Engineering Projects for the Community

Shoba Krishnan, Ruth Davis
Santa Clara University, Santa Clara, CA, U.S.A, skrishnan@scu.edu

Abstract

"Tell me, and I forget. Teach me, and I may remember. Involve me, and I learn." BEN FRANKLIN
Today's industries need engineering graduates who have a broad outlook on the world. This has prompted many engineering programs to develop and use innovative strategies that integrate active learning with relevant engineering applications. This paper presents a course "Engineering Projects for the Community" at our school that brings engineering undergraduates and community organizations together in a partnership that helps integrate service with academic education. From a professional standpoint, these students gain the experience of working for clients on problems with real world constraints to see how engineers impact and influence the world around them. Placing engineering within a community context broadens the view of engineering and has the potential to attract a wider pool of students to the field. In this paper we present the results of surveys and reflections of the students supporting the effectiveness of this approach.

1. Introduction

National statistics show that 5 of the top 30 fastest growing occupations are in engineering and computing[1]. Yet the United States continues to matriculate science and engineering graduates at rates well below global averages. Students receiving their undergraduate degrees in the natural sciences or engineering from United States institutions represent 16 percent of total enrollment of those institutions. This contrasts with 47 percent in China, 38 percent in South Korea, and 27 percent in France[2]. The National Academies' report paints a bleak picture of America's competitive position in the world[3]. The principal focus of the original "Gathering Storm" report in 2005 was on STEM (science, technology, engineering, and math) fields, both because of their critical importance in creating jobs and because of the failure of the American education system in these areas[4]. The "revised" report states that the situation has worsened. This has prompted many institutions to emphasize skills such as interdisciplinary teamwork, effective oral and written communication, and social consciousness, while preparing students to be competent ethical professionals and effective global citizens.
Experiential learning through involvement in community-based projects integrates service with academic education. Students apply classroom knowledge to community problems, thus enhancing learning while providing needed services to society. Research has shown that experiential learning reinforces classroom knowledge and helps in student retention. It was reported[5], anecdotally, that showing the social relevance of engineering by engaging the students with the community in an effort to define and implement projects that meet real needs seemed to have a positive effect on the involvement of women and minority students.
The course "Engineering projects for the community", aims to create a learning experience for engineering undergraduates that fosters the development of scientific principles, technical knowledge in STEM disciplines, and workforce skills through serving the community in real-world projects. Engineering education is often compartmentalized into discrete chunks that students "learn" for a term without incorporating the knowledge in a conceptual framework that allows them to build on what they know and constantly revise and grow in their expertise. This course encourages meaningful learning, which allows students the opportunity to relate the

various components of their education, and to reflect on their choice of vocation and possible impact on the world. Our data shows that this approach peaks the students' interests in engineering, and improves the students' communication and analytical skills. We present student reflections that show that solving problems in the community helps them understand the relevance of engineering and increases the effectiveness of student learning.

2. Integrating the University Core

At Santa Clara University (SCU) we aim to instill the knowledge, habits of thought and action, and orientation to society that we believe will best prepare our students for life. Santa Clara University's curriculum is centered on the three C's of Competence, Conscience, and Compassion. Our program prepares engineering students to not only be proficient in engineering and science principles but to be aware of the interplay among science, technology, and society. Towards that goal, the university has a new core education experience[6] that includes requirements in "Experiential Learning for Social Justice" (ELSJ) and "Civic Engagement," as well as other more traditional areas. Description of these requirements and how we adapted our course to incorporate the learning objectives are described below.

2.1 Experiential Learning for Social Justice

At SCU, students will encounter experiential learning for social justice through study abroad, community-based learning in courses and immersion experiences. Assignments in ELSJ courses will be aligned with the following learning objectives. Students will be able to

- recognize the benefits of life-long responsible citizenship and civic engagement in personal and professional activities (Civic Life);
- interact appropriately, sensitively, and self-critically with people in the communities in which they work and appreciate the formal and informal knowledge, wisdom, and skills that individuals in these communities possess (Perspective);
- recognize, analyze, and understand social reality and injustices in contemporary society, including recognizing the relative privilege or marginalization of their own and other groups (Social Justice);
- be able to make vocational choices in light of both their greatest gifts and the world's greatest needs (Civic Engagement).

