Engineering Your Community: Experiences of Students in a Service-Learning Engineering Design Course

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Abstract:
One of the significant issues facing engineering over the past several decades has been the recruitment and retention of students, particularly minority and female students. One method that has proven fruitful in attracting these groups is to utilize a service-learning approach to show the applicability of course content and the ways that it can positively affect others. Many programs, such as Engineers Without Borders, target service opportunities for engineers in a developing country and typically attract a higher percentage of female and minority participants than the national averages for engineering. Opportunities such as these are wonderful, but there are vast opportunities available within one's own community as well. At the University of Cincinnati, a course was piloted with a group of honors students based on the Engineering Projects in Community Service (EPICS) framework to allow vertically integrated and multidisciplinary student teams to work on projects to aid the residents and staff of a local, inpatient facility catering to individuals with debilitating neurological diseases. The class was open to any student in the university's honors program, and drew students from engineering, art and design, and the sciences.

In this paper, a description of the curricular structure and the student projects are presented. In addition, a subset of the students in the course present their own experiences with the course and how their participation has affected their view of engineering and their future careers. These students first reflected on their own unique experiences with the course, specifically focusing on working in a multidisciplinary and vertically-integrated team, the development of teamwork and technical skills, and the impact of the course on their view of engineering. After reflecting, each student analyzed the reflections of the other participating students and the commonalities and differences in the experiences were identified and are presented, with implications for similar courses/programs.

Background:
One of the significant issues facing engineering over the past several decades has been the recruitment and retention of students, particularly minority and female students[1-3]. As a result, many programs have been developed over the years to attract female and minority students to STEM disciplines. These programs range from programs at the college level to provide academic and social support, often associated with the Society of Women Engineers (SWE) and the National Society of Black Engineers (NSBE), to high school, middle school, and elementary school initiatives designed to excite women and minorities about engineering when they are first forming their ideas about their futures.

However, once students from these populations have been recruited, efforts must be made to retain them within engineering. One method that has proven fruitful in helping to retain these groups, especially women, is to utilize a service-learning approach, which demonstrates the applicability of course content and the ways that it can positively affect others[4-7]. Many programs, such as Engineers Without Borders, target service opportunities for engineers in a developing country. Other programs, such as the EPICS program founded at Purdue University, focus on service opportunities in the community around the institution. Regardless of the venue,

these programs typically attract a higher percentage of female and minority participants than the national averages for engineering.

At its foundation, service-learning is the marriage of service within a local, regional, or global community with academic learning[8]. More precisely, Hatcher and Bringle[9] define service learning by the following:

> *We view service-learning as a credit-bearing educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of the course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility.*

In order to fulfill each of the requirements expressed above, a service-learning experience must utilize each of the following four components[10]:

1. Service – Service must be provided to an underserved group or area. In engineering, this often takes the form of providing engineering skills and services to address a problem facing the underserved group.
2. Academic Content – Given that a service-learning experience requires the participants to gain a broader understanding and appreciation of disciplinary content, the experience must be associated with some type of academic content. Within engineering, this may be content from a specific disciplinary course or may be more general engineering skills, such as problem-solving and design.
3. Partnerships and Reciprocity – In any service-learning experience, there are a number of entities involved. In the majority of experiences, there are three main players: the students, the faculty or mentor, and the community. Each of these groups must form a relationship with the others. In a well-executed service-learning experience, these relationships become partnerships, in which each entity contributes to the project and receives a benefit from the experience.
4. Analysis and Reflection – One of the critical components that makes service-learning such an effective pedagogy is the use of reflection throughout the experience. Reflection is essential because it is the primary method for connecting the curricular content to the service experience. For many students, this will be the first time they are applying their disciplinary knowledge to a real-world problem, and thus they will need guidance in understanding how the work they are accomplishing on their projects relates to the course content. Reflection also allows for the opportunity to connect the course content and students' disciplines to broader societal issues.

