AC 2010-2201: EFFECTS OF STUDENT-CUSTOMER INTERACTION IN A CORNERSTONE DESIGN PROJECT

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Effects of Student-Customer Interaction in a Cornerstone Design Project

Abstract

Similar to other first-year cornerstone engineering design courses, "Exploration of Engineering Design" at a large land-grant university features a large enrollment of students (1000+) that represent a wide variety of engineering disciplines. The instructors are faced each year with the challenge of providing a meaningful, appropriate and valuable project experience that supports learning and fosters interest about engineering design for their diverse audience.

In response to this challenge, the course instructors initiated a service-learning design project as a means of achieving broad engineering design learning objectives, such as identifying customer requirements, framing an open-ended design problem, and following a systematic approach to generate and select design alternatives. Named "ROXIE" (an acronym for "Real Outreach eXperiences In Engineering), this project provides students the opportunity to work with real customers, serving as "Design Consultants" for non-profit organizations. Through their interaction with their "clients," student teams frame the design problem and work towards its solution by following the design methodology taught in class.

To investigate the potential benefits of the student/customer interaction found in ROXIE, the authors compare it with an alternative design project program. Students working on projects in this alternative program ("HELP": Human-centered Engineering Learning Projects) are tasked with designing an assistive technology device. While similar to ROXIE in that its projects are centered in community service, HELP projects are speculative in nature and thus do not provide students an opportunity to work with "real" customers.

In this paper, the authors perform a comparative analysis of the ROXIE and HELP projects using data from student survey responses as a means of identifying the effects of including a student/customer interaction component in a cornerstone design experience. Excerpts from student interviews and reflection essays are provided as a means of placing survey responses in context.

1 Introduction

1.1 The Cornerstone Design Project

First-year engineering courses with design project elements are an emerging trend [1]. A 1999 study identified 43 ABET accredited universities and colleges that featured a first-year design experience for mechanical, civil and electrical engineering majors [2]. A description of several courses (and their associated projects) that expose first-year students to design experiences is provided in [3].

The creation of a first-year design project is an important task. Dally and Zhang suggest that first-year engineering courses without design experiences are unsatisfactory because theoretical content is not sufficiently linked to application [4]. First-year design projects provide students

with a context in which to apply course content (e.g., graphics communication, programming, basic engineering analysis, design methodology, etc.). They also provide a structured opportunity for students to further develop their critical thinking and problem solving skills. This application of engineering principles allows students to gain a clearer perspective of the true nature of the discipline. This perspective is further shaped by their early interaction with engineering faculty. Furthermore, it has been asserted that these "cornerstone" design experiences enhance student interest and retention in engineering (especially among women and minorities [5]), motivate learning in upper-division courses, and improve performance in capstone design courses [5,1].

1.2 Service-Learning in Cornerstone Design

Of the many project alternatives that exist for cornerstone courses ([2]), the authors have looked towards a service-learning project as a means of achieving their course's design learning objectives [6,7]. Service-learning is defined as a "method under which students learn and develop through active participation in thoughtfully organized service" [8]. In the context of engineering design courses, projects centered in service-learning typically feature the student teams designing a product or process that meets the needs of a community partner in need.

Service-learning activities are becoming more prevalent in engineering curricula as instructors discover that their pedagogical objectives of problem solving, working in groups, and experiential learning match well with the stated criteria of service-learning [9]. Duffy and coauthors suggest that service-learning team projects provide students an opportunity to learn and demonstrate ABET learning outcomes pertaining to teaming, communication, understanding the impact of engineering solutions, and the identification, formulation, and solution of design problems [10]. Furthermore, service-learning experiences have been shown have positive impacts on retention, civic responsibility, personal development, and a deeper understanding of the subject matter [11]. As such, service-learning themed design projects are appearing in first-year design courses [12-15].

It has been suggested, however, that the major drawback of such a project is in resource commitment [12]. The benefits of dealing with an "actual customer" and a "real-world problem" might be offset by the need to assist teams with the uncertainties associated with the open-ended nature of the project. This concern is magnified for those cornerstone courses that have large enrollments, as arranging connections with a sufficient amount of community partners might be too resource intensive to sustain [16].

