The Impacts of Real Clients in Project-Based Service-Learning Courses

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Introduction

Client-based service-learning is increasingly prevalent in engineering education and is shown to improve valuable technical and professional skills when properly executed. True service-learning partners students and community clients to provide services that meet an authentic need in order to achieve desired student learning outcomes. Using this definition, the mutually beneficial and direct interaction between the students and the client to solve a real problem is indispensable for a service-learning experience. Conversely, other research suggests that working with a client is an unnecessary hassle; it is possible to create similar gains in both students' skills and attitudes toward community service as long as the project is representative of an actual community issue.

This paper examines the impacts of direct community interaction on students' attitudes and skills. To accomplish this, we analyze an established first-year engineering design course at the University of Colorado Boulder, which reaches 44% of the first-year engineering undergraduate student population per year and involves multiple types of projects over each semester. Building upon previous research at this university, we distinguish more rigorously between projects that involve a community client who is available for meetings and direct interaction, a theoretical or geographically distant client who does not interact directly with students, and projects that are not client-centered. We compare students' professional and technical skills when engaged in client-based projects to theoretical and non-client projects. We also examine the endurance of gains in students' practical skills over time (2-3 years after the course) to determine if the skills gain in the service-learning group remains elevated, in response to research that suggests student attitudes toward both professional and technical skills decline between first-year and capstone design projects. Using multiple methods informed by current education research, including examination of student attitude surveys and focus groups with students, we provide support for the value that client-based service-learning projects add to overall student experiences. This paper addresses: *Do projects involving direct interaction with a community client have a greater and more enduring impact on students' skills and attitudes when compared to service-themed projects and projects lacking community collaboration?*

Background

Several studies demonstrate that the addition of service-learning to courses helps to expand technical and professional skills, and by developing and immediately applying these skills, particularly in the first year, students gain a more meaningful experience.[1,2,3,4] Oakes and Thompson of Purdue University, home of the EPICS program, note that along with meeting educational and service goals, students often prefer completing projects with obvious and useful purposes.[1]

Furthermore, client-based service-learning is becoming increasingly prevalent in engineering education and is also shown to improve valuable technical and professional skills when properly executed. Currently, there are several discussions developing around what components need to be in place for students to gain these skills. Some practitioners maintain that benefits to learning come from helping the community while teaching students through a project *for* the community.[5]

A study at Northeastern University suggests that similar gains as those seen in client-based service-learning can be acquired by completing projects that are thematically similar or representative of an actual community issue.[6] This study proposes that a theoretical client can be used to take the place of a community client and hypothesizes that students respond similarly between situations where a class project is client-specific and situations are not client-based, yet theoretically could help someone. Although this research finds that theoretical clients are a successful way to eliminate logistical difficulties in coordinating client-based projects, Northeastern University still plans to expand the number of client-based service-learning projects offered.[6] The recommended continued pursuit of clients hints that the extra effort required by faculty to coordinate these experiences might still be worthwhile.

Service-learning projects may also meet some ABET accreditation standards better than non-service-learning projects. In a study of introductory engineering students, service projects were significantly more effective in meeting three of the ABET standards: ability to design a system, component or process to meet desired needs; ability to identify, formulate, and solve engineering problems; and ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.[7] A fourth ABET standard that can be addressed through service-learning projects is the requirement that students have an understanding of the ethical issues engineers may face. Some researchers argue that service projects promote an often-neglected fundamental component of ethics: the notion that doing good deeds in the world and workplace is as critical as preventing the bad.[8] In this way, community service and service-learning projects teach valuable ethical lessons that achieve goals that are essential to a meaningful college degree.

Solid technical and professional skills are important for our students' success in the engineering workforce. Often team-based in nature, project-based first-year engineering courses result in increased gains in knowledge across genders and are effective in increasing students' self efficacy and confidence in using the engineering design process.[4,9,10,11,12] This is impactful, especially in light of the results from the prominent APPLES study that concludes that first-year students tend to enter their engineering courses already highly confident in their abilities to solve open-ended problems, their math and science knowledge, and professional/interpersonal skills.[12] For women who may have rated their knowledge and design skills lower at the beginning of their first-year project-based learning (PBL) experience, Knight et al. report a closing of the gender gap on those skills by course end.[13] Unfortunately, other research shows that student attitudes toward both professional and technical skills decline between first-year and capstone design projects.[14] Perhaps service-learning courses are the answer to enduring impacts on skills, ethics, and attitudes.

Research Hypothesis

In order to deliver the largest benefits to students, universities must continually evaluate the courses they offer and apply the findings of current research. Recently, freshman design courses have come under examination; specifically the courses which have potential for implementation of a service-learning component into these sometimes-required courses. At The University of

Colorado (CU) Boulder's College of Engineering and Applied Science's (CEAS), the first-year engineering design projects class (FYEP) occasionally incorporates service-learning by asking teams to design and build a project for a client. To examine the value of having a client, we distinguish more rigorously between projects that involve a local community client (i.e. community-based high-need individuals, or government, educational or non-profit agencies), a theoretical or geographically distant client who does not interact directly with students, and projects that are not client-centered.