Curricular Structure:

At the University of Cincinnati, a course was piloted during the fall 2014 semester with a group of honors students based on the Engineering Projects in Community Service (EPICS) framework to allow vertically integrated and multidisciplinary student teams to work on projects to aid the residents and staff of the Beechwood Home, a local, inpatient facility catering to individuals with debilitating neurological diseases. Students were required to register for a 3-credit hour course that met once per week for 3 hours, and received a letter grade at the end of the semester. The class was open to any student in the university's honors program, and drew a total of 17 students

from engineering, art and design, and the sciences. A breakdown of the student participants is shown in Table 1.

Table 1: Breakdown of Participants in Course

Major	Number
Biology	1
Biomedical Engineering	4
Chemical Engineering	3
Computer Engineering	1
Computer Science	1
Electrical Engineering	2
Industrial Design	1
Mechanical Engineering	4
Total	**17**

Year	Number
First-Year	2
Sophomore	7
Pre-Junior	3
Junior	0
Senior	5

Gender	Number
Female	7
Male	10

During the regularly scheduled meeting time, instructors led discussions on a variety of topics, including engineering design and problem-solving, brainstorming, team dynamics, and background information on the types of illnesses faced by the residents at the partner facility. Each project team updated the class on their progress over the past week, their plans for the next week, and discussed any problems they were facing. The remainder of the time was devoted to working on the projects. Students were also expected to work on their projects outside of class, as necessitated by the project.

In addition to the work on their projects, students were also required to complete several other assignments throughout the semester. Each week, students were required to answer several reflection questions related to the topics discussed during class or to the status of work on the projects. Also, at the beginning and end of the semester, students completed a form where they outlined their goals for the semester (both academically and from a project standpoint) and how well they felt they did in accomplishing those goals.

In addition, three presentations were made during the semester. The first occurred during the third week of the semester so that the student teams and community partner could agree on the goals of the projects. The second presentation took place in the middle of the semester to provide the opportunity for students to receive technical feedback on their projects. The final presentation took place during finals week, in which students presented their progress on their projects to the community partner and their plans moving forward.

Overall, 5 projects were undertaken by the students: a physical therapy device to aid in maintaining hand strength and flexibility, an interactive game table to allow for residents to interact and exercise cognitive functions, a wheelchair mounted remote to interface with a system installed in the elevators to allow residents more independence within the facility, a wheelchair mounted system that would track the location of residents and would alert staff members in the event of a tip, and a device mounted in a resident's room to aid in calling for assistance through vision tracking. In the following section, three of these projects will be discussed in more detail.

Exemplar Projects:

Euchre Game Table

One of the goals of the Beechwood home is to allow residents to live their lives as independently as possible. Many are still capable of eating lunch without help and navigating around both the facility and in their individual rooms. However, one of the shortcomings at the facility was activities for the residents to engage in when official programs are not running. Socializing and having fun are essential parts to keeping a sharp and healthy mind amidst circumstances that can be fairly sad. Their current mental exercise consists of a limited number of daily seminars that only account for a few hours of the day and television for the rest of the time. Finding an alternative to television that encouraged much richer sensory stimulation was the problem that this team set out to solve. The idea was to create a game that was accessible by people with fairly limited motor abilities. It was hypothesized that through this medium, the residents would be able to receive a combination of visual stimulation by looking at the colors and items on screen, motor stimulation by pressing different buttons, and mental stimulation by using the information given to make intelligent decisions to try and emerge victorious. Another stipulation was that the table that held the gaming system needed to contain the ability to change its height so that residents with different sized wheelchairs could still participate in the game. Euchre was chosen as the game to implement, which is a 4 player card game and a particular favorite for the Beechwood residents. The game itself was developed using the Unity game engine. It has multiplayer functionality through WIFI and allows the residents to use a modified laptop configuration to interact with each other. The adjustable height solution used a modified car jack to achieve the desired motion. This was done to save money by not buying a premade table while also allowing staff members to easily change the height of the device.