1.3 The Effects of a Customer/Student Interaction in a Student Design Project

In this paper the authors make progress towards identifying the effects of customer/student interaction in a service-learning cornerstone design project. Specifically, the authors investigate the presence of significant differences in student perception of design learning and in project attitudes for two project types: (i) a service-learning themed project that features students working with community partners to solve a design task and (ii) a speculative project that is centered in the design of assistive technology devices to enable disabled or handicapped persons to accomplish day-to-day tasks. To provide context for the paper, the authors provide an overview of the course in which the projects were implemented in Section 2. The two project types are detailed in Section 3. In Section 4, differences between the two project types are

identified through analysis of 620 student survey responses and excerpts from student interviews and reflection essays. Closure is offered in Section 5.

2 Context: "Exploration of Engineering Design"

The context for this paper is a required introductory course for a large land-grant university. The course, "Exploration of Engineering Design" (ENGE1114), is the second in a series of courses required for all first-year engineering students (except those intending to enter Computer Science or Electrical and Computer Engineering). The course features a large enrollment (1000+ in Spring 2009) of students who have yet to formally declare their desired engineering major. The two-credit, semester-long course is structured around two weekly meetings: one large group meeting (50 minutes; ~300 seat) orchestrated by faculty instructors, and one workshop session (2 hours; ~35 seat) monitored by a graduate teaching assistant.

Given the diversity of its participants' engineering interests, the course's primary learning objective – to gain an understanding of the engineering design process – is broadly formulated so that the content is relevant to all engineering disciplines. This objective is embodied through the three content modules that compose the course:

- Design Methodology: Systematic approaches to open-ended design problems incorporating project management, structured concept generation and selection, and design communication.
- Graphics Communication: Graphical communication of design ideas through reading engineering drawings, computer-aided solid modeling, and sketching and visualization techniques.
- Programming: Structured problem solving through algorithm development and basic programming principles (e.g., syntax, decision structures, and looping structures).

Table 1. Organization of Content Delivery for the ENGE1114 Design Methodology Module

Week	Large-Group Meeting Topic	Workshop Activity
1	Design Method Overview, Project Management and Teaming	Team-building activities: Students complete Myers-Brigg personality tests and reflect on the results as a team. Student teams then compete in a balloon tower building competition. Teams then begin drafting their Code of Cooperation and their project Gantt Chart.
2	Generating Requirements	Generating requirements for products and processes: Students are asked to identify requirements for a process ("design the perfect camping trip") and a product ("design a device to assist in hauling equipment on trails").
3	Functions and Concept Generation	Functional decomposition: Students learn about function and means through dissection of See-N-Say toys.
4	Alternative Generation & Selection	Selection: Students learn about metrics and the selection decision matrix through a paper airplane design competition.

The content of the 4-week long design methodology module (Table 1) is focused in the early stages of design (problem definition and conceptual design), as these skills are important to all engineering disciplines. The Boyer Commission on Educating Undergraduates in the Research University has recommended that students gain practice with problem definition skills within their first year [17]. The ability to frame and scope engineering problems is a stated educational outcome of ABET [18]. Dym suggests that first-year students can have meaningful design

experiences that are focused in problem identification and conceptual design as it introduces them to techniques that structure their creative thoughts [12].

Design instruction in the course is organized to help students advance their understanding through progressive cognitive levels: knowledge is gained through text reading, comprehension is gained through the context and examples provided in the large-group meetings, application is provided via hands-on workshop activities, and analysis and synthesis are provided through a semester-long design project experience. The purpose of the design project is to provide students an opportunity to both synthesize the content modules and to engage in engineering design in the context of an open-ended problem. Additional learning objectives for the design project include:

Through the successful completion of the project, students will be able to

- demonstrate an understanding of the engineering design process;
- demonstrate an understanding of project management methods;
- communicate engineering information in formal written and oral reports;
- participate in the successful completion of a major group design project;
- practice and improve teaming, negotiation, and interpersonal skills.

