Capstone Design Projects: Enabling the Disabled

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Abstract

The purpose of this paper is to show how some of the ABET EC 2000 criteria can be satisfied with "service-learning" student design projects. In addition to meeting ABET requirements, these "designing for the disabled" types of team design projects have other, less obvious, educational benefits that are not normally met with the traditional industrial projects. Several examples of these types of projects will be discussed showing their specific educational benefits.

Introduction

Service-learning is receiving increased attention from educators because of the opportunities for helping the community while demonstrating ABET EC 2000 criteria. Service learning projects are typically sponsored by a community partner and give students the opportunity to interact with people outside their socio-economic groups and disciplines, and also include issues other than engineering. At Rose-Hulman Institute of Technology the senior mechanical engineering capstone design courses traditionally have included projects to help the handicapped. These projects are initiated by a variety of groups such as local hospitals, schools, physicians, therapists, and support groups.

These service-learning projects require different skills from an industrial sponsored project. With industrial projects, the sponsors are usually engineers who can explain their problem in technical language. With service-learning projects students must communicate with non-technical people and interpret loosely developed problem statements such as, "I want to be able to brush my hair without help." This communication directly relates to EC 2000 Criterion 3 (g), "an ability to communicate effectively" and EC 2000 Criterion 3 (c), "an ability to design a system, component, or process to meet desired needs." The students must listen attentively, think creatively, and then design a product to meet a specific need