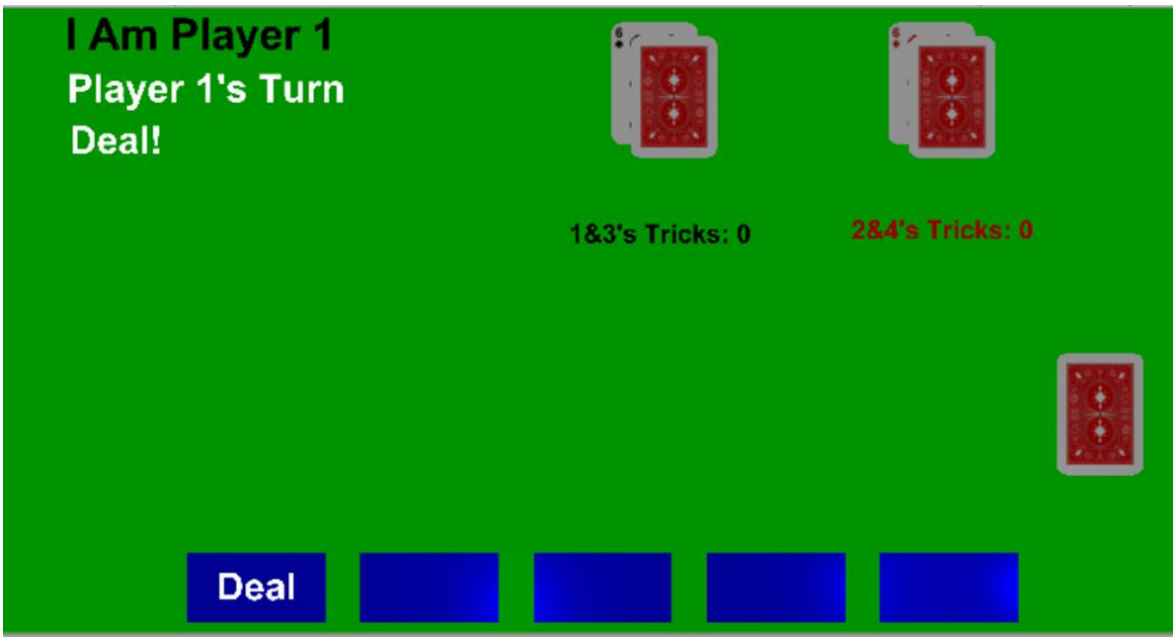

Figure 1: Euchre Game User Interface

Physical Therapy Device

This project group consisted of two senior biomedical engineering students and a senior mechanical engineering student. Due to the skills and interests of each member, the group decided to work on developing a physical therapy device. In order to develop a device that would have the greatest use and impact, the group decided to develop a device that would focus on exercising the hand and wrist. Almost all of the residents at the Beechwood Home are confined to wheelchairs and many of them utilize joysticks as a means of control. The overall goal of the project was to develop a device to mimic the muscle actions that are most crucial to a resident's daily life such as those involved in operating an electric wheel chair. The device is intended to assist with monitoring the decline of motor function in the hand and wrist of patients suffering from chronic neurological disorders. In order to best serve these needs, the device is designed with the user interface and the functional resistance in mind. The device needs to allow motions for pronation, supination, palmar flexion and dorsiflexion of the wrist. Due to the nature of the conditions of the residents at Beechwood Home, it is not expected that the exercise will result in an increase of strength. The device is more intended to hopefully delay the loss of strength and mobility and provide data to track degradation over time.