In addition, the instructors identified ABET outcomes ([18]) for which the cornerstone project should work towards:

- An ability to design a system, component, or process to meet desired needs within realistic constraints such as economical, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (Outcome c).
- An ability to function on multidisciplinary teams (Outcome d).
- An ability to identify, formulate, and solve engineering problems (Outcome e)
- An understanding of professional and ethical responsibility (Outcome f)
- An ability to communicate effectively (Outcome g)
- The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (Outcome h).

These learning objectives are similar to those identified by other first-year design courses which feature a project activity [19,3,20].

3 Design Project Alternatives

In order to investigate the potential effects of student/customer interaction on student design experience, two project alternatives were assigned to different student groups. The project types were assigned by lecture section; each project type was assigned to two of the four sections. The two project alternatives are presented in this section.

3.1 "Real Outreach Experiences In Engineering"

Similar to other service-learning engineering design projects, the "Real Outreach eXperiences In Engineering" (ROXIE) project partners student teams with non-profit community organizations

and tasks each team with designing a solution for a need of their respective community partner. In the context of this project, the community partners play the role of a customer: they describe their needs and provide input on their known objectives, constraints, and preferences. The students serve as design consultants: they work with the community partner to gather information and needs statements. At the closure of the semester they present a solution to their clients need (typically in the form of a formal report and a CAD model of the proposed product).

Working with the Campus/Community Outreach office, community partners in need of design assistance were identified prior to the beginning of the semester. To ensure that the partners were not solely soliciting volunteers for a service project, they were required to submit an instructor-approved description of the project. These design project statements (13 in total) were then presented to the students along with information about the mission of the corresponding community organization. Student teams' indicated their three project preferences; projects were assigned based on the stated number of teams with which the partner was willing to work. Additional details of implementation of the ROXIE project are provided in [6].

A sample of ROXIE projects are presented in Table 2. A unique feature of the ROXIE projects is that they are not all associated with product design. Some projects, like designing a plan for collecting excess fruit, involve designing a process. These types of projects were deemed appropriate as they could be used to reinforce the need for a generalized design methodology. This variety is also beneficial as providing only one project presents students with only one project theme could give them a narrow view of engineering design [3].

Table 2. Example ROXIE Design Projects

Community Organization	Project Description
YMCA	Design a logistical plan for sending students out to area farms during the picking season to pick excess fruit which will be given to the Food Pantry.
	Design a way to make the pool steps easier to take in and out.
University Facilities	Design and build a functional utility tricycle to facilitate the collection of recyclables.
	Design an in-office recycling container for all university offices.
Daycare	Design a solution to a drainage problem in the playground area.
	Design a way to store "outside" toys and protect them from inclement weather.
Animal Shelter	Design a way to efficiently manage volunteer scheduling online for multiple projects.
Town Neighborhood Services	Design a system to enable businesses and neighborhoods to alert town to graffiti.
Literacy Volunteers	Design a layout for a new "used" book store.
University Student Club	Design a way to prevent exterior bathroom pipes from freezing.
District Forest Ranger	Design a lightweight portable puppet theater.

3.2 "Human-centered Engineering Learning Projects"

The alternative project offered to students was titled "Human-centered Learning Projects" (HELP). These projects were focused on the design of assistive technology devices – devices that assist disabled or impaired individuals with accomplishing day-to-day tasks. Offered in previous iterations of the course, these types of projects were shown to provide context-based learning for student teams that expanded their awareness of more diverse populations [21]. Similar to service-learning projects, these projects might be more motivating to students since design solutions have the potential to make a difference to a group or an individual.

A sample of some of the HELP project descriptions are offered below. These prompts asked students to design a(n):

- alarm clock for the hearing impaired
- system for storing and transporting canned goods between floors for a food bank
- means of opening a wine bottle with one hand
- golf ball and tee placer for persons who cannot or prefer not to bend
- crutch that is easy to place/store out of the way when not in use
- car jack that does not require the user to bend over
- aid for planting seeds in garden without the need for the user to bend over
- process/plan for transit volunteers to follow in order to efficiently clean transit stops

Unlike the ROXIE projects, the HELP projects did not formally pair the students with a "real" customer. Instead, students had to speculate product design objectives, constraints, and functions solely from the provided design project prompt.