The goal of this research is to focus on improving first-year undergraduate student engineering design experiences to meet the changing skills required of today's engineering student graduates. Specifically, we investigate if the context of service-based engineering impacts both immediate and enduring student self-perceived technical and professional skills. *Do projects involving direct interaction with a community client have a greater and more enduring impact on students' skills and attitudes when compared to service-themed projects and projects lacking community collaboration for a sample of engineering undergraduate student enrolled in a First Year Engineering Projects course? Are these outcomes impacted by gender, ethnicity, or first-generation college-bound status?*

Methods

Setting for analysis

The *First Year Engineering Projects* (FYEP) course at CU-Boulder is the setting for analysis for this paper and has been described in previous research.[4] This course allows students to work in collaborative teams of 4-5 students to design and create engineering products that are displayed at an end-of-semester design expo for industry and the public. Team projects range from designs such as toys or educational modules to assistive technologies with actual or theoretical clients (See Table 1). Project topics are chosen at the discretion of individual professors and differ across the many sections of the course each semester. Students in all sections engage in reflection on their learning in a variety of ways, including journal assignments, an end-of-semester final report, and open-ended post-survey questions. Each section of the course is capped at a maximum enrollment of 32 students.

Table 1. Sample projects in FYEP

Project Category	Sample Projects
Local Community Client	Assistive technology for a medically fragile elementary/high school student Structure to discourage fence hopping at local homeless shelter Circular saw training tool for local firefighters
Theoretical or Geographically-Distant Client	Solar powered water heater for developing community Water purification system for developing community
No Client	Rube Goldberg System Ferrofluid Display

The majority of the students do not volunteer to take FYEP but complete it as a departmental requirement, including mechanical, civil, environmental, and aerospace engineering students. Engineering students that are required to take FYEP by their departments usually enroll into a section that meets their schedule constraints and not necessarily with a professor from their home department. Additionally, professors are not required to choose their project topic based on their departmental research focus; students do not know section topics prior to enrollment. In turn, the sections fill with a random mix of students from different disciplines.

Participants

The analysis in this report contains survey data information on approximately 631 FYEP engineering students enrolled in 26 sections of FYEP over five semesters (fall 2010 through fall 2012). Participants included 26% females (n= 165) and 74% males (n=466). 14% of students (n=89) identified as students typically underrepresented in engineering (male and female African American, Hispanic, Native American and multicultural students, referred to as underrepresented minority students, or URM, in our college). 14% of students (n=87) identified as students who are the first in their family to attend college. Most engineering majors offered at CU-Boulder are represented. 47% of students were enrolled in a section of FYEP that engaged a local community client (n=299), 17% of the students were enrolled in a section of FYEP that had a theoretical or geographically distant client (n=110), and 35% of students were enrolled in section of FYEP that was not client-centered (n=222). Overall, there were 14 professors for the 26 sections over five semesters, with some professors who teach only in the fall or spring, while others teach every semester.

Statistical Analysis

Instrument Design

Since 2008, students in the FYEP course were given an online engineering attitude assessment during class in the first week and final week of each semester with the goal of measuring change in student interest and affinity towards engineering. Several existing surveys were borrowed and assimilated into the FYEP survey, with most questions asked on a five-point Likert-type scale ranging from "not at all" to "definitely." The survey was refined over the first few years, and has been in its current form since fall 2010. The pre-semester survey contained 133 items relating to prior experiences, motivation, attitudes, interests, and demographics, while the post-semester survey repeated the 89 attitude and interest items. This paper discusses items from the Academic Pathways of People Learning Engineering Survey (APPLES), which included measurements of students' self-estimates of knowledge of engineering and skills related to engineering design work (26 items from the 89 total attitude and interest items on the survey).[12] The validity of the survey was examined and the attitude and interest items (n=89) had an internal reliability using Cronbach's Alpha of 0.97 (a value exceeding 0.7 is thought to be adequate).[4,15]

Surveys for all participating students were conducted under the University's Institutional Review Board (IRB) approval, and student responses were coded to protect participant identity.

Variables in the Statistical Analysis

The two dependent variables that were examined in this paper include students' self-estimates of their technical skills and professional skills. Selected survey items for each factor are presented in Table 2. Other variables collected for this analysis include section of the course for which the student was enrolled, gender, ethnicity, and a status of first-generation college-bound student.

Table 2. Factors, Related Questions and Representative Constituent Items for the FYEP Survey

Factor, Question, and selected constituent items
Technical skills (10 items)
Please rate how well prepared you are to incorporate each of the following items while practicing as an engineer:
Applying the Design Loop
Manufacturing Skills
Data analysis
Problem solving
Math
Conducting experiments
Professional skills (16 items)
Please rate how well prepared you are to incorporate each of the following items while practicing as an engineer:
Presentation Skills
Written technical communication
Teamwork
Management skills
Communication
Creativity

In order to model and examine the impact of the service-learning on students' attitudes numerically, multiple binary indicator variables were created to sort data into mutually exclusive categories (See Table 3). These variables have a value of 1 or 0 and represent the participation or non-participation in a categorical grouping of interest. In this analysis, students could belong to a variable of Community Client (a value of 1,0), representing those projects engaged with a local community client (n=299), Theoretical Client (a value of 0,1), representing projects with a theoretical or geographically distant client (n=110), or No Client (a value of 0,0), representing projects that were not client-centered (n=222).