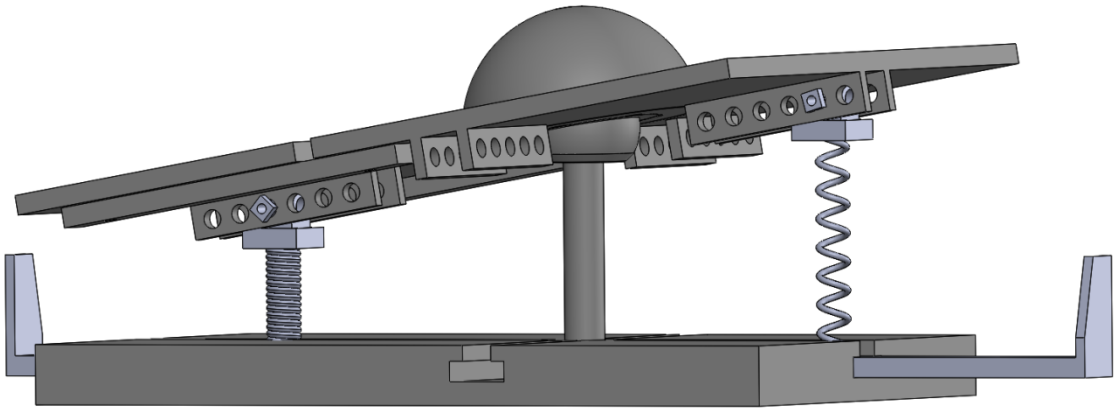

Figure 2: Prototype Design for Physical Therapy Device

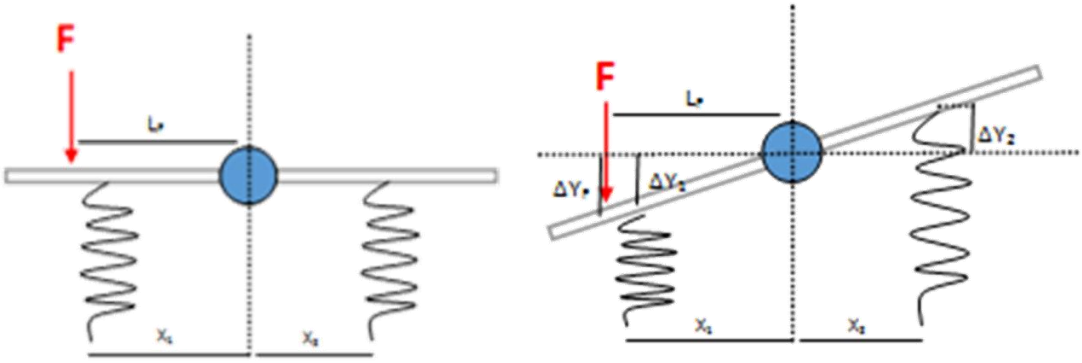

Figure 3: Schematics of device in neutral position (left) and activated position (right)

Elevator Automation

The residents of Beechwood home often experience difficulty operating the elevators in the facility. This is caused mainly by the location of the elevator buttons coupled with the limited reach of residents in wheelchairs. This causes the affected residents to have to wait by the elevator for assistance for extended periods of time. This problem has been looked at by a group previously who came to the conclusion that the best solution would be pressure pads on the floor that, when rolled onto, would indicate the resident's floor choice. However, these improvements have yet to be implemented so the problem was revisited. The original intent of this project was just elevator automation but developed into creating a system that the residents could use to control multiple aspects of their environment such as TV's, lights, and calling a nurse as well as the elevators. This system involves one central remote that will be can be mounted onto a wheelchair or used as a standalone device and various receivers used to physically control the desired devises such as TV's or lights. The remote prototype is nearly complete and the receiver is being developed.

Figure 4: Latest Remote Prototype

Methodology:

At the conclusion of the course, a small group of students from the class chose to continue their involvement and wrote reflections on their experience throughout the semester. A set of questions were developed to help guide the students in their reflections and to help provide commonality. The students from the class that chose to participate are shown below:

Table 2: Student Participants

Participant	Major	Year
1	Mechanical Engineering	Senior
2	Biomedical Engineering	Senior
3	Electrical Engineering	Sophomore
4	Electrical Engineering	Sophomore
5	Mechanical Engineering	First-Year

Once each student completed their reflection, they were compiled and exchanged. The students and instructors then reviewed each student's experience from the semester to identify commonalities and differences. The results of each member's analyses were then discussed within the group to arrive at the final set of common experiences.