A total of 27 different HELP project prompts were presented to those students involved. Student teams indicated their top three choices for a project. Projects were assigned based on these requests, with the constraint that no more than two of the same project could be present in the same workshop.

4 Results and Discussion

The project assignment scheme detailed in Section 3 resulted in 19 workshop sections being assigned to HELP projects and 13 workshop sections assigned to ROXIE projects. While two groups of instructors taught two lecture periods a piece, their potential impact on results was mitigated as they each taught lecture periods of students engaged in both of the project types.

To compare the effects of these two project types, the authors collected three sources of data: (i) an online student survey was administered at the closure of the design project; (ii) students were invited to voluntarily participate in a structured interview; (iii) students were required to submit a brief essay in which they reflected on their project experiences. The results of the survey provide the core of the analysis; excerpts from the interviews and essays provide context to survey responses where appropriate.

The online survey, administered in-class, consisted of 14 five-level Likert items (5 = "Strongly Agree," 4 = "Agree," 3 = "Undecided," 2 = "Disagree," and 1 = "Strongly Disagree"). A total of 620 survey responses were received: 397 HELP students and 223 ROXIE students. As survey responses were not normally distributed, a Wilcoxon signed-rank (non-parametric) test was conducted for each Likert item to identify statistically significant differences between the responses of the two project groups. Statistically significant differences are assumed at a significance level of 0.05.

4.1 Student Perception of Design Abilities

Eight Likert survey statements asked students to evaluate how their design-related abilities (e.g., ability to communicate, ability to identify customer requirements, etc.) changed as a result of participating in the design project. The mean responses of the participants (grouped by project type), and the z-values of the Wilcoxon signed-rank test for each statement are presented in Table 3.

Table 3. Results of Survey Questions Pertaining to Students' Perception of Abilities

Question	ROXIE Mean	HELP Mean	z-value
Participating in this project experience did not enhance my ability to work in a team.	2.58	2.48	0.198
I am more socially conscious as a result of this project.	3.28	3.02	0.0001
This project enhanced my understanding of the engineering design process and its associated tools.	3.77	3.9	0.2162
I am now more confident in my ability to identify customer requirements	3.95	3.75	0.0092
I am better prepared to manage a project as a result of this experience	3.82	3.73	0.2444
I am now more confident in my ability to communicate my design ideas as a result of this project experience.	3.74	3.7	0.5074
I am now more confident in my ability to frame and scope an engineering problem	3.72	3.84	0.1217
I am more aware of the potential broad impact of engineering solutions as a result of this project.	3.53	3.53	0.826

As can be seen in Table 3, few responses are significantly different between the two project types. The type of project to which students were assigned does not seem to influence their perception of gains in abilities pertaining to project management, teaming, or framing engineering design problems. This does not suggest that gains were not seen by students, as seen from excerpts from interviews and essays:

> "I used to think that being an engineer just meant going to college, learning a lot of math; you get a job then you sit down at a desk, write blueprints, and then go in a shop and make whatever you wrote on the paper (laughs). Now I see it's really it's a large team effort. The more you give, the better it is. And if everybody gives, you'll be successful."
>
> – ROXIE Student Interview

> "It's hard for me to say now what I consciously thought engineering was, but I feel like I had more of a view that it was a little more individual than I do now. Now that we've gone through the design process [I see] that there's a lot more aspects to designing a real product. It's obvious to me know that you need a lot of workers with different specializations … it's really hard to make something by yourself. I didn't really have a strong idea of that before this project, but I definitely understand that now."
>
> – HELP Student Interview

4.1.1 Ability to Identify Customer Requirements

As seen in Table 1, there is a statistical difference (z-value < 0.01) between the two student groups' perceptions of their ability to identify customer requirements. While both student groups perceived themselves to be better at identifying customer requirements as a result of their project (84.5% of ROXIE students and 74.6% of HELP students responded "Strongly agree" or "Agree"

to the statement), there was a positive significant difference in the ROXIE students' response projects (Figure 1).

