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122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society

Paper ID #11901

Development and Implementation of a Long-Term Freshmen Service Project: The Design and Deployment of an Engineering Outreach Experience for Underserved Populations

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Abstract

Freshmen year programs in engineering have received recent and growing attention as a method to engage first year students in their profession and start them on a path to success. Service learning is a well-known pedagogical method that has been shown to improve retention, especially of underrepresented groups in engineering, and to promote deeper learning through reflection. This paper describes the implementation of a new long-term (full year) service learning project where 240 freshmen mechanical engineering students worked together in small teams to design and deploy an engineering outreach experience for a designated age-group of 4^{th}-11^{th} grade students. This educational experience is designed to expose the freshmen engineering students to a variety of concepts and skills necessary for successful negotiation of their engineering careers. The project encourages the freshmen to challenge their assumptions and conceptions of what an engineer is and does. Other knowledge and skills gained include understanding and using the engineering design process, effectively working on engineering teams, effectively communicating, planning and making decisions, all while solving an open-ended problem. The experience also asks the freshmen to consider diverse perspectives as they design for the targeted populations. The paper describes the project implementation and presents results from student reflections and from a survey. Lessons learned and recommendations for best practices are also presented.

Freshmen Year Context and Objectives

During the 2010-2011 academic year the department of Mechanical Engineering at California Polytechnic State University - San Luis Obispo (Cal Poly) began a process of redesigning the freshmen year experience for its incoming Mechanical Engineering students. At Cal Poly students enter the university with a declared major and begin taking major courses their first quarter. The department is large, with 180-240 incoming freshmen each year and a total of 1177 students. The previous freshmen year was somewhat traditional in approach and consisted of several classes on design communication, a broad introductory course including a lecture that provided an overview of various Mechanical Engineering subjects (e.g. mechanics, thermodynamics, mechatronics, and design) and supported those with a three hour/ week hands-on laboratory. There was a strong feeling among the faculty that the freshmen year could be redesigned to better support the overall program goals. One often cited goal of the redesign of freshmen engineering programs is to increase retention through discipline-specific design activities.[1-3] At Cal Poly, the one-year retention rate of Mechanical Engineering students is currently over 95% and the two-year retention rates are above 80% and generally rising over the last decade. These percentages are roughly the same when sorted by gender and ethnicity, making retention only a minor concern in this redesign. A bigger goal for the curriculum designers was to steer students not interested in Mechanical Engineering into other programs early in their time at Cal Poly, since changing majors becomes more difficult if not impossible in the third and fourth years. Other broad goals included building a community of learners and a first introduction to the design process.

A survey of the engineering education literature was performed to guide the development of a freshmen year experience. A wide variety of freshmen engineering curricular design is available, and this paper is not intended as a review of these. Brannan and Wankat[4] report on a survey of first year programs, noting in particular that many innovative, large freshmen programs focus on laboratory and design content.[5-8] Several other specific examples will be mentioned in the following sections.

After reviewing the literature and the goals of the entire four year Mechanical Engineering program, the faculty identified the main objectives of the freshmen year redesign.

- *Knowledge of the Mechanical Engineering Discipline:* Introduce students to the field of mechanical engineering with the goal of helping the students better understand the discipline. This will allow students to make an informed decision early in their career whether to continue to pursue a Mechanical Engineering degree or switch to another major.
- *Professional Skills and Attitudes:* Give students skills necessary to succeed in the program and as professional engineers. This includes developing teamwork skills, fostering good study habits, developing a growth mindset with regards to education, and ethically fulfilling their professional obligations of service to humanity.
- *Design Methodology:* Students learn how to approach open-ended engineering design problems with a structured design process and to communicate their ideas through writing, speech and engineering drawings.
- *Create a Community:* Allow students to make connections with the Cal Poly Mechanical Engineering community and develop support systems that will help them succeed during their time as students. This includes getting to know the faculty, understanding department procedures, finding extra-curricular opportunities and gaining exposure to other academic opportunities such as study abroad.

New Freshmen Year

To address these goals, several structural changes were made. First, all Mechanical Engineering freshmen were put in a lockstep program so that they took the same four core ME courses during the same quarter with block scheduling. This ensured that all ME freshmen would finish the freshmen year with the same core set of courses completed and with ample opportunity to make social connections. Although the larger goal of integrating general science, math and communication proved unrealistic at this time, the core ME curriculum was integrated. Finally, to achieve the objectives related to teamwork, project management and professional responsibility, the faculty decided to include a long-term service-learning design project spanning the first year. For this project, students would work in teams to address the needs of an external client. Many similar models exist in the literature. For example, the ROXIE[9] program at Virginia Tech engages a cohort of freshmen in the design process through a large number of service projects for the benefit of many community partners. Similarily, the EPICS[10-11] program at Purdue reports using the design of an Engineering Outreach Experience as a suitable design problem to engage freshmen students with an introduction to the engineering discipline.