Results:
Several common experiences were identified:

1. The service learning aspect gave true purpose to the project and was something students hadn't experienced in any of their other courses.

   "Gives the project more meaning, an actual motivation. A lot of other projects are based on hypotheticals, which makes them about the grades. In real life, we're not trying to get grades we're trying to solve problems, get results, make a change."

   "Adding a service component to the project give it a purpose other than a grade. Giving my game to others and watching them enjoy themselves is much more rewarding than any satisfaction a high GPA can provide."

   "Through my engineering courses and co-op experience, I had the opportunity to take part in various design projects but this course presented a unique opportunity to design my own project while also giving back to the community."

2. Teams had the opportunity to formulate their own projects which required creative thinking and inspired more effort leading to better results.

   "This class allowed us to really take ownership of our projects because we were able to conceive them ourselves. We were given the opportunity to speak with residents and staff at the Beechwood Home about their wants and needs, and then analyze how we would be able to work to best meet those needs. This was unique to this course as most courses outline very specific projects for the students to work on and problems to solve."

   "Each project focused on one or more problems Beechwood's staff or residents faced on a regular basis but were not pre-determined by Beechwood or the course instructors. Instead, the projects were developed by the students after visiting and observing Beechwood Home where we were able to interact with the staff and residents to better understand their needs and wants."

"This was a great experience for us, not only in creative thinking, but in the entire new product development process. Since the direction of the project was decided almost fully by the students it was very easy to be passionate about what we were doing."

3. All five teams involved in the class were multi-disciplinary.

   "The industrial design student in our group utilized his artistic abilities helped define and make decisions about some of the aesthetic as well as functional parts of the table portion of the project. He was able to rapid prototype some our designs by creating Solidworks drafts for me to 3D print. The other person who influenced the group was a biomedical engineer. She had interest in mechanical manufacturing. She was intent on contributing a large part of the design. This led to some good discussion and debating about how to best implement the adjustable table mechanic. The two people mentioned above developed a different solution than mine, and they were eventually able to convince me that their design was more accessible than my idea. The friendly competition of ideas drove us towards the best solution for that situation."

   "Many courses in the undergraduate curriculum only allow for students to work with other students in their major. This course allowed for cross-discipline groups to work together which then allowed the students to gain different perspectives from students in other majors. In the workforce it will be expected for an engineer to be able to work with many people from different disciplines."

   The experiences of the students in the group involved with this study were similar to those expressed by the rest of the class on the end-of-semester course evaluations. For instance, several other students commented on the multidisciplinary nature of the teams.

   "I also enjoyed the interdisciplinary aspect of the course. Outside of co-op, I haven't had the opportunity to work on engineering projects with students of other engineering disciplines."

   "Even though it was called an engineering class, I enjoyed having a DAAP student in the class, since I don't have many classes with them, and he had a different perspective."

4. Time constraints were an issue. Evaluating options, deciding on the "best" design and creating a prototype in a single semester were significant challenges for the students.

   "Through past experience of working on projects, I know that time is always an issue. A group can have grand ideas of making an elaborate design, but plans can easily fall short due inevitable complications. Time management was a nightmare because all of our schedules conflicted almost every hour of the week. This meant that we had to work independently or in groups of two or three most of the time."

5. The scope of each project was initially too large and teams had to make modifications.

   "My group members wanted to expand on the theme of entertainment and proposed making multiple games for our system. I had to work to convince them to take the project one step at a time. I knew that if we tried to spread ourselves too thin we would get overwhelmed, especially since no one knew anything about game development at the start of the project."

   "At the end of the semester, we had a functional mechanical prototype but we were not able to achieve every muscle action that we originally proposed due to time and space constraints within the prototype housing."

