mean difference, and post-survey effect sizes for overall student participation in 10th Grade
Creative Engineering Design on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference	Effect Size (Post Survey)
Community Service	**82**	**4.31 (0.52)**	**4.40 (0.57)**	**0.09***	0.18
Efficacy	**82**	**4.21 (0.55)**	**4.32 (0.55)**	**0.11***	0.21
Awareness	**82**	**4.57 (0.41)**	**4.57 (0.51)**	**0**	-0.02

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

How Does a PBSL Context Impact Attitudes?

There is a push to examine the impact of a real-world PBSL context to enhance engineering design courses. To break this impact out from traditional project courses, we divided the *Creative Engineering Design* sections into two categories, PBSL (N= 1 section, 23 students) and non-service PBL (N=2 sections, 59 students). The students in the PBSL section designed an accessible drinking water fountain product for a disabled 5th grader at one of the feeder middle schools while the other two sections designed a model crane and a robotic rover.

To look for differences in attitudes, we compared sections of the course with and without a service component. The descriptive statistics are given in Table 3. The students in the PBSL section of the course out-gained their peers in non-service PBL sections for efficacy ($p<0.05$) and awareness ($p = 0.120$, not significant). The students in non-service PBL sections out-gained their peers in PBSL-based sections with regard to attitudes towards community service. A closer look offers that the students in the PBSL sections scored much higher than their peers on the pre-survey, and an independent samples t-test confirms that there is indeed a significant difference in pre-survey scores between the two groups. The post-survey scores of the non-service PBL sections were still lower than the PBSL participants. The authors suspect this was due to students' self-selection in to the section, as evidenced by the higher percentage of students who actively participate in 2-4 service activities yearly (PBSL = 35%, non-service PBSL =20%).

Table 3. **Results by Service**.
Cell entries contain mean scores, (standard deviations), mean difference, post-survey effect sizes, and between groups significance for student participation by service in 10th Grade *Creative Engineering Design* on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference	Effect Size (Post Survey)	Between Groups (sig.)
Community Service						
All	**82**	**4.31 (0.52)**	**4.40 (0.57)**	**0.09***	0.18	
Service - All	23	4.50 (0.43)	4.57 (0.53)	0.06	0.40	0.000
No Service - All	59	4.24 (0.54)	4.34 (0.57)	0.11*		
Efficacy						
All	**82**	**4.21 (0.55)**	**4.32 (0.55)**	**0.11***	0.21	
Service - All	23	4.31 (0.57)	4.58 (0.42)	0.27*	0.61	0.000
No Service - All	59	4.17 (0.54)	4.23 (0.57)	0.06		
Awareness						
All	**82**	**4.57 (0.41)**	**4.57 (0.51)**	**0**	-0.02	
Service - All	23	4.55 (0.51)	4.69 (0.39)	0.15	0.38	0.000
No Service - All	59	4.58 (0.36)	4.51 (0.48)	-0.07		

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

A repeated measures ANOVA was used to determine any within-subject and between-groups effect by service, resulting in significant between-groups interactions for all three factors. Students in PBSL-based and non-service PBL sections are indeed changing their attitudes over time at a different rate, with independent t-test confirming differences in pre-surveys scores between the groups for community service ($p<0.05$) and significant differences in post-survey scores between the two groups for efficacy ($p<0.05$). One limitation of the data is the small size of the groupings, which can cause non-significant results regardless of experimental impact.

Are Students of Different Genders Impacted Differently by PBSL Projects?

In an effort to further understand the impacts of PBSL on females and males, we analyzed our data set with respect to gender. For the fall 2010 sections of *Creative Engineering Design*, there were 26 females (32%) and 56 males (68%). For this paper, we compared females in PBSL sections to females in non-service PBL sections and again for males. Again, descriptive statistics were generated using a paired-samples t-test; the results are provided in Table 4.