Service Learning and Design

A key element of undergraduate engineering education is learning to design.[12] Experience with design in school is considered critical for students as they learn how to apply theory while working on a design project.[13-14] Design is an iterative process that consists of devising a system, component, or process to satisfy a desired need. Learning design is best accomplished through multiple experiences throughout a four year curriculum. Prior to the freshmen year changes at Cal Poly, the Mechanical Engineering curriculum consisted of a "Design Thinking" or creativity course in the sophomore year, two machine design courses in the junior year and a full year capstone design project course in the senior year. Effective engineering design experience should motivate students to develop a variety of design skills that are difficult to attain in typical lectures and laboratories. These experiences can also provide opportunities for students to further develop program outcomes as specified by ABET Criterion 3a-k. These include the ability to:

1) Function on a multidisciplinary team
2) Communicate effectively
3) Design and conduct experiments
4) Analyze and interpret data
5) Design a system that is within realistic constraints

Engineering educators across the U.S. have recognized the power of this approach. For example, the number of team-based and multidisciplinary team-based capstone classes across the U.S. has increased[15] since 1995, likely due to the influence of ABET on U.S. engineering programs.[16] Similarly, the number of "Cornerstone" freshmen engineering design project classes has increased, although by no means are they universal in U.S. engineering curricula[4]. Cornerstone design experiences require significant faculty involvement, and from the student's point of view, projects should be motivating and challenging but not overwhelming. This requires a faculty advisor to work closely with each student group and external client as project specifications are determined and design concepts are evaluated.[17]

Anticipated Student Outcomes for the Freshmen Service Project

The Freshmen Service Project (FSP) was conceived and designed to complement the other courses in the freshmen year. Unique to the project is that it would span three quarters and be part of four different courses. This would allow students to work on project management and teamwork skills necessary over such a long-term task. The goals for student outcomes were:

- Describe what it means to be "an engineer".
- Apply the engineering design process to an open-ended problem (one that does not have a "right" solution).
- Successfully work on a team of peers to accomplish a common goal and understand the importance of social processes in engineering.
- Demonstrate written and oral communication skills.
- Consider and discuss perspectives of diverse groups when making decisions.

Description of the Freshmen Service Project

During the 2013-2014 academic year, the Mechanical Engineering Freshmen Service Project spanned three quarters and was supported in four separate courses. Similar to Purdue's EPIC's program[10-11], the freshmen students were tasked with designing, building and deploying a hands-on engineering outreach experience to a defined age group of underserved grade-school students that highlighted some element of engineering. During the first quarter, the students were placed in teams of six and introduced to the design process during their three-hour weekly laboratory. Figure 1 shows a simplified model of the design process presented to the students and revisited throughout the project. To give further experience with the design process, the students completed a "mini" two week design project in the fall quarter. The design goal of this short-term project was to create a prototype "Corn Hole" launching device for persons with disabilities. The students were then tasked with completing their service project using the same process.

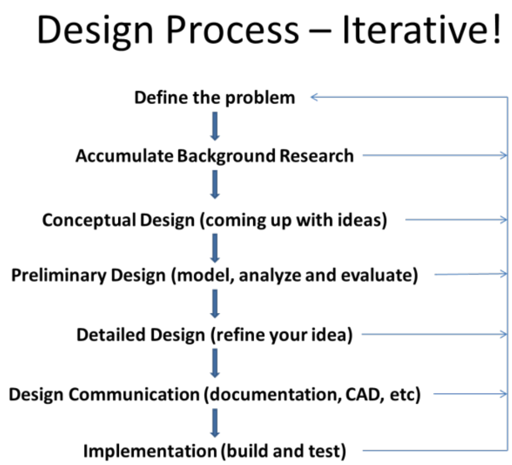

Figure 1: Simplified Design Process Presented to the Mechanical Engineering Freshmen Emphasizing Iteration

Specific work on the outreach experience included a project definition phase where the students were assigned a client consisting of underserved grade school students in 4^{th}-6^{th} grade, 7^{th}-8^{th} grade, or 9^{th}-11^{th} grade. As part of the problem definition phase, the engineering students met with Cal Poly student teachers to gain a better understanding of the needs of their users (the grade school children). Additionally, each team was assigned a senior engineering student mentor from the Department's capstone design sequence. These mentors were available to answer design questions and also to provide guidance about the Mechanical Engineering experience. By the end of the first (fall) quarter each team selected a concept for the experience and presented it to the instructor and other students in their respective lab section.