Table 3. Indicator variables for type of FYEP service project, used in analyses.

Project Type Variable	**Number of students (Female, URM, FirstGen)**
Community Client	299 (84, 39, 47)
Theoretical Client	110 (21, 20, 18)
No Client	222 (60, 30, 22)

Methods for Statistical Analysis

In order to distribute students into service, theoretical service, and non-service projects, we began by speaking with faculty about the focus of their section projects. For each of the faculty that responded to our request, we downloaded the online survey responses for those sections and coded the data accordingly. For the factors of professional and technical skills, individual student 1-5 Likert-scale responses were combined into a composite score for each student. For example, a higher average of the sixteen pre-survey item scores for professional skills (teamwork, communication, etc.) specifies a student's greater initial overall perception of their professional skills. Finally, each set of survey responses was paired pre- to post- for each individual and all data was compiled into a single database in Excel and inspected for missing values and data entry errors. We removed students who did not complete either a pre- or post- survey from the data set prior to analysis. We also examined missing data for patterns and determined that no patterns exist for each administration of the survey.

Paired sample t-tests were used with each analysis to determine mean, standard deviation, and significance of paired differences. Repeated measures of analysis of variance (ANOVA) were used when appropriate to examine the longitudinal change in attitudes within and between groups. IBM SPSS® statistical software package (version 21) was used for all analyses in the paper.

Qualitative Focus Groups

Along with a statistical analysis of survey results, we held three small focus groups of undergraduate upper class (junior and senior) engineering students that participated in FYEP during their first year of college. The focus groups were intentionally separated by project topic (local community client, theoretical or geographically-distant client, or no client) to allow for students with similar projects to construct shared meaning about their course experience. Nine students participated in three thirty-minute focus groups (n=3, 4, and 2), including seven women, eight juniors, and one senior. The focus group questions included discussion on the type of project they had, their experience of developing and presenting their products, the impact of the course on their technical and professional skills, and whether they have applied their FYEP experience to any other courses/jobs during subsequent semesters.

The qualitative focus groups are exploratory in nature and analyzed using a scissor-and-sort technique to determine common themes and enduring impacts of knowledge and skills gained.[16] Small focus groups for all participating students are conducted under the University's Institutional Review Board (IRB) approval, and student discussions are anonymized to protect participant identity.

Results

The results reported in this paper are from matched pre- to post- surveys of 631 students enrolled in FYEP over five academic semesters (fall 2010 through fall 2012). The data is also separated into the three conditions of interest: projects that involve a community client who is available for meetings and direct interaction, a theoretical or geographically distant client who does not interact directly with students, and projects that are not client-centered. The trends in pre- to post- mean scores of students' perceived technical and professional skills are presented in Table 4 and graphically in Appendix A. A paired-samples t-test was used to analyze the within-person differences that occur pre- to post-semester and indicated that students who scored higher on the pre-survey also scored higher on the post-survey.

Table 4. Results by Type of Service-Based Project.

Cell entries contain mean scores, (standard deviations), mean difference, and paired significance for undergraduate students in First Year Engineering Projects on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference
Technical Skills				
All	**631**	**3.36 (0.63)**	**3.78 (0.57)**	**0.42***
Community Client	299	3.36 (0.66)	3.82 (0.57)	**0.46***
Theoretical Client	110	3.40 (0.61)	3.82 (.54)	0.42*
No Client	222	3.35 (0.60)	3.72 (0.59)	0.37*
Professional Skills				
All	**631**	**3.62 (0.57)**	**3.83 (0.57)**	**0.21***
Community Client	299	3.65 (0.61)	3.88 (0.57)	**0.24***
Theoretical Client	110	3.57 (0.53)	3.80 (0.55)	0.23*
No Client	222	3.61 (0.55)	3.78 (0.58)	0.17*

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

The pre- to post-mean scores of the overall FYEP students in Table 4 indicate a significant gain from the pre-assessment in self-rated technical skills and professional skills. There were also significant gains in students' perceived technical and professional skills for all types of FYEP projects, with students engaged in local client-based projects slightly outgaining their peers in both professional and technical skills. A repeated measures ANOVA was used to determine any within-subject and between-groups effect by service, resulting in no significant ($p<0.05$) within- or between-groups interactions. Students in all three groups had similar changes in attitudes and perceptions over the course of the semester, reflecting the overall course patterns.

Are female students differentially impacted by service-based projects?

In an effort to understand the impacts of instructional practices in service-learning on female students, we also analyzed our data set with respect to gender. Specifically, we compare the differences in self-reported technical and professional skills by female students between the three treatment groups. Descriptive statistics were generated using a paired-samples t-test and the results are given in Table 5 and graphically for both genders in Appendix A.

Overall, females in this study started with statistically significant lower pre-survey self-rated technical skills than their male peers (as seen in Appendix A; $p<0.01$). Continuing the patterns in the different service groups, all female students also increased in their technical and professional skills scores over the course of the semester. The female students that interacted with a client during FYEP had the greatest gains in perceived technical skills. The females who had a project focused on a theoretical or geographically-distant client started with the lowest perceived professional skills and had the greatest gains in this skills area. Repeated measures ANOVA resulted in no significant ($p<0.05$) within-or between-groups interactions by gender and service. It is also interesting to note that females that engaged in local community clients started and ended with the highest perceived professional skills scores, similar to the overall cohort. Since the students do not select their section of FYEP knowing the type of project in which they will participate, it is interesting that this cohort consistently starts and ends with the highest perceived skills.