2.2 Civic Engagement

From the civic engagement requirement, students' would develop capacities for and commitment to addressing major contemporary social issues raised by scientific and technological advances. This core requirement should also expand student understanding of the basis of and skills needed to effectively participate in contemporary life, including investigation, critical thinking, communication, and collaboration. Assignments will be aligned with the following learning objectives. Students will be able to

- critically evaluate, and express reasoned opinions about, the role of public organizations (governmental, non-governmental, multilateral, or international) in civic life through both oral and written work. (Civic Life, Communication)
- analyze and evaluate civic issues by engaging in active and collaborative learning with peers and others through one or more of the following: working cooperatively with other students in class; actual observation and participation in the contemporary ramifications of various types of civic life or civic discourse; or working with civic organizations beyond the walls of the University. (Civic Life, Collaboration, and Civic Engagement)

3. Interdisciplinary Course Description

In order to meet these university core requirements as well as promote the integration of engineering concepts into service learning projects we developed a course "Engineering projects for the community" (ENGR110). Community-Based Projects[7] are distinguished through an interaction, motivation, and/or impact that involve a community beyond the university. This course includes service and civic learning experiences for each of the engineering disciplines; provides interdisciplinary projects of the students' choice; and includes structured reflection as a key course component. The course objectives are detailed below.

- Gain practical engineering experience working on a project in the community.
- Learn to use the engineering design process to design a service or product
- Develop project management, organizational, and leadership skills
- Develop effective listening and collaboration skills while working with customers
- Recognize and understand ethical responsibilities of engineers.

During the course, students visit several community partners at their sites to understand the operation and needs of each agency. Students self-select into teams that are typically interdisciplinary, in order to complete a service project. The interdisciplinary undergraduate student teams design, test, and deploy functional systems to solve engineering-based problems for the benefit of the communities and agencies that serve them. The community interactions are in fields such as environmental engineering, health and medical technologies, assistive and rehabilitative technology, web-based services for non-profits, infrastructure development for social programs and educational models. The students meet regularly with their community customer to elicit specifications for the need, feedback on design choices, and coordination for final deployment of the end-product. The students hold regular design reviews to ensure that the quality of the end result meets the standards of the school of engineering and satisfaction of the community partner. By the end of the class, each team completes a comprehensive conceptual design based on creative problem solving and preliminary impact analysis with the deliverables being complete design details, a significant portion of the hardware/software for the project, and a demonstration of the design along with a design report.

The course includes weekly meetings which provide training in all phases of the engineering design process from needs assessment through viability and social impact. The course provides sessions on topics that help students go beyond just the engineering tasks and help them prepare for working in a global setting. Some topics include:

- Working in Teams/Dealing with Conflict;
- Science, Technology and Society;
- Effective/Professional Communication- technical writing and oral presentations;
- Entrepreneurial Thinking- innovation and product development;
- Reflection on Personal Goals, Lifelong Learning, and Vocation.

The course may be taken multiple times for credit and work on projects span all phases of the engineering design process and some projects extend into several quarters. Teams are encouraged to be vertically integrated including team members at various levels, and prior experience in the course will enable students to assume leadership roles.