During the second (winter) quarter, the project continued as part of their Freshmen Engineering Seminar course. This course is designed to focus on academic and professional skills. During the quarter, the students were tasked with refining their concepts and producing a prototype of the experiences. A hardware review day was held in which the students demonstrated their activities to the faculty for feedback. In the third (spring) quarter the teams finalized their outreach experiences and deployed them to a cohort of grade school students from their assigned age group at one of two events. The first event was an "Engineering Day" where 200 students from local elementary schools were bussed to the Cal Poly campus and experienced four of the outreach events for 25 minutes each. The second event was a public "Engineering Night" in which children from local schools were invited to attend with their parents in an expo (trade show) format. Unfortunately, most children attending these events were from fairly affluent families, so the goal of exposing the freshmen to an underserved population was not attainable in this first year of the FSP. This shortcoming was addressed in the current second year implementation of the FSP, where around 500 grade school children from underserved populations were the clients for the outreach experiences. More information on the changes implemented for the second year of the FSP is given in the Conclusions and Improvements section of this paper.

Reflection and Assessment

At three times during the project, students were prompted to submit a written reflection on their experiences. After project completion, they were asked to complete a voluntary survey on the Freshmen Service Project. The overall timeline for the FSP is given in Figure 2.

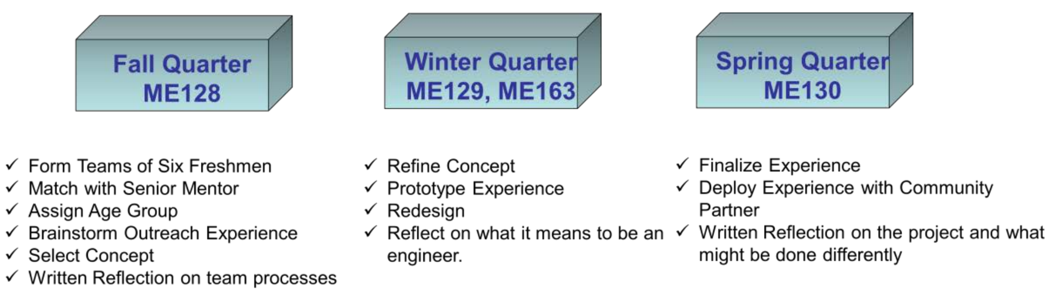

Figure 2: Timeline for FSP Activities

Representative Projects

The FSP students were given minimal requirements regarding the form of the outreach experience. The basic requirements included safety, fun, engineering related (not a science fair) and "hands-on". There were a total of 40 teams of six freshmen each completing the FSP and each outreach experience was unique. One example project was a basic electric circuits exploration, where grade school kids were given instruction and a basic set of components and asked to create circuits to illuminate lights or ring bells. Another involved earthquake engineering. For this experience, the FSP students designed and built a hand drill-powered shake table. Grade school students then built structures from spaghetti and shook them until they were destroyed. A third example was candle-powered boat races. Grade school children built simple boats powered by candles and raced them in a water-filled tray. Figure 3 contains images of the Engineering Day event.

Figure 3: Engineering Day Event

Written Reflections and Post Project Survey

Written Reflections

Service Learning is widely considered a "High-Impact" educational practice.[18] It can foster deep learning and promote both personal and practical gains. In the context of the FSP, a service-learning experience has students working on real world problems for very tangible real people, with whom they interact to understand and define the scope and objectives of their design projects. Reflection is widely recognized as a means to assist students in making connections between their experiences and finding meaning.[19] It is considered an integral part of service learning experiences[20] and its application in engineering education is growing.[21]

Throughout the FSP, the students were asked to respond with written reflections to directed prompts on their team processes, what it means to be an engineer, and the overall experience of designing and deploying an engineering outreach experience. These prompts were intended to engage the students to think critically about their experience working on the project, as well as their overall experience in the freshmen year. The prompts are given in Table 1 and the students were asked to write 500 words at a minimum. The written content was qualitatively analyzed in order to assess student attainment of the learning outcomes. The results of this analysis on the first and third reflections are presented in the next section.

Post Class Survey

In order to assess the impact of the FSP in a more quantitative manner, the students were given an anonymous post-project survey. The survey consisted of 23 Likert scale questions that asked the students to quantify how the FSP supported the overall goals for the freshmen year. This was a very broad survey covering many aspects of the overall four-year Mechanical Engineering program goals, many of which did not apply to the FSP. The Likert scale questions and results are given in the next section. Additionally, there were seven open-ended prompts shown in Table 2, and finally a yes/no question about whether the project should be continued with next year's group of freshmen.