Table 5. Results by Type of Service-Based Project and Gender.
Cell entries contain mean scores, (standard deviations), mean difference, and paired significance for undergraduate students in First Year Engineering Projects by gender on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference
Technical Skills				
All	**631**	**3.36 (0.63)**	**3.78 (0.57)**	**0.42***
Community Client-Females	84	3.16 (0.60)	3.73 (0.54)	**0.57***
Theoretical Client-Females	21	3.19 (0.60)	3.69 (0.55)	0.49*
No Client-Females	60	3.18 (0.61)	3.65 (0.58)	0.47*
Professional Skills				
All	**631**	**3.62 (0.57)**	**3.83 (0.57)**	**0.21***
Community Client-Females	84	3.71 (0.60)	4.00 (0.51)	0.29*
Theoretical Client-Females	21	3.58 (0.52)	3.93 (0.58)	**0.35***
No Client-Females	60	3.67 (0.57)	3.84 (0.53)	0.17*

*Significant at the $p<0.05$ level, paired t-test; **bold** indicates greatest gains

Are URM students differentially impacted by service-based projects?

In an effort to understand the impacts of emerging instructional practices in service-learning on students that are typically underrepresented in engineering (URM), we again analyzed our data set with respect to this demographic. For this paper, we defined URM students as both female and male African American, Hispanic, Native American and multicultural students (n=89). Descriptive statistics were generated using a paired-samples t-test and the results are given in Table 6 and graphically in Appendix A.

Table 6. Results by Type of Service-Based Project and URM.
Cell entries contain mean scores, (standard deviations), mean difference, and paired significance for undergraduate students in First Year Engineering Projects by URM on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference
Technical Skills				
All	**631**	**3.36 (0.63)**	**3.78 (0.57)**	**0.42***
Community Client-URM	39	3.42 (0.78)	3.99 (0.61)	**0.58***
Theoretical Client-URM	20	3.42 (0.61)	3.89 (0.62)	0.47*
No Client-URM	30	3.31 (0.59)	3.74 (0.55)	0.42*
Professional Skills				
All	**631**	**3.62 (0.57)**	**3.83 (0.57)**	**0.21***
Community Client-URM	39	3.78 (0.59)	4.11 (0.53)	0.32*
Theoretical Client-URM	20	3.54 (0.63)	3.88 (0.51)	**0.34***
No Client-URM	30	3.60 (0.58)	3.76 (0.47)	0.16

*Significant at the $p<0.05$ level, paired t-test; **bold** indicates greatest gains

All students that self-identify as URM students on the FYEP survey increased in their technical and professional skills scores over the course of the semester, similar to the overall course. The URM students who engaged with a local service client had greater mean differences in gains for perceived technical skills. The URM students who had a project focused on a theoretical or geographically-distant client had the greatest gains in perceived professional skills. Repeated measures ANOVA resulted in no significant ($p<0.05$) within-or between-groups interactions by URM and service. Again, we find it interesting that URM students who engaged in local community clients started and ended with the highest perceived professional skills scores, despite the randomization of students into different sections of FYEP.

Are first-generation college-bound students differentially impacted by service-based projects?

Lastly, we analyzed our data set with respect to students that self-identify as the first in their families to attend college, or first-generation college-bound students (FirstGeneration). There were 87 students over these five semesters of FYEP who self-identified as FirstGeneration. Descriptive statistics were generated using a paired-samples t-test and the results are given in Table 7 and graphically in Appendix A.

Table 7. Results by Type of Service-Based Project and First-Generation College Bound Student Status (FirstGeneration).

Cell entries contain mean scores, (standard deviations), mean difference, and paired significance for undergraduate students in First Year Engineering Projects by FirstGeneration on variables of interest.

Variable	N	Pre Survey Mean (SD)	Post Survey Mean (SD)	Mean Difference
Technical Skills				
All	**631**	**3.36 (0.63)**	**3.78 (0.57)**	**0.42***
Community Client-FirstGeneration	47	3.28 (0.74)	3.77 (0.66)	**0.49***
Theoretical Client-FirstGeneration	18	3.61 (0.47)	3.91 (0.42)	0.30*
No Client-FirstGeneration	22	3.50 (0.57)	3.66 (0.56)	0.16
Professional Skills				
All	**631**	**3.62 (0.57)**	**3.83 (0.57)**	**0.21***
Community Client-FirstGeneration	47	3.71 (0.69)	3.88 (0.66)	0.17*
Theoretical Client-FirstGeneration	18	3.54 (0.54)	3.87 (0.53)	**0.34***
No Client-FirstGeneration	22	3.65 (0.49)	3.69 (0.47)	0.04

*Significant at the $p<0.05$ level, paired t-test; **bold** indicates greatest gains

Of the 87 students who identified as first-generation college-bound students during the five semesters of FYEP, over half of them were engaged in local community client projects. The subgroup of students in the Client group did not start with the highest pre-survey scores for technical skills. They did, however, display the greatest gains in perceived technical skills over the duration of the semester. The FirstGeneration students who had a project focused on a theoretical or geographically –distant client reported greater gains than their peers in professional skills, while the FirstGeneration students who engaged with a local client again started with the highest mean professional skills scores. Repeated measures ANOVA resulted in no significant ($p<0.05$) within-or between-groups interactions by FirstGeneration and service. 40% of firstgeneration students are classified as URM, compared to 14% in the overall student cohort. The similar trends that emerge between URM and first-generation student classification in our analyses are not a surprise.