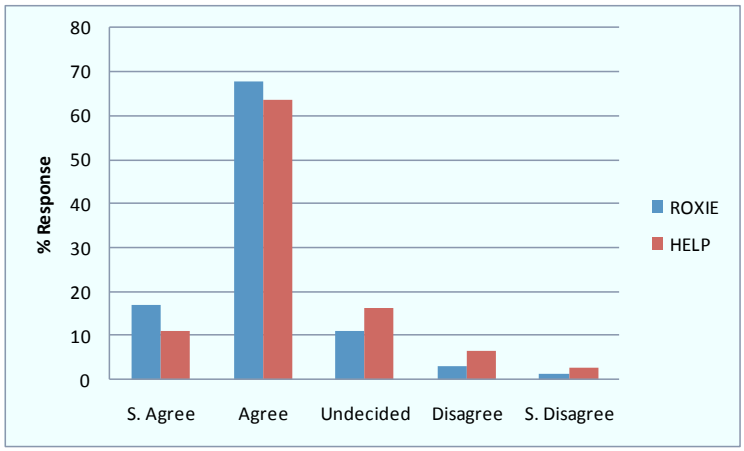

Figure 1. Response to Likert item, "I am now more confident in my ability to identify customer requirements."

The large statistical significance in this response suggests that this is a clear benefit of a student's interaction with a real customer in a design project. This difference in perception is attributed to the ROXIE students' interaction with real customers.

> "Another great aspect of this project was the opportunity to work with actual clients. It was my first experience solving a real problem and it was indeed difficult to parameterize a real problem as compared to professor-designed problems. Despite being more difficult, it was rather enlightening to gain experience in this field. I understand now how important it is to understand what a client wants, to be in constant contact with them, yet not let their wants interfere with their needs and what the best outcome actually is. I have learned how to effectively interview a client and to take notes on what is relevant and what isn't. I am also now more aware of how to use the information provided to me to produce what the client needs as opposed to what he or she expects and wants. Again, I feel that this information was very useful to me and I am certain that now that I am more cognizant of these techniques I can use them in future engineering projects… This project has made engineering more real to me and I appreciate it more now that I understand how critical our work is."
>
> – ROXIE Student essay

Each interview with students involved with HELP projects indicated that requirements were generated through a group "brainstorming" session. While students involved in the HELP projects were encouraged to find a real "customer" to help provide a basis on which to ideate product requirements, only 17% of HELP students reported that they engaged a potential customer. However, interviews suggest that those students who contacted a customer for HELP projects did not include them in identifying requirements. For example, a student tasked with designing a wine bottle opener for users with use of only one hand provided the following anecdote:

> "One of the guys in the group did know an amputee. So he talked to him some ... It was kinda like one discussion. He used that to bring that back to the group. … he said what

was important as far as a wine bottle opener; things like stability. It helped with metrics for the project as far as evaluating what was most important for our design. But [we gathered requirements] mostly via online research."

– HELP student interview

Similarly, when tasked with developing a seed planter for users who cannot bend at the waist, another HELP student identified a potential customer (his elderly grandmother), but did not approach her for assistance in identifying product requirements:

"Once we had our idea for it, we asked her 'Do you think you would buy it; would your friends buy it; is it a good idea?' [Our interaction] wasn't something where we kept up with her and updated her on the project."

– HELP student interview

4.1.2 Design Process Understanding

Of interest in this study is whether or not the different projects affect students' perception of their understanding of the design process. No statistical significance was discovered between the two project types; both student groups rated themselves highly in this ability: 75.6% of ROXIE students and 85.4% of HELP students responded "Strongly agree" or "Agree" to the statement (Figure 2).