Table 1: Written Reflection Prompts

Reflection #1: Teamwork
For your yearlong design project you are working with a team of engineering students to design and deploy an engineering outreach experience for a defined age group. Like any complex engineering project, it takes a team of professionals working together to successfully deliver a high quality result. The quality of teamwork will be evident in the final product you deliver. For this assignment, please reflect on your engineering team experience so far. In your reflection, comment on how well the team is functioning by specifically saying what is working well and what is not. Also comment on how the team could function better and what specifically you could do about it. Finally please discuss what you have discovered about yourself and how you interact with your peers.
Reflection #2: What it means to be an engineer
For your yearlong design project you are working to design and deploy an outreach experience to convey some aspect of engineering to grade school kids. For this assignment, please reflect on how you view yourself as an engineer in training. In your reflection please comment on how that view has changed or expanded since you started this project. What aspects of engineering do you perceive positively and what aspects negatively. Finally what would you still like to learn about being an engineer?
Reflection #3: What would you do differently?
Having recently completed your yearlong design project, we are asking you to think deeply about the experience. During the course of your first year at Cal Poly, you may have discovered many things about yourself and how you feel about your chosen field of study. This knowledge becomes valuable when you use it in new contexts to improve your performance. For this assignment, please answer the question, "If you were given this same team-based project to do again, what would you do differently and why? " Please frame your response from the standpoint of how you would approach the work differently and how you would interface differently as part of your team based on what you learned about yourself and working with others.

Table 2: Open-Ended Survey Prompts

Question #	
24	What has been the most enjoyable/rewarding experience for you working on the FSP?
25	What has been the least enjoyable or rewarding experience for you working on the FSP?
26	What has been the single greatest lesson or takeaway from this project that you see yourself applying to the rest of your engineering career in college?
27	What about the project did you find particularly challenging?
28	What are your thoughts about the culmination of the project with your presentation at the engineering outreach event (either morning/evening or both)?
29	What suggestions do you have for making the FSP better next year?
30	What advice would you give freshmen who are at the beginning of their FSP next year?

Results and Discussion

Analysis of Written Reflections

Twenty student responses were selected at random for analysis, and responses grouped according to emergent themes. AntConc software (http://www.laurenceanthony.net/) was used to obtain word counts and test for concordance. Results from the first and last reflection prompts are reported here.

Reflection #1 (beginning of second quarter):

Overall experience. No one indicated they had a bad experience so far. The majority (12/20) seemed to feel that the team experience was good, but had reservations with remarks such as "I like my group, but I feel we are not creative as we can be" and "Overall my team is working together decently well." A few seemed to be very excited about the project, remarking "To summarize my experience thus far with my yearlong project group, to say it has gone smoothly is an understatement", "In conclusion, my team has strong creativity, communication, and hard work", and "terrific, couldn't be better."

What is working well. Student responses grouped around four major themes: (a) distribution of workload, (b) communication, (c) work being performed, and (d) social aspects. Many teams reported a "divide and conquer" strategy, where the group was split into sub-teams who tackled separate tasks. One student reported we "divided the group up into pairs and each constructed sufficient prototypes to demonstrate in front of the class." Communication was also often reported as a strength (but as seen below, was often a team weakness). For example, "We utilize cell phone group chats and social networking sites such as Facebook to keep up with each other as quickly and efficiently as possible." Many teams reported using Group Chat, social media, and Google Groups to foster collaboration. Several students discussed the actual work being done on the project: "What we have done well is come up with ideas", and "One great thing about our team is that we are not afraid to take on a big challenge." Finally, several students mentioned the social aspects of getting to know others in the major. "My group is honestly everything I could ask for, everyone in the group is dedicated, hardworking, willing to provide feedback to the others, and someone I can call a friend."

What is not working well. Student responses showed issues with (a) communication, (b) meeting together as a team, and (c) task completion. Interestingly (but not surprisingly), communication also was reported as a weakness by many students. One student reported that "the team was unresponsive to my text inquiries", and another remarked that "Communication between team members is relatively poor." This was related to the fact that even though task delegation was listed as a strength (see above), the teams rarely got together as an entire group to discuss their concept designs and class presentation. Examples included "The only thing that I think we really need to work on is doing some together as a team instead of doing work individually for the team" and we "divided and then did not meet again as a full group until final presentation." The last comment also refers to the fact that many groups seemed to procrastinate, and that tasks did not always get done in a timely manner. Only a few respondents complained about some group members not doing their fair share of the work.