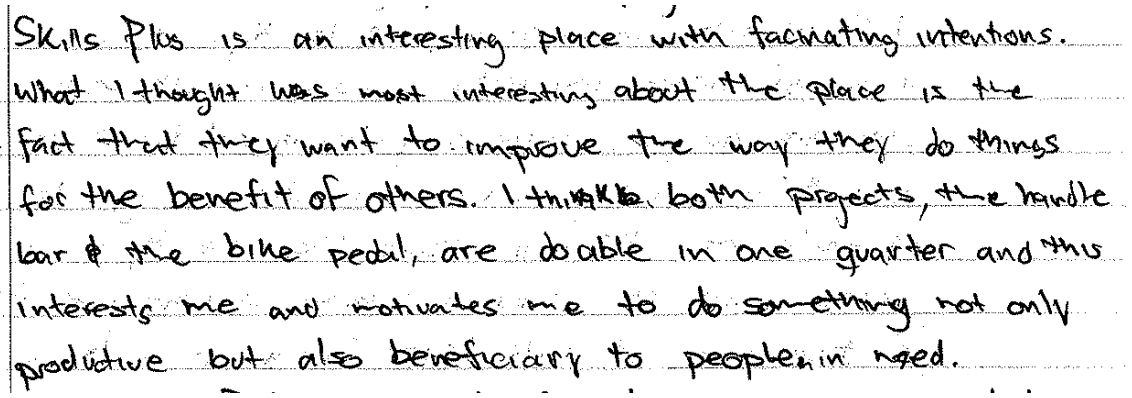
4. Assessment of student learning

Our objective is to develop curriculum that engages students in taking responsibility for the definition and integration of their educational experience, encouraging reflection on vocation, resulting in meaningful learning and success in STEM fields. We used various products of the course, such as presentations, reflections, and their final written report, to assess student learning outcomes.

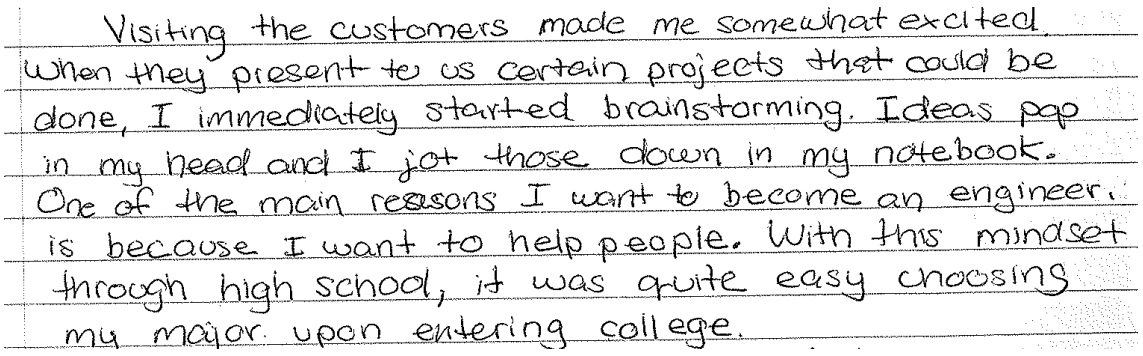
We will now describe the reflections written throughout the quarter and provide samples from student work. These excerpts from their reflections show that students understand the reciprocal nature of a successful customer relationship; and that they have listened and developed a solid understanding of the customer's needs and roles. We are presenting evidence of students' understanding of concepts, acquisition of knowledge, and increased confidence that they can use their knowledge in ways that are relevant and meaningful to them.

4.1 Reflection 1: Community Visits

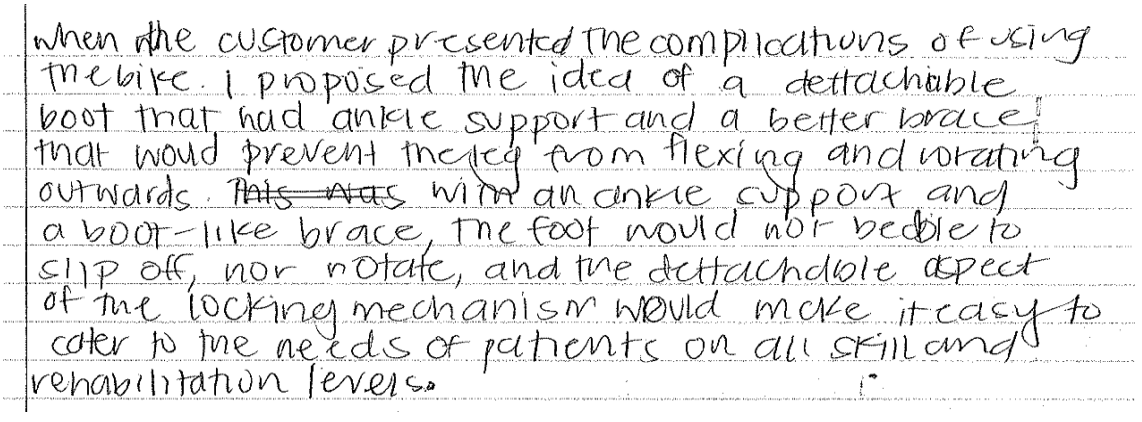
The first reflection in the course is to understand the community partners and students detail the issue/problem that the client wants to address and how the problem relates to the mission of the partner. They have to gather information on the end-users and describe the engineering project possibilities.