Table 4. **Results by Service and Gender**.
Cell entries contain mean scores, (standard deviations), mean difference, post-survey effect sizes, and between groups significance for student participation by gender in 10th Grade *Creative Engineering Design* on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference	Effect Size (Post Survey)	Between Groups (sig.)
Community Service						
All	**82**	**4.31 (0.52)**	**4.40 (0.57)**	**0.09***	0.18	
Service - Females	9	4.54 (0.21)	4.55 (0.45)	0.01	0.22	0.153
No Service - Females	17	4.25 (0.42)	4.48 (0.32)	0.23		
Service - Males	14	4.48 (0.54)	4.58 (0.59)	0.1	0.45	0.125
No Service - Males	42	4.23 (0.58)	4.29 (0.64)	0.06		
Efficacy						
All	**82**	**4.21 (0.55)**	**4.32 (0.55)**	**0.11***	0.21	
Service - Females	9	4.10 (0.79)	4.39 (0.49)	0.29	0.67	0.220
No Service - Females	17	3.94 (0.46)	4.01 (0.57)	0.07		
Service - Males	14	4.44 (0.33)	4.69 (0.33)	0.25*	0.69	0.059
No Service - Males	42	4.26 (0.54)	4.31 (0.55)	0.05		
Awareness						
All	**82**	**4.57 (0.41)**	**4.57 (0.51)**	**0**	-0.02	
Service - Females	9	4.58 (0.52)	4.62 (0.40)	0.04	0.15	0.948
No Service - Females	17	4.65 (0.26)	4.56 (0.39)	-0.08		
Service - Males	14	4.52 (0.53)	4.74 (0.39)	0.22	0.49	0.016
No Service - Males	42	4.56 (0.40)	4.49 (0.51)	-0.07		

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

Once again, the only factor where students in non-service PBL sections out-gained their peers in PBSL sections is in attitudes towards community service. Again, the students in the PBSL section started higher on their pre-survey than their peers. Though none of these mean differences are statistically significant, this difference is more noticeable for females in the cohort. The only significant gain by gender was in the increase in efficacy for males in the PBSL class ($p<0.05$), but both females and males in the PBSL class outgained their peers in both efficacy and awareness. Again, it is important to note that all students started with fairly high scores, ranking between "probably yes" and "definitely yes." One limitation of the data is the small size of the groupings, which can cause non-significant results regardless of experimental impact.

It seems as if the female students may have scored much higher on both the pre- and post-surveys for this variable. An independent samples t-test was used to determine any significant differences between pre- and post-survey scores. There were only significant differences between males in PBSL sections and non-service PBL sections on the post-survey for efficacy. A repeated measures ANOVA was used to determine between-groups effect, resulting in significant between-groups interaction for males in awareness.

Overall, the females and males in the PBSL section showed a greater increase than their peers in self-rated efficacy and awareness, with a greater difference in attitudes towards community service for students in non-service PBL sections. Again, it should be noted that sample sizes are small.

Are Students of Different Ethnicities Impacted Differently by PBSL Projects?

Lastly, we wondered if there was any difference between students in the PBSL section and non-service PBL sections of *Creative Engineering Design* by ethnicity. For this analysis, majority students included both female and male Caucasian and Asian students (N=52, 63%), while URM students included female and male African American, Hispanic, Native American and multicultural students (N=30, 37%). Table 5 displays these mean scores.

Table 5. **Results by Service and Ethnicity**.
Cell entries contain mean scores, (standard deviations), mean difference, post-survey effect sizes, and between groups significance for student participation by ethnicity in 10th Grade *Creative Engineering Design* on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference	Effect Size (Post Survey)	Between Groups (sig.)
Community Service						
All	**82**	**4.31 (0.52)**	**4.40 (0.57)**	**0.09***	0.18	
Service - URM	9	4.62 (0.25)	4.53 (0.43)	-0.09	0.31	0.192
No Service - URM	21	4.33 (0.47)	4.40 (0.42)	0.07		
Service - Majority	14	4.43 (0.51)	4.59 (0.60)	0.16*	0.43	0.130
No Service - Majority	38	4.18 (0.58)	4.31 (0.65)	0.13*		
Efficacy						
All	**82**	**4.21 (0.55)**	**4.32 (0.55)**	**0.11***	0.21	
Service - URM	9	4.18 (0.84)	4.46 (0.53)	0.28	0.66	0.400
No Service - URM	21	4.17 (0.55)	4.09 (0.56)	-0.07		
Service - Majority	14	4.39 (0.31)	4.65 (0.320	0.13	0.63	0.059
No Service - Majority	38	4.17 (0.54)	4.30 (0.56)	0.13		
Awareness						
All	**82**	**4.57 (0.41)**	**4.57 (0.51)**	**0**	-0.02	
Service-URM	9	4.49 (0.58)	4.58 (0.44)	0.09	0.18	0.775
No Service - URM	21	4.64 (0.24)	4.51 (0.40)	-0.13		
Service- Majority	14	4.58 (0.480	4.77 (0.36)	0.19	0.50	0.289
No Service- Majority	38	4.56 (0.42)	4.51 (0.52)	-0.05		

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

First of all, the majority students in both PBSL and non-service PBL sections of the course had significantly greater gains in scores than the URM peers in attitudes towards community service. Interestingly, the URM students in the PBSL section had a decrease in community service score over the course of the semester, though it is important to note that they started out the highest on the pre-survey. The URM students in the PBSL section outgained their peers in efficacy, while the majority students did not show any difference in mean scores for this factor over the semester. As for awareness, both the PBSL URM and majority students outgained their peers, and, in fact, the non-service PBL students all decreased in this factor over time. Again, it should be noted that sample sizes are small.