Reflection #3 (after the Engineering Design Day):

Overall Experience: Although not in the reflection prompt, many students offered overall impressions of the FSP. The experience on the actual day was overwhelmingly positive, with students remarking that: "Their [the kids] excitement and creativity made it a special time for me", "The kids seemed to really enjoy our project and in the end the experience was very rewarding", and "I remember thinking at the end of the year expo, 'Wow, this is actually pretty cool.' This YLP turned out way better than I'd expected". Other comments were not as positive (as you will see below in the survey results): "The problem with this project was that neither I nor my teammates really got much out of it. The project was easy to complete and did not require much fabrication or design work", "Overall I think this project was not at all serious engineering group project, but it did force us to solve problems without guidance", and "I think the Yearlong Project was too spread out." There were several suggestions that the project time be reduced to one or two quarters.

What you would do differently? Several students addressed the overall project instead of what they personally would do differently – these will be discussed below in the survey section. Student reflections had three major themes around what they personally would do differently: (a) communication, (b) team dynamics, and (c) design of the project. As in the first reflection, communication was mentioned as something that needed to be improved: "Communication within my group this year wasn't the best because we never were very decisive about meeting regularly" and "The first thing I would do differently is create a more precise way of contacting each other." The students also recognized the importance of good team skills. Students mentioned that "trying to organize and get consensus from six other people [is difficult]"and "It constantly seemed like there was one or two group members who constantly had to pick up the slack and make sure things were getting done while three or four members were unresponsive and uninterested." Finally, an interesting finding is that many of the students would choose to do more complex projects because they did not feel that they learned much about engineering by choosing their specific topic. "I wish we could have chosen a topic that would expose not only the children to engineering but us to new engineering techniques as well", "First I would have been set on doing a more advanced project that required more time and thought to build" and "because the preparation for this event was quite simple, the group did not have to meet as often, meeting itineraries were quite simple, and communication was not nearly as vital as it might have been for other groups."

Survey Results

The survey was given as part of the Moodle course management system at the end of the third quarter. This was approximately two months after the outreach experiences were deployed. Unfortunately only 57/225 students in the FSP took the survey, which indicates that the margin for error in response is 12%. Table 3 gives the average response to the Likert questions.

On the surface, the survey results were disappointing, but not altogether unanticipated. For the most part, the students indicated that the FSP did not address many of the broader Mechanical Engineering program goals. The nature of the project would not lead them in those directions. On a more positive note, the highest rated items were related to three of the anticipated outcomes of the project, although the raw scores were not particularly high. First, the students felt that the FSP improved their ability to function on a team (Q9) and secondly it exposed them to the department and the resources at Cal Poly (Q22). Third highest (Q8) was that the students felt the FSP had some impact on their ability to design. As evidenced by the last question, the survey respondents were split on whether the project should be continued for future freshmen mechanical engineers.

More telling was a thematic analysis of some of the open-ended responses. Reported here are the analysis of Questions 24, 26 & 27.

Table 3: Responses to FSP Survey using a 5-pt Likert Scale:
1 Not at all 2) Very Little 3) Some 4) A Lot 5) A Great Deal

Q #	Question	Ave.Score
1	The Freshmen Service Project (FSP) improved my ability to use math concepts to solve engineering problems	1.37
2	The Freshmen Service Project (FSP) improved my understanding of manufacturing.	1.95
3	The FSP improved my ability to use Chemistry concepts to solve engineering problems.	1.26
4	The FSP has improved my ability to use physics concepts to help solve engineering problems.	2.12
5	The FSP has improved my ability to use engineering concepts to help solve problems.	2.52
6	The FSP improved my ability to design an experiment to obtain measurements or gain additional knowledge about a process.	2.43
7	The FSP improved my ability to analyze and interpret engineering data.	1.89
8	The FSP improved my ability to design a device or process to meet a stated need.	2.82
9	The FSP improved my ability to function effectively in different team roles.	3.12
10	The FSP improved my ability to formulate and solve engineering problems.	2.51
11	The FSP improved my ability to use laboratory procedures and equipment.	1.88
12	The FSP improved my ability to use software packages to solve engineering problems.	1.30
13	The FSP improved my ability to use CAD software.	1.23
14	The FSP improved my knowledge of professional and ethical responsibility.	2.49
15	The FSP improved my ability to write reports effectively.	2.18
16	The FSP improved my ability to make effective oral presentations.	2.00
17	The FSP improved my knowledge about the potential risks (to the public) and impacts that an engineering solution or design may have.	2.39
18	The FSP improved my ability to apply knowledge about current issues (economic, environmental, political, societal, etc.) to engineering related problems	1.52
19	The FSP improved my appreciation of the need to engage in life-long learning.	2.56
20	The FSP broadened my perspective on what engineering is.	2.59
21	My ability to develop and evaluate solutions for a given problem or requirement has grown by participating in the yearlong project.	2.52
22	The FSP exposed me to the Mechanical Engineering department and resources at Cal Poly.	3.09
23	The FSP was effective at connecting me to my peers and faculty in Mechanical Engineering at Cal Poly.	2.63
31	Do you think we should have the FSP be about designing a hardware based engineering outreach experience again next year	Yes: 60% No: 40%

Q24) What has been the most enjoyable/rewarding experience for you working on the FSP?
Forty-four student responses were analyzed and grouped into four main themes: The Deployment of the Outreach Experience (47%), Design Process (30%), Teamwork (15%), and Nothing (9%). Some typical comments include:

Deployment of the Outreach Experience:

"It was very rewarding seeing the kids get so excited over the projects they got to make and try out."