The group also identified some differences in student experiences:

1. The timing in academic career affected the experience. First-year students had very little background in engineering whereas seniors had a solid background in their major along with several co-op rotations.

   "Gave first-year students opportunity to learn about/experience engineering that they would otherwise have to wait until at least next year for and solidifies their desire to become an engineer"

   "As a Sophomore with AP credit, I've had a bit of exposure to some electrical engineering courses. In particular, this class came after I've had extensive exposure to programming concepts, so it was no surprise that many of the ideas I helped contribute were related to this field."

   "My project group consisted of two senior biomedical engineering students in addition to myself, a senior mechanical engineering student. Due to each of our skills and interests, we decided to work on developing a physical therapy device."

2. For some students, the project tied in directly with their major and for other students, the project did not relate to their major at all.

   "Some of the students did not gain experience in their particular major (specifically the biomedical engineers) due to the nature of the project."

   "This course introduced me to a new branch of electrical engineering: medical devices. I have found my foray into this field to be extremely fascinating, particularly because of its emphasis on service. Everything we created was done with the intent to help others, which is not something that can necessarily be said about other career branches for my major. Having the experience of exploring this field through design considerations and decisions has shown me how challenging and enjoyable a job in medical devices could be."

   "The mix of majors in my group allowed each of us to focus on different aspects of the project. The two biomedical engineers were able to focus on the functional motions and

what muscles would be activated. This then allowed me to focus on designing the mechanisms necessary to facilitate the motions and the variable resistances needed for these motions."

"Being an electrical engineering student, leading the design of an electronic device pushed me to grow and develop my skills that directly relate to my major while also giving me an opportunity to develop as a member of an engineering team."

Conclusions:

Overall, the students had a very positive experience in the class. The service-learning aspect of the course allowed for students to work on projects that had direct impact on people, which added a new component to the problem for many of them. Students also appreciated the multidisciplinary nature of the project teams, as most had not had this experience except for an occasional project while on co-op. However, many teams struggled with the open-endedness of the course, finding time management and project scope to be especially problematic.

As would be expected, academic standing and major played a significant role in the experiences of the students. First year students had a very different experience from senior students and depending on the nature of the project, students with different disciplinary backgrounds had very different experiences as well. In most cases, however, this was turned into a positive as different aspects of the projects were identified that aligned with the skills of each member on the team.

Since this was the first attempt to offer a course of this type, there are several aspects that were identified for improvement for the next offering. Several students mentioned in the course evaluations that clearer expectations and more guidance were needed. This is an area that the instructors have identified as well as needing to be improved for future offerings of the course.

"I would say to have checkpoints throughout the year. I know it's hard since everyone has different projects and it is hard to say how much needs to be done by a certain point in the year, but one of the main problems everyone seemed to have was running out of time."

"Just because of experience, I expected the course structure to be more detailed. For the most part, this course was more of a guided independent study. I personally enjoyed that but I think the students who are younger may have benefitted more from lecture related to project goal setting/background research/brainstorming, etc."

The group involved in this paper also identified a number of ways to improve the course:

1. Students should spend more time interacting with the Beechwood Home residents possibly through volunteer opportunities.
2. The course should be expanded to a two semester sequence. The first semester would focus on developing a good design and the second semester would focus on creating a prototype.
3. The group size should be capped at four students. Larger groups tend to be very inefficient.

4. More non-engineering students should be encouraged to register for the course. The one industrial design student was very helpful in more than one of the projects. Business students interested in marketing would also be helpful in the second semester course.

This course has been a great experience for both the instructors and the students, and the instructors look forward to offering it again in the near future. We leave you with the words of one student commenting on his/her experience in the course:

> *"This course put human life into the equation. Throughout my time at the University of Cincinnati and before, human lives are rarely the main focus of the problem. Therefore, I don't always think about the implications the work I am doing may have on other people. The experiential aspects of this course forced me to rethink how I learn in order to put human life into my thought process."*

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