Skills Plus is an interesting place with facinating intentions. What I thought was most interesting about the place is the fact that they want to improve the way they do things for the benefit of others. I think both projects, the handle bar & the bike pedal, are doable in one quarter and this interests me and motivates me to do something not only productive but also beneficiary to people in need.



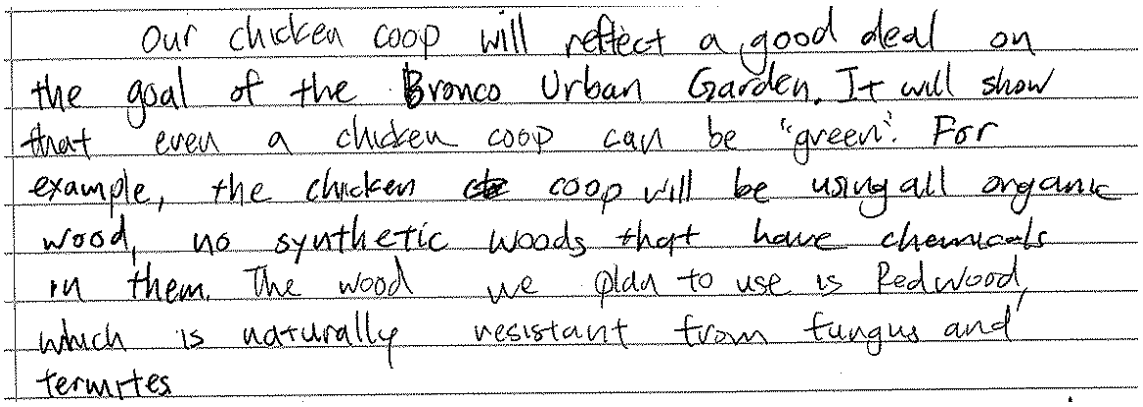
Visiting the customers made me somewhat excited when they present to us certain projects that could be done, I immediately started brainstorming. Ideas pop in my head and I jot those down in my notebook. One of the main reasons I want to become an engineer, is because I want to help people. With this mindset through high school, it was quite easy choosing my major upon entering college.



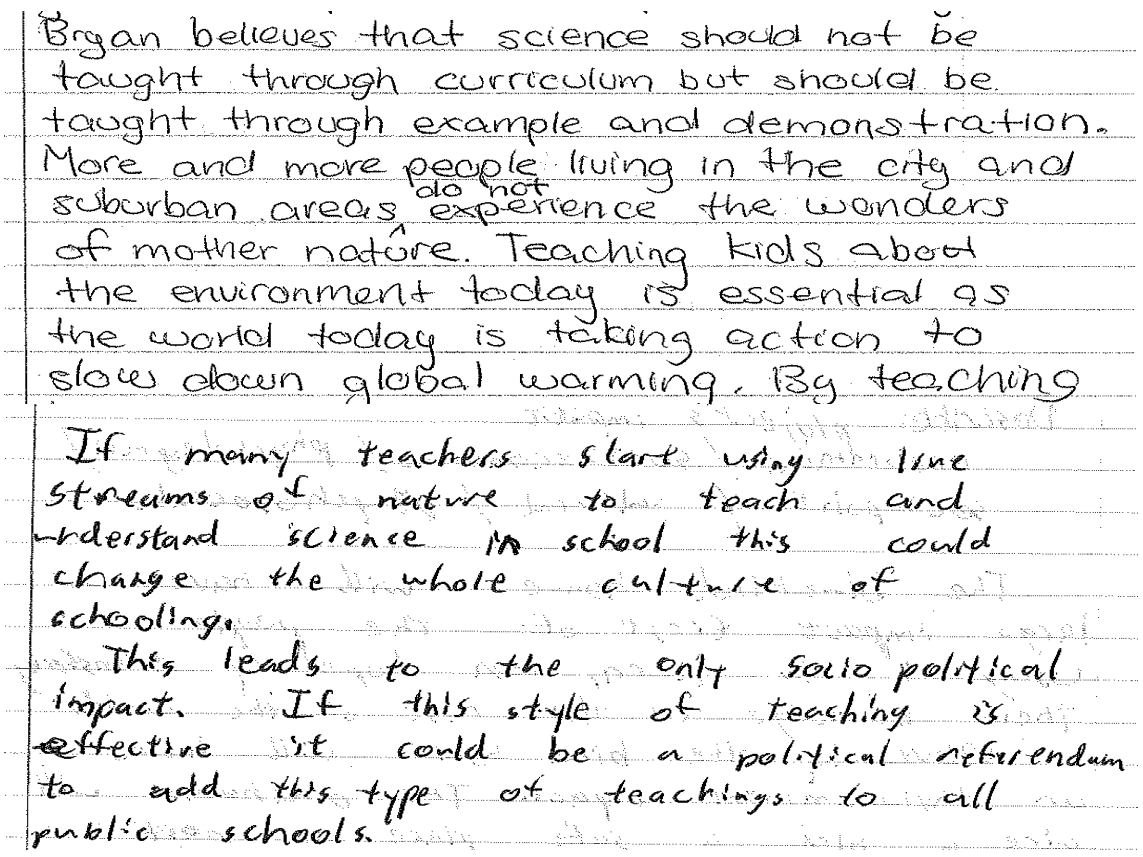
when the customer presented the complications of using the bike. I proposed the idea of a detachable boot that had ankle support and a better brace that would prevent the leg from flexing and rotating outwards. ~~This was~~ with an ankle support and a boot-like brace, the foot would not be able to slip off, nor rotate, and the detachable aspect of the locking mechanism would make it easy to cater to the needs of patients on all skill and rehabilitation levels.