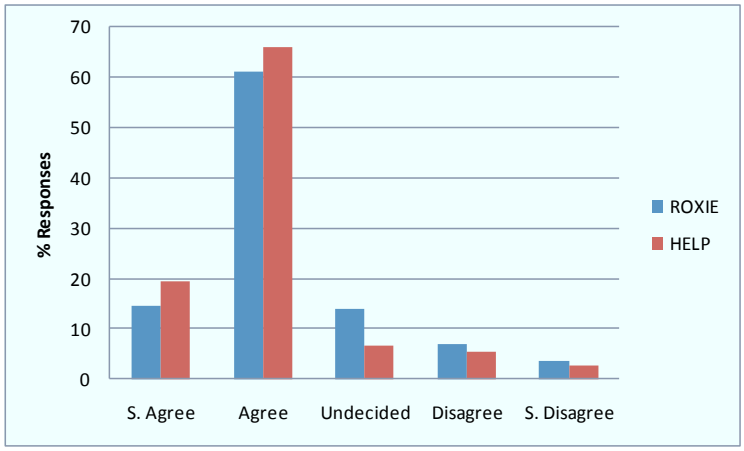

Figure 2. Student response to Likert item, "This project enhanced my understanding of the engineering design process and its associated tools."

These findings are corroborated by the following excerpts from student reflection essays:

"Prior to this class, I was involved in a few design initiatives in which my team and I sought to solve various problems. We did this in a very disorganized fashion, in that we simply set down ideas, most of the time with a solution in mind, and worked toward that. Modifications were made along the way. At the end of this, documentation was done. Comparing this with my knowledge now, it is clear that I am by far more informed, organized and effective as a design engineers and also as a team member."

– ROXIE student Essay

> "Up until the start of the project I did not know a lot about engineering design. I knew that a task as large as this would be made up by a group of engineers that would work together to complete the task but other than that, I was new to the idea. As we started to progress through the semester and started to work more and more into the project, I started to learn more about the actual process of engineering design. There was a lot more to do than I had originally thought but every step and process I learned became more and more relevant and important as I went along."
>
> – ROXIE student Essay

The more positive response received from students involved with HELP projects, as compared to those with ROXIE projects, could be related to their perception of their project's relevance to engineering design. As design methods are traditionally taught in the context of product design, some students might have found it difficult to abstract these tools in the context of other design contexts (Section 4.2). While some students were unable to separate their understanding of the design process from the context of their design project topic, others were able to abstract learning:

> "Overall I do not know how much of the information I learned about the blacksmith shop I will use in the future, but I will definitely use the information I learned about decision making. Everything I learned about the design project is definitely going to help me in the future since I am becoming a Civil Engineer. I will have to make some huge decisions in the future and I want to make sure I make the right one."
>
> – ROXIE student Essay

> "At the beginning of the semester, when project assignments were first given, I remember my group joking about how our project has no engineering relevance; how interior designing is not considered engineering. However, now that it's the end, I've come to realize the project allowed me to apply what I was learning in class. For example, in class, we discussed various design tools such as morphological charts, decision matrix, objective trees, and the 6-3-5 method. While working on our project, all these design tools were utilized. They helped my group to organize our thoughts and make informative decisions. … While many engineering design tools were applied, the actual project I was asked to work on, I feel had no real relevance to the engineering world. My group and I were assigned to redesign a bookstore, and while this may involve some engineering software such as Autodesk Inventor, I don't believe it was that beneficial to me. Being able to apply the design tools, work with a client, be on a team, were all valuable experiences, but I was expecting something more than just being asked to repaint, and replace carpeting for a bookstore. On a good note, though, this project made me feel more confident when working with design tools, and more comfortable when speaking with clients and other team members."
>
> – ROXIE student Essay

<u>4.1.3 Awareness of Broad Impact of Engineering Solutions</u>

The mean response to the Likert item "I am more aware of the potential broad impact of engineering solutions as a result of this project" was equivalent between the two project types. Roughly 65% of both student groups responded "Strongly Agree" or "Agree" to the statement.

This result suggests that both project types' focus in assisting others through engineering design is beneficial towards furthering students' achievement of ABET Outcome H (Section 2).
In addition, students involved with ROXIE were statistically more likely to feel more socially conscious as a result of their project experience than those students involved with HELP (Figure 3).