"Teaching the children concepts and seeing their excitement."

"Working with the kids in engineering was rewarding because we were hopefully able to inspire them to dream of being an engineer."

Design Process:

"Assembling our project and testing it - we built a pretty cool device for our project!"

"The most enjoyable thing in this project was the process of brainstorming and planning."

Teamwork:

"Working with and getting to know my team."

"Working together with my fellow freshman ME's was the most enjoyable and rewarding aspect of the FYLP."

Q26) What has been the single greatest lesson or takeaway from this project that you see yourself applying to the rest of your engineering career in college?
39 student responses were analyzed and grouped into five main themes: Teamwork (46%), Professional Skills and Attitudes (23%), Design Skills (15%), Importance of Service (7.6%) and Nothing (7.6%) Some typical comments include:

Teamwork:

"Team work is essential"

"I have learned a lot about effective group work in a more serious and long term situation."

"Maybe not always liking your group members but still being able to complete a task with them."

Professional Skills and Attitudes:

"Always produce the best quality possible. Do not try to cheat the small stuff or think you can get away with doing minimal."

"Don't Procrastinate"

"Learning to enjoy the learning process"

Design Skills:

"The use and design of a design matrix seems to be the most useful tool that I'll take away from this project and experience. It made the tougher decisions in the design process much less arbitrary, and more analytical. "

Importance of Service:

"Engineering is bigger than us students getting our degrees. It also includes sharing our knowledge with the people around us."

Q27) What about the project did you find particularly challenging?
Thirty-eight student responses were analyzed and grouped into five main themes with two uncategorized responses: Teamwork (29%), Finding Times to Meet Outside Class (24%), Designing and Building (18%), Nothing (13%) and Unclear Instructor Expectations (11%)

Conclusions and Improvements

The first year of the Freshmen Service Project was a qualified success. All the elementary school children and teachers who participated in the Engineering Day event had high praise for the freshmen students, citing their patience, professionalism, and the quality of the outreach experiences. Feedback from the participants at the evening event was overwhelmingly positive as well.

The FSP was also successful in terms of the five desired student outcomes of the FSP. First, in the middle reflection assignment students provided thoughtful responses about what it means to be "an engineer." Second, the project was a user-oriented and open-ended design problem with no "correct solution." This presented challenges to some students who were uncomfortable with the nature of having to determine their own project requirements, while others seemed to recognize this as the nature of engineering design. Furthermore, a significant number of students saw the importance of their role in defining the problem and in taking responsibility for their own education by expressing a desire to have designed a more challenging solution after the FSP was completed. Third, the addition of the FSP to the freshmen year clearly added elements of team work and long term management of a design project to the freshmen student experience. From student comments it is clear that many of them recognized the importance of teamwork in engineering and an understanding of where to find resources to support design activities on campus. Fourth, written and oral communication skills were practiced through reflections and presentations. The reflections focused on several of the learning goals we hoped to achieve, including communication skills, team dynamics, and social aspects of the project. The reflections also pointed toward some areas for improvement, some of which were also revealed in the survey. One aspect is to make sure students choose projects that are sufficiently complex to require everyone on the team to be involved and to necessitate the use of engineering design principles. Finally, for the fifth objective, students were encouraged to consider diverse perspectives when developing their outreach experience. However, during the first year of the FSP, we were unable to significantly reach out to an underserved population, and this limited the students' exposure to that diversity. This limitation has been rectified in the current, second year of the FSP.

From the student survey, the most common complaints and suggestions for improvement included calls for more structure, organization and clarity of the goals. Many students also suggested a shorter duration for the project. Conversely a few students called for making the project "more challenging" and finally a significant number suggested eliminating the project entirely because in the words of one student "...it served no purpose for us as engineering students."