4.2 Reflection 2: Societal Impact

In this narrative, students comment on the project's impact in terms of environmental, socioeconomic, physiological, sociopolitical or cultural factors. They detail their interaction with the communities in which they worked and how they learnt from the formal and informal knowledge that individuals in these communities possess. They reflect deeper to recognize, analyze, and understand social reality and injustices in contemporary society.



Our chicken coop will reflect a good deal on the goal of the Bronco Urban Garden. It will show that even a chicken coop can be "green". For example, the chicken ~~co~~ coop will be using all organic wood, no synthetic woods that have chemicals in them. The wood we plan to use is Redwood, which is naturally resistant from fungus and termites



Bryan believes that science should not be taught through curriculum but should be taught through example and demonstration. More and more people living in the city and suburban areas do not experience the wonders of mother nature. Teaching kids about the environment today is essential as the world today is taking action to slow down global warming. By teaching

If many teachers start using live streams of nature to teach and understand science in school this could change the whole culture of schooling.

This leads to the only socio political impact. If this style of teaching is effective it could be a political referendum to add this type of teachings to all public schools.

4.3 Reflection 3: Learning gains

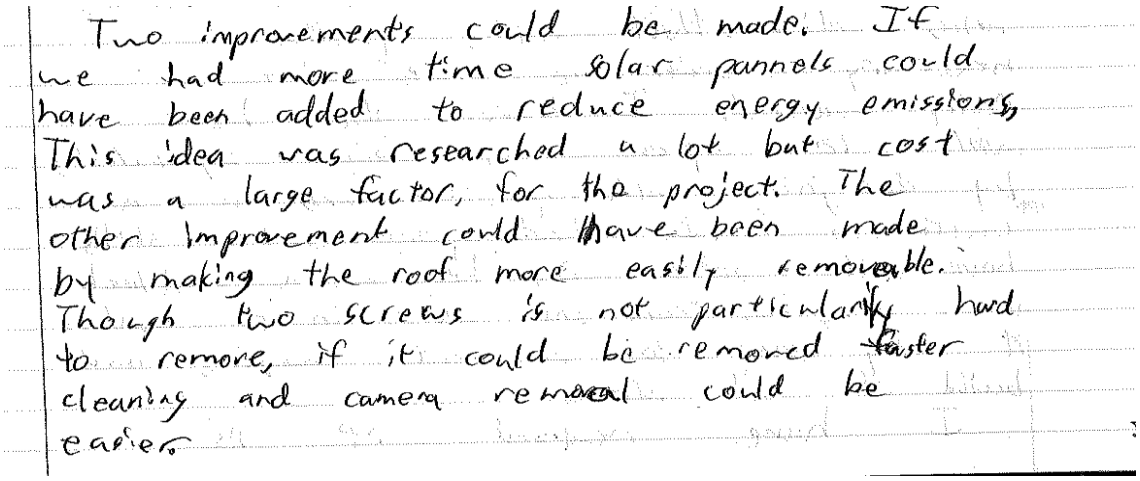
Students comment on the work their team has completed on the project and describe the key decisions that were made in the process and suggestions for improvements to the design. They also self reflect on how they benefited (personally, academically, or otherwise) through this course and their work on the project; how the customer contributed to their attitudes and knowledge and how this overall experience improved their engineering skills.