Qualitative Focus Group Results

While quantitatively there were minimal differences between student reporting of technical and professional skills and the type of project, anecdotally, we heard from upper class students about their perceived differences between projects and the impacts of the course on their future pursuits. We conducted three small student focus groups in spring 2013 (for students who were previously enrolled in the FYEP courses) for nine students, with focus groups separated by project type (client, theoretical or geographically-distant client, or no client). Shared themes that emerged from all three focus groups included learning about engineering and the design process, the usefulness of knowledge gained from the projects during subsequent courses and/or jobs, and wishing they had better understood the applicability of the projects course at the time.

Students agreed that the course helped them understand engineering and engineering design, often citing that the course kept them excited about their chosen field of study. Students reported that the course, "Confirmed for me that I really wanted to do environmental engineering with a biological focus," and "It absolutely reaffirmed the fact that I wanted to be an engineer." This is not surprising, in light of the positive retention research associated with first-year engineering design projects courses.[13]

Students also talked across groups about the usefulness of knowledge gained and how they had wished they understood better how useful the class was at the time. For example, one junior mentioned, "I actually did a work-study spring semester of last year and pretty much everything I learned from projects (FYEP) was directly poured into that." Another student talked about how she hadn't realized the environmental topic would help her with chemical engineering at the time. "But I realized that as a chemical engineer later that what I learned, like about heat transfer, during this (class) was perfect. I learned so much through that class and through making the water heater about a class that I would later take." And another student offered, "I liked how it was in the same sort of format like senior design where you had to go in and you had to make a presentation with your initial designs and then revise and you had to make several presentations and write a paper and do presentations and stuff… I thought that was good practice." Students also mentioned not understanding the value of what they were learning in the moment, such as "It would have been nice to (hear) you got to take this seriously, like you're doing stuff now," and, "Being freshman and not understanding time management, we let it pile up a little bit more." Two women from the focus groups discussed their subsequent involvement in K-12 engineering after the projects course and being able to use their presentation skills and knowledge of engineering design from the FYEP course with the younger students.

Specific to service-based projects, students in the client and theoretical or geographically-distant client groups expanded their discussion to include the motivation of having a client project. One junior woman talked extensively about her experience with a local community client. "After we went out to the assisted living place, it was more motivating because the clients were excited… but also the people that were working in the building and were helping were really excited because they'd say, "Oh he really always wants to do his laundry and we have to help him and… every time, he's like trying to do it himself but he can't quite do it. It wasn't just like the clients, it was also the people who work with the clients and, yeah, it made you more motivated since they were excited about it." Students who engaged in client-based projects also appreciated the usefulness of their final projects, describing how the projects were functional and less likely to be recycled. "You knew like that it wasn't going to go like get ripped apart and like stuck back down in the (basement)," and "A lot of people had projects that didn't work when you walked around." Projects without a client-focus were described as "superfluous" and one women related, "I remember at our expo there was a walking bike or something, and they had combined basically a bicycle and a treadmill, and you could walk on the bicycle, and it moves the wheels, and I was like well that's neat, but I'm going to be saving people's lives here with my water design so I think I liked the practicality and the applicability about our project." Not surprisingly, the no-client group also noticed client-based projects in other sections but preferred to have fewer performance outcomes and a project that was "just for fun."

As we anticipated, student focus groups also described team struggles, team dynamics, and how much they learned about working with other students in different disciplines, since practicing teamwork is a primary objective of the course. Overall, the focus group discussions support our quantitative results with little distinction between conditions of treatment on perceived gains in technical and professional skills. The focus groups do provide more insight into the attitudes around client and non-client based projects between groups. Students who engaged in client-based projects spoke more often of motivation and practicality of their experience. The focus groups also highlighted the enduring impacts of early project-based and service-learning experiences on students' technical and professional skills.

Limitations of the Study

The findings of these analyses must be placed within the limitations of this study. First of all, we note that courses and experiences outside FYEP have an impact on student perceptions and attitudes. However, most first-year engineering students in the University of Colorado Boulder's College of Engineering and Applied Science (CEAS) take very similar courses regardless of major (calculus, calculus-based physics or chemistry for engineers, an introduction to engineering course, and a social-science or humanities elective).

Another limitation is variation among instructors and instruction of the various types of projects. To try and reduce the impact of instructor variation, a common schedule, design milestones, and rubrics are offered to all instructors during a weekly FYEP meeting, with the intent to make the same resources and background research on student learning available to all. Of course, use of these resources is hard to enforce in the actual classroom. Instructor enthusiasm for the semester-long project topics also varies between instructors, with obvious bias towards their own project. End-of-semester student completed evaluations, Faculty Course Questionnaires, often rank this course and its instructors among the highest in our CEAS.