> "All in all, this project was about the partner. It was wonderful getting to work with a community partner that was right here in [town]. … This factor gave it the real world touch. We were really solving a real life problem this wasn't a problem on a piece of paper just made up, this was a real life showing of problems around the area. It was a great tool and an even better hands-on showing of what modern day engineering design consists of."
>
> – ROXIE student Essay

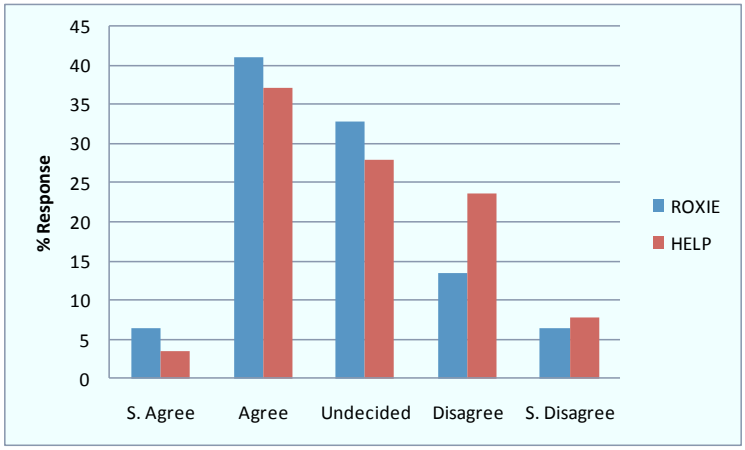

Figure 3. Response to Likert item, "I am more socially conscious as a result of this project."

As can be seen in Figure 3, a large percentage of respondents from both projects were undecided about their (dis)agreement with this Likert item. For the ROXIE project, 47.4% responded "Strongly Agree" or "Agree," 32.9% responded "Undecided," and 19.81% responded "Strongly Disagree" or "Disagree." Unfortunately, there was not a question directed at this point in the structured interview so as to provide more understanding of this indecision; this deficiency will be alleviated in future interviews.

4.2 Project Attitudes

In addition to those statements regarding students' perception of ability, six additional Likert statements were written to assess students' attitudes towards their design projects. The mean responses of the participants (grouped by project type), and the z-values of the Wilcoxon signed-rank test for each statement are presented in Table 4. As can be seen for all but one of the statements, no statistical difference in project attitudes is found between the two project types.

4.2.1 Project Relevance to Engineering Design

The sole significant difference found in student attitudes of the two project types is their response to the statement, "This project was clearly related to engineering design" (Figure 4).

89.7% of students involved with HELP projects responded "Strongly Agree" or "Agree" to the statement, compared to 59.9% of those involved with ROXIE projects.

Table 4. Results of Survey Questions Pertaining to Students' Project Attitudes

Question	ROXIE Mean	HELP Mean	z-value
This project increased my interest in engineering.	3.12	3.24	0.2344
This project was clearly related to engineering design.	3.41	4.13	0.0001
This project experience reaffirmed (or helped me with) my decision to study engineering	3.07	3.04	0.66
This project interested me.	3.13	3.1	0.5538
This project challenged me	3.25	3.28	0.8462
I would recommend that this project be continued in future implementations of ENGE1114	3.23	3.4	0.1254

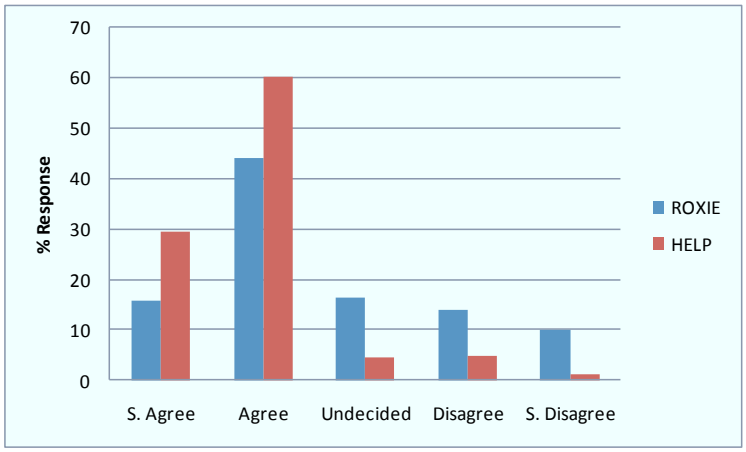

Figure 4. Response to Likert Item, "This project was clearly related to engineering design."