Reflection # 3: Learning Gains

Never would I have thought that in participating in ENGR 110 I would be throwing myself into one of the most exciting projects. Now that I know, I could not be more excited. This journey taken over the 10 week period has been an interesting one. The fact that I am part of a team working to better our community with such an important project makes it even better. So far though, I'd say we are on a good track and on pace to finish our chicken coop with all the "state-of-the-art" options added. In the 10 weeks we've had, we've met with our customer, designed a product for him, got his feed back and repaired it all ready to begin the build phase. This will be the real fun part.

I also learned that you should be very prepared before meeting with a customer or in any case anyone you talk to about their field (related jobs too in away) It was definetly easier to talk to Patrick once I learned about the problem and did some research. Another thing I learned was that designs constantly change so you have to communicate with each other clearly or you will be on separate pages.

This project really helped me learn about project management. I've never worked on a project this large. It really requires more thought and planning. We cannot just build from an idea. We cannot afford to start all over. With the time, money and work required, we need to get it right the first time. Having to manage all the details was a challenge, but a great learning experience as well


Two improvements could be made. If we had more time solar pannels could have been added to reduce energy emissions, This idea was researched a lot but cost was a large factor, for the project. The other Improvement could have been made by making the roof more easily removable. Though two screws is not particularly hard to remove, if it could be removed faster cleaning and camera removal could be easier.

5. Analysis of Course Enrollment

We have tracked the enrollment statistics in the course over the past three years as shown in Figure 1. Even though the numbers in the classes are small, data shows that there is steady increase over the past two years.

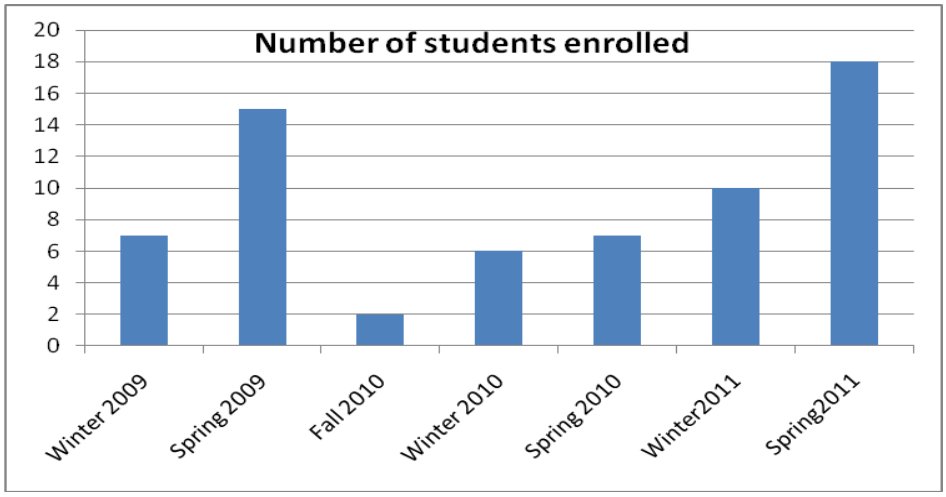


Figure 1: Student enrollment in ENGR110.