While it seems as if there may be large differences in pre-survey scores, especially for community service, an independent samples t-test did not determine any significant differences between the pre-survey scores and only significant differences in post-survey scores on efficacy between majority students. A repeated measures ANOVA was used to determine between-groups effect, again resulting in no significant between-groups interactions.

Limitations of the Study

The findings of these analyses should be placed within the limitations of this study. First of all, the cohort of participants is a small sample and comes from one semester of high school students in a STEM Academy at a local high school, which limits the generalizability of the findings. Also, 12 students in this study took two concurrent sections of the *Creative Engineering Design* course (PBSL and non-service PBL) during the fall 2010 semester. Of these students, four were Hispanic female students, while the remaining eight were majority male students. For purposes of this paper, those students who “doubled” sections of the course were considered with the treatment group, since they engaged with an actual service-based client during the semester. Small focus group results indicated that four female students who “doubled” indicated a preference for the PBSL section of the course.

It is difficult to differentiate the learning that went on between the sections of the course. Data on grades was not useful in comparing student learning between sections, since all grades for students in these classes were relatively high. The high grades reflect the aim of the course to encourage students into engineering. Although the sections were taught by two separate instructors, anecdotal evidence indicates that both teachers are highly regarded by students. The teachers also worked closely together on daily basis on the course, shared an office space and sometimes engaged in each other’s classes.

The students were aware of the other sections. Small focus groups indicated that students cross-talked to each other about the projects and course requirements. It was evident that many students were also excited about the projects in the other sections, with no obvious preference for any one topic. Students who did not double were also able to list advantages and disadvantages of each type of project.

It will be useful to discover if trends continue as we extend this study across additional semesters.

Key Findings and Discussion

Sophisticated, integrated course work and reinforcing with students the choices they must make in order to be academically prepared for a post-secondary engineering and/or other STEM education is a main thrust of the Skyline High School STEM Academy. Unfortunately, K-12 engineering initiatives such as these alone will not create a significant enough STEM pipeline, since most high school students are not academically prepared to enter engineering college. While K-12 engineering experiences, such as engineering electives, may inspire an interest in engineering, students must also make course selections across the curriculum that adequately prepare them for an engineering future. We know that small, yet vitally important, changes in curriculum can, and do, impact students' perceptions about engineering. PBSL is one such example of the changes that have the ability to positively influence a student's career choice.

Overall, our analysis indicates that the hands-on engineering design projects offered in the 10th grade *Creative Engineering Design* course increase students' attitudes towards community service and efficacy with engineering skills. The students in the PBSL section of the course out-gained their peers in non-service PBL sections for efficacy and awareness. The female and URM students in the PBSL section had the greatest gains in efficacy over the course of the semester. The non-service PBL females and majority students had the greatest gains for attitudes towards community service, though it is important to note again that the PBSL students started with very high attitude scores on this factor.

Skyline High School's four-year STEM curriculum focuses on higher-level thinking, communication, writing and many other 21st-century skills necessary for successful student learning. Students have expressed that the project team concept that is utilized in all of the STEM classes is essential for their learning and development as students prepare to be leaders in today's global economy. Students earn their STEM certificate fully understanding the design process and beginning to get a feel early on how engineers contribute to the health, happiness and welfare of society—a result of the early decision made by the leadership team to focus on the engineering design process and embed it into the day rather than do "science fair" type projects in an after-school environment, as many STEM programs do. The STEM Academy allows students to design, test, re-design their products and present, and communicate their results, and engages students in enriching projects that they work on for many weeks or an entire semester—while learning that engineering is meaningful work that benefits humanity and our planet. Through the Academy, students are engaged during the school day, making science, technology, engineering and math part of their world every day.

As such, PBSL projects foster an even deeper sense of the value of engineering and its impact on society. Through an awareness of giving back to the community, students in the STEM Academy understand how engineering relates to their everyday lives and improves the lives of others, especially when one of their own community members is positively impacted by their projects. The experience solidifies their role in engineering, in addition to allowing them to imagine impacts that reach beyond their own backyard—moving from a water fountain for a disabled classmate to a water-treatment system for an impoverished third world country.

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