Based on many of these comments, several changes were implemented in the FSP for the current 2014-2015 academic year. First, it was shortened to two quarters and the teams were formed with four students instead of six to ease teammate scheduling and give more individual responsibility. This resulted in 48 teams of freshmen, each designing a unique outreach experience. Also, more emphasis was placed on training the instructors and senior student mentors about the goals of the project, the nature of open-ended design problems and the importance of conveying and following a more structured design process. Finally, by changing the deployment of the experience, we have been able to reach out to approximately 500 underserved grade school children. This was attained by first sending thirteen FSP teams (serving about 260 kids) into after-school classrooms for a program funded by a state school enrichment and safety grant whose mission is to close the achievement gap. Secondly, a lower income school district was able to acquire funding to bring 220 children to campus for an Engineering Day Event which featured outreach experiences designed by 12 FSP teams. Approximately 80% of these children had never been on a college campus. Eight teams (serving about 200 kids) also traveled to a more affluent school for in-class activities and approximately 200 people attended the "Engineering Night" public event involving the final 15 FSP teams.

Acknowledgements

The authors acknowledge the support of the Joy Harkins and the Cal Poly Center for Community Engagement and we are indebted to Dr. Don Moss and Dr. Julie Herron from the Cal Poly School of Education who arranged for fruitful interdisciplinary meetings of Mechanical Engineering Freshmen and their student teachers that provided invaluable feedback to our students. We would also like to thank the teachers and Dan Block, Principal of Bishop's Peak and Teach Elementary schools who rearranged their schedules to bring 200 of their students to the Cal Poly campus.

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Appendix A: Freshmen Service Project Assignment

Design of an Engineering Outreach Experience – Full Year Team Project

Background

Service is a fundamental tenant of a Professional engineering. As an example, the National Society of Profession Engineer's Creed begins: "As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare." As you begin your journey here at Cal Poly, we would like you to take some time to reflect on what it means to be an engineer. For some of you this may seem self-evident while for others you may only have a hazy idea. One reason for this ambiguity is that engineers do so many different things for our society. It is often difficult to describe in a simple statement what it is we do as compared to other professions. For example, it is pretty clear to most of us that Medical Doctors are engaged in the profession of improving human health. Engineers on the other hand often have a diverse impact on the lives of others whether it is by providing much needed clean water to parts of the world that lack or providing the latest smart-phone that enhances our ability to access information and keep us in contact with our loved ones.

An area of service in all professions is outreach. Outreach involves educating the wider society about one's profession. In most professions, outreach is an expected component to professional conduct. For example, lawyers often engage in “Mock Trial” competitions where middle and senior high school learn about the legal system and profession. Lawyers provide their time to work with the students on a pro-bono (or free) basis. Likewise the American Institute of Architects (AIA) uses outreach to educate the public about various issues in their profession (such as the latest sustainability practices). Engineering Outreach usually takes the form of educating and inspiring youth to engage in the engineering profession. Perhaps you experienced such an activity when you were in high school that made you want to study engineering. Your goal for your freshmen year project will be to develop an outreach experience for K-12 students to educate them about the engineering profession and inspire them to learn more. At the same time you will learn some valuable skills that you can employ throughout your career as an engineer. These include:

Anticipated Outcomes:

- Describe what it means to be “an engineer”
- Apply the engineering design process to an open-ended problem (one that does not have a “right” solution).
- Successfully work on a team of peers to accomplish a common goal and understand the importance of team processes in engineering.
- Demonstrate written and oral communication skills
- Consider and discuss perspectives of diverse groups when making decisions.

Overview of the Project

During the entire 2013-2014 academic year, you will work in teams of six to design an outreach experience to teach underserved grade school students about engineering. The project will be a component of your freshmen Mechanical Engineering classes (ME128,129,163 and 130). The designed outreach experience will include information about what it means to be an engineer along with an age appropriate hands-on exercise that highlights some element of engineering application. This project is open-ended, meaning that there is not a correct answer. You will apply an engineering design process to determine the form of the outreach experience. During the first quarter, you will be assigned a team and a target age group (4^{th}-6^{th} graders, 7^{th}-8^{th} graders, or 9^{th}-11^{th} graders) and begin applying the design process to create the outreach experience. By the end of the quarter you will select a concept for the experience and present it to your lab section. During the second quarter you will refine the concept and prototype the experience. In the spring you will finalize the outreach experience and deploy it to a cohort of students from your assigned age group in an expo (trade show) format. After deployment, you will assess its effectiveness. The overall timeline for the project is given in Figure 1. During the project, mentorship from senior Mechanical Engineering and Education students will be available.