Distinguishing between different types of service-learning projects can be difficult. For this paper, we defined two major categories of service-learning projects. The first group included projects that involve a community client who is available for meetings and direct interaction;

student teams met with their client face-to-face at least once per semester. The second group included a theoretical or geographically distant client who does not interact directly with students; the students never met their client for a face-to-face interaction. More of the service-learning based projects fell into the first category.

Overall, it would be useful to extend this study to all entering first-year students across semesters to see if the trends continue.

Discussion

In this paper, we set out to answer the questions, *Do projects involving direct interaction with a community client have a greater and more enduring impact on students' skills and attitudes when compared to service-themed projects and projects lacking community collaboration for a sample of engineering undergraduate student enrolled in a First Year Engineering Projects course? Are these outcomes impacted by gender, ethnicity, or first-generation college-bound status?*

Our analysis included the survey responses from 631 undergraduate students engaged in a semester-long first-year engineering design projects course (FYEP) over five unique semesters in the College of Engineering and Applied Science at the University of Colorado Boulder. Specifically, we looked at a change in perceived professional and technical skills pre- to post-semester using an online engineering attitudes survey with items that have been used by other engineering colleges around the nation. The technical and professional skills items (n=26) help us to understand how our undergraduate students feel about the value of their education. The skills have also been deemed important by industry and professional societies.

All students in FYEP showed significant gains in perceived technical and professional skills, which reflects previous research in this area.[4,12,13] Similar gains were also seen for the three types of FYEP projects or conditions of interest in this paper: local community clients, theoretically or geographically distant clients, or no clients. Students engaged in local community client-based projects slightly outgained their peers in both professional and technical skills, but not to a statistically significant degree.

As for impacts by targeted student populations (female, URM, and first-generation college bound), the results were similar for each group. Female, URM and first-generation students who interacted with a client during FYEP all started with the lowest perceived technical skills and outgained their peers in this skills area over the semester. Also, all three populations who had a project focused on a theoretical or geographically –distant client started with the lowest pre-semester scores for professional skills and had the greatest gains over the semester. It is interesting that our targeted populations who engaged in local community clients started and ended with the highest perceived professional skills scores, since the students do not select their section of FYEP knowing the type of project in which they will participate.

Our focus groups reflected the overall quantitative gains in perceived knowledge and skills across treatment conditions. All three focus groups involved discussions on learning, the usefulness of knowledge gained on future experiences, and wishing they had better understood the applicability of the projects course at the time. Students who engaged in community or theoretical client-based projects spoke more often of real-world motivation and practicality, while students within the different conditions preferred the type of project (client or not) that they completed.

Collectively, students benefit greatly from the FYEP course, as measured in both technical and professional skill gains. While the skill gains are significant in every category, there are no significant differences among or between groups (female, URM, first-generation) or by treatment (local community clients, theoretically or geographically distant clients, or no clients). Follow-up focus-group discussions indicate that the course's effectiveness does not depend on project type; however, they hint that the benefits of service-learning projects may extend beyond the self-reported technical and professional skills, to specific outcomes such as "impact of engineering on society" (ABET h) or "professional and ethical responsibility" (ABET f). Suggested future research includes administration of the skills survey to a cohort of upper class students (who took FYEP) to determine any endurance in self-reported technical and professional skills gains by project type.

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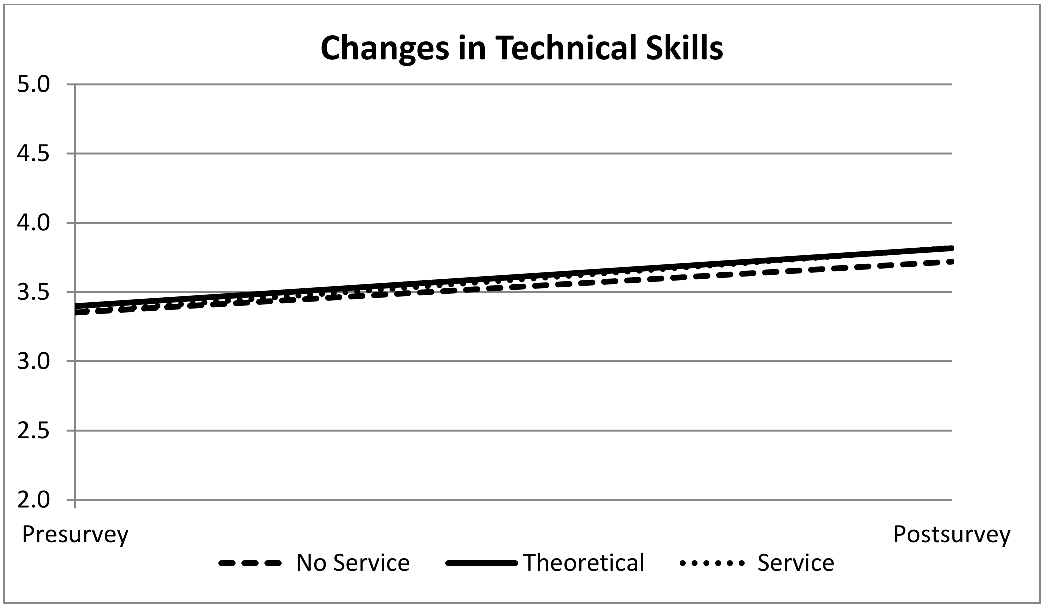
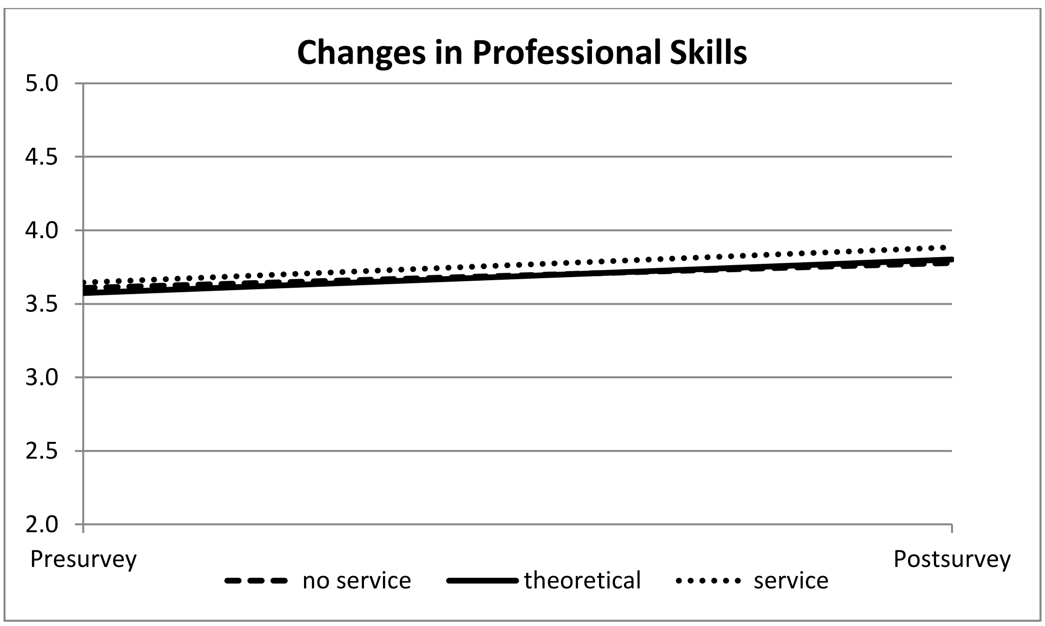
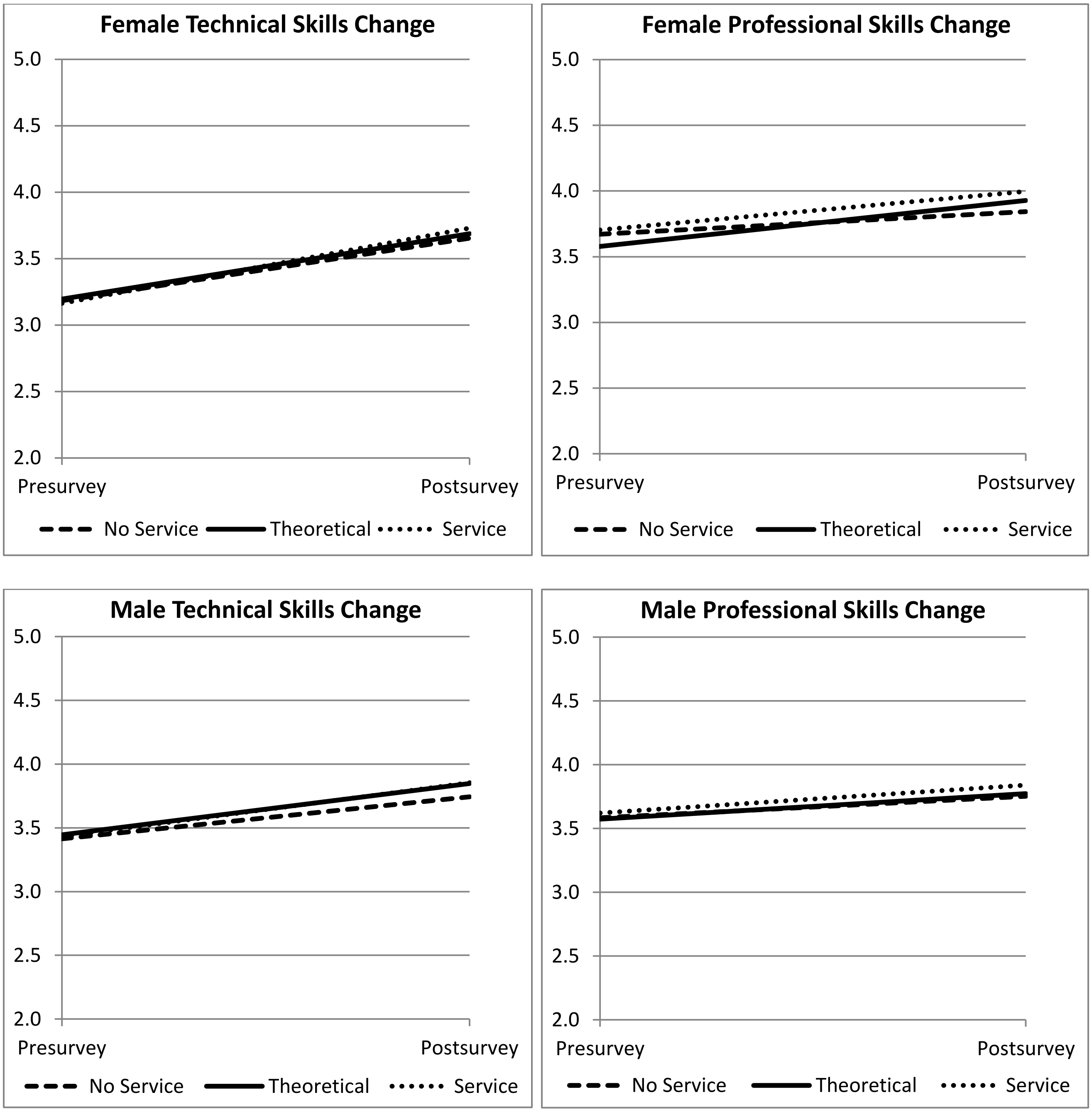
Appendix A: Graphical Representations of Technical and Professional Skills by Variables of Interest

Figure A1. Results by Type of Service-Based Project.

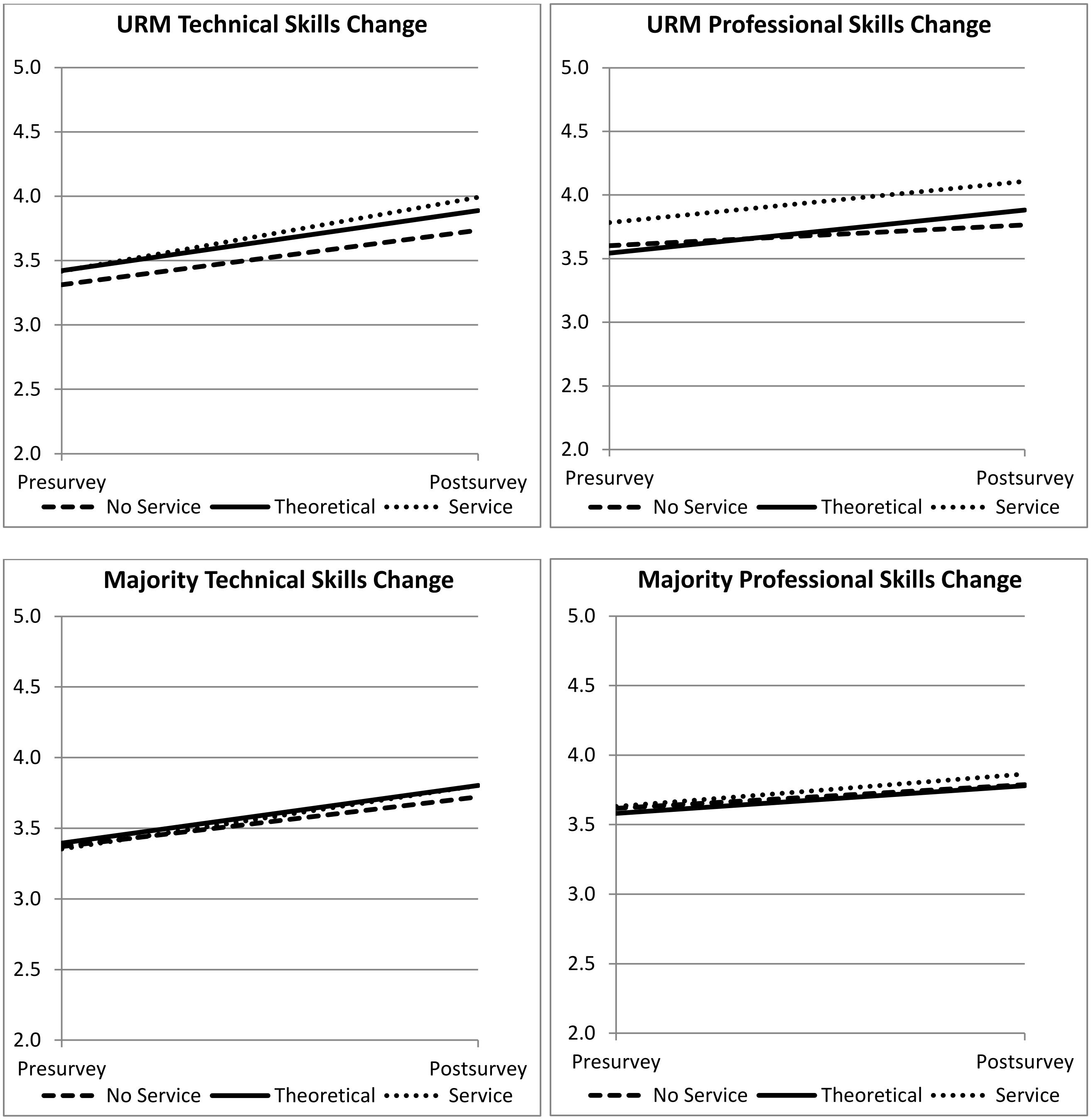




Figures A.2-5. Results by Type of Service-Based Project and Gender.



Figures A.6-9. Results by Type of Service-Based Project and URM.



Figures A.10-13. Results by Type of Service-Based Project and First-Generation College Bound Student Status (FirstGeneration).