We have tracked the diversity of students involved in the projects as this helps us measure the extent to which this approach helps attract and retain a diverse student body in engineering. Over the course of three years we find that 39% of the students who elected to participate in the course were women; even though engineering enrollments at the time were only 23% female. We also looked at the variety of majors and level of the students that were taking the courses as this helps us assess the interdisciplinary nature of the teams and whether vertical integration is possible. This is especially important in community projects which come from a wide range of fields and student self select into teams based on interest. We feel that having multiple levels helps younger classmen learn the fundamentals of the engineering design process while juniors and seniors can apply their classroom engineering knowledge to real-world problems. Our data plotted in Figure 2 shows that the course is taken predominantly by juniors whose primary reason is to get prior experience and ideas for their senior capstone project. There is not a very even distribution in majors and efforts have to be made to make the course attractive not only to engineering majors but also to non-engineers.

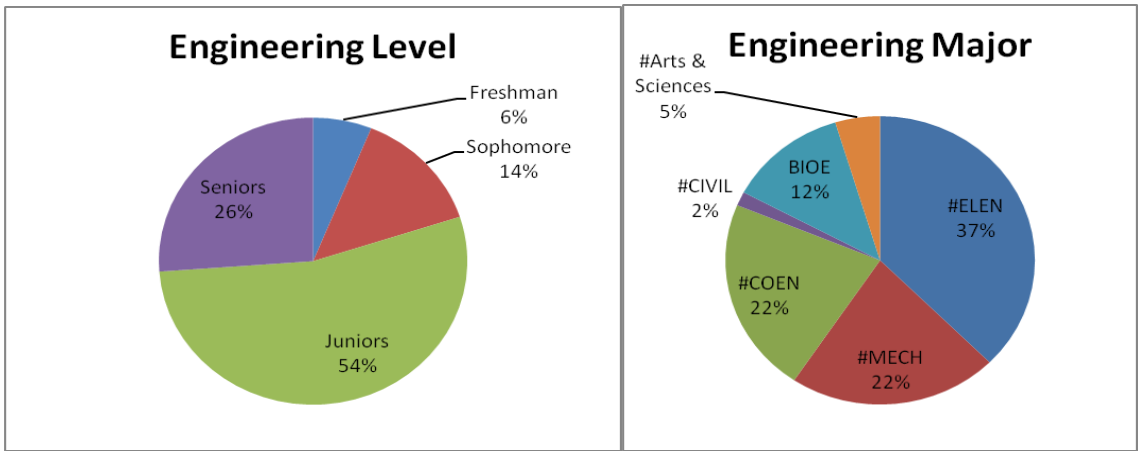


Figure 2: Student statistics in ENGR 110.

Students are surveyed as they enter the course and upon completion of the course. The introductory survey asks about their background, interests, and goals desired through the project experience. The exit survey determines their level of satisfaction with their course, and in their achievement of project goals, and will gauge how attitudes have changed on certain factors. This data collection is ongoing and is too preliminary at this stage but we plan to compare pre and post responses and use the results to improve the course. We also assess the quality of experience for our community partners in the community-based projects to track success in satisfying customer expectations and the number of people touched by each project.

6. Conclusions

Our initial findings suggest that this course enhances our engineering undergraduates' readiness and preparation for future employment by developing stronger communications, team-building, and project skills. Results indicate that this course will also help to increase their expertise and attitudes as active, civically-engaged engineering professionals, able and willing to take on community projects and deliver a quality product meeting customer expectations. We will continue to improve and extend our course as we feel involvement in community-based projects contributes to an increase in student retention in STEM fields.

7. Acknowledgements

The authors wish to acknowledge the support for this project from the National Science Foundation CCLI Grant #0737110 "Pathways to Meaningful Learning."

References

1. "Occupational Employment Projections to 2018," *Monthly Labor Review,* November, 2009.
2. *Science and Engineering Indicators 2010*. Arlington, VA: National Science Foundation (NSB 10-01).
3. *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, National Academies Press, Washington, D.C. 2010.
4. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, National Academies Press, Washington, D.C. 2007.
5. R.E. Davis, "Community-Based Learning Develops Diverse Engineering Workforce," *Innovations 2005: World Innovations in Engineering Education and Research.* iNEER/Begell House Publishing, Arlington VA, 2005, pp. 7-16.
6. http://www.scu.edu/provost/ugst/core2009/corecurriculumoverview.cfm
7. http://www.scu.edu/engineering/ideas/