It is hypothesized that the lower perception of relevance for ROXIE projects might be attributed to the manner in which some projects required the design of a process (as compared to the product design nature of the HELP projects). As discussed in Section 3.1, the instructional team intentionally included process-oriented projects to appeal to those students not majoring in product-oriented disciplines (e.g., Materials Science and Engineering, Industrial and Systems Engineering, Chemical Engineering, etc.).

An example is found in an interview with a ROXIE student whose team was tasked with designing a process that would alert the partner to reports of graffiti from local businesses. The student noted her teammates' dissatisfaction with the process-oriented project:

> "I want to be an Industrial and Systems Engineer. … I think of systems. I didn't see this as a bad project to get … because it is a system. It's how to make [the community partner's] life easier; by giving her an Excel file to look at (laughs) instead of 50 emails. But that's not really how my teammates were thinking."

Interestingly, this attitude was expressed despite that, unlike most of the "product-oriented" ROXIE projects, this team implemented their proposed solution to the design problem. When asked about the desire to construct a prototype of their design solution, the student responded,

> "We did build our [solution], but it's not like a physical thing, it's more of a computer survey. So in that aspect we did build it, however, I think my team would've worked a lot better if they had had something to get together to build aside from a paper, because they just saw the paper as not worthwhile. If they had something physical to build that was actually going to go out and someone was going to do something with it … that would've probably helped [the team] more than just giving our community partner a paper to read."

Furthermore, through student interviews the authors discovered a case wherein two students of different teams who worked on the same product-oriented ROXIE project responded oppositely when questioned about their project's relevance to design. While one student immediately answered in the affirmative, the other student responded:

> "Not really. But, actually the process we went through was pretty similar to what we learned in class: how to get the team together, analyze a problem… you know, those kinds of steps. But um, I don't really think fixing, you know, providing insulation is really engineering work."

This statement followed the student's thorough explanation of his team's design of a system to prevent exposed water pipes from freezing in the winter. At the closure of the interview, when asked how the project might have affected his view of engineering, the same student offered the following:

> "I really learned what it means to be an engineer. I actually felt a little like an engineer – because I got to apply problem solving skills."

These interview responses might indicate that student attitudes to the relevance of their projects were heavily dependent on their perception of what engineering design entails.

Unlike the ROXIE students interviewed, HELP students interviewed expressed no hesitation in affirming their project's relevance to design. However, it is clear that student perception of design is altered even for HELP project participants:

> "This project has slightly affected my perception of the engineering field but not the definition. My definition of engineering has not changed any because of this project; we did everything that I expected and engineer to have to do. My perception, however, has changed slightly. I never thought of engineers working on projects to design little things like this. Growing up I always knew that someone designed the small things, but I always thought of engineers as the ones who design all of the big cool things, such as cars, boats, bridges, buildings, and so on. I am glad to see that engineers also help to design the small things; this makes me even happier to know that maybe one day I can design something that could help millions of people in the world."
>
> – HELP student Essay

5 Summary

In this paper, the authors assess the potential effects of a student/customer interaction in a cornerstone design project on students' perceived abilities to perform design and their project attitudes. Two project types were compared: (i) a service-learning themed project that features students working with community partners to solve a design task (ROXIE) and (ii) a speculative project that is centered in the design of assistive technology devices to enable disabled or handicapped persons to accomplish day-to-day tasks (HELP). Analysis was completed through the comparison of student responses to an online survey, structured interviews, and reflection essays.

While few differences were found in students' perception of design learning improvements (e.g., teaming, communication, project management) as a result of the project, it is clear that those working with "real" customers (i.e., ROXIE participants) perceived their projects to have directly affected their ability to identify customer requirements. Additionally, those involved with the service-learning project considered themselves to be more socially conscious than those working on the assistive technology projects.

Few statistically significant differences were found in students' attitudes towards the project types. Compared to ROXIE participants, HELP participants more often perceived their project as being clearly related to engineering design. Interview excerpts suggest that this difference might be related to students' perception of what design entails – a topic of merit for future research.

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