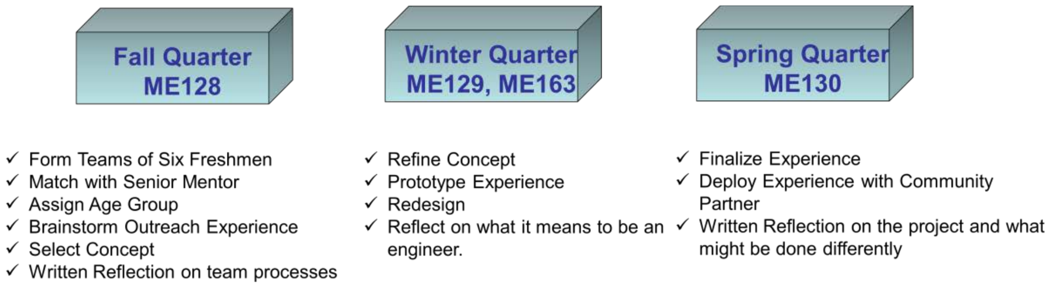

Figure 1: Activities for each quarter of the Service Learning Experience

Deployment

The final deployment of your designed experience will occur in the spring quarter. Table 1 lists the tentative times and dates of the deployment depending on your assigned age group. The experiences will be available to the target audience in an expo (or trade show) format. The target audience will wander around, free to engage in the activities that interest them. You should design your activity to keep your customer engaged anywhere from 5 to 30 minutes. Invitations for participation will be focused on local schools with diverse and historically underserved populations.

Table 1: Time and Dates of Deployment, Location on Cal Poly Campus

4th-6th graders	Friday May 16th	9-11 am
7th-8th Graders	Friday May 16th or Saturday May 17th	6-8:30 pm TBD
9th-11th Graders	Friday May 16th	6-8:30 pm

Teams

Students will be pre-assigned from your ME128 lab sections. This will be your team for the entire academic year even if you are not in the same sections of ME129 or ME130. There will be nominally six students per team and each will be assigned an upper class student mentor towards the end of the fall quarter.

Design Process

Your team will be use an engineering design process to complete this project. Engineering design is a “thoughtful” process that can be understood, however, this process typically does not progress in a linear fashion. That said, there are some basic steps which must be accomplished to complete a design task. These steps include:

- Defining the problem (framing) and associated constraints
- Accumulate Background Research
- Conceptual Design (coming up with ideas to solve the problem and choosing a concept)
- Preliminary Design (modeling, analyzing and evaluating your chosen concept)
- Detailed Design (refining the concept and working out the details)
- Design Communication (documentation such as drawings, reports, presentations, CAD models, etc.)
- Implementation (building and testing hardware, producing and presenting to the client)

There are many sub steps to each of these overall activities. Although the steps are written in prescriptive fashion, this does not imply that once a step is accomplished, it is finished. For example, it is expected that your team may choose a concept, but find out during preliminary design that the idea has a major flaw and must be abandoned. In this situation, you must go back to the Conceptual Design phase to generate more concepts and select a new one to move forward with. Likewise you might find out during the Detailed Design phase that more background research is necessary. Different steps may have to be repeated many times for particularly difficult or unique design problems. The first quarter of this project will focus on the first three steps of this process with the goal of selecting an appropriate concept by the end of the quarter.

Notes on Engineering Outreach Experiences

Engineering outreach has been a fairly common form of community engagement of the last 20 years. As such there are many examples available for your reference. You should use these to help you understand what makes a good outreach experiences. During ME128, you will be exposed to several experiences that are commonly used for outreach. These include the spaghetti bridge design project and the mechanical dissection of the gas engine. Other examples of appropriate engineering outreach activities can be found on the internet. You should definitely look at what others are doing! The experience you design should include a hands-on, learn by doing style activity. The experience should also give your students an idea about a science/engineering concept and a sense of what engineers do (besides driving trains!). Some basic requirements of a good engineering outreach experience are that it be simple, fun, focus on a basic concept, and be age appropriate. One of the first tasks for your team is to further develop this list of requirements.

Deliverables

ME128: Fall 2013

Develop Experience Requirements
Conceptualize Possible Outreach Experiences
Select Trial Experience to Prototype
Written Reflection on “What it means to be an engineer” (500 words minimum due last day of lab”
20-30 minute presentation to lab section on project status, Walk-around demonstrations

ME129 –ME163: Winter 2014

Refine your concept and develop prototype
Written Reflection on your team experience (500 words minimum due date to be determined in ME163)
CAD drawings of hardware associated with your designed experience.

ME130: Spring 2014

Deploy the experience with the community partner (time and location TBD)
Written reflection about whether the outreach experience satisfied the goals and personal reflection on what you learned about yourself as an engineer (1000 words minimum).

References and Resources:

http://www.collegemocktrial.org/ - Outreach in the Law Profession

http://www.aia.org/practicing/AIAB096756?dvid=&recspec=AIAB096756 – An example of AIA outreach.

http://www.outreach.engineering.utoronto.ca/Page4.aspx - **An example of an outreach program**

Dym, C., and Little, P, Engineering Design: A Project Based Introduction, John Wiley and Sons, 2009 - **An Excellent Introduction to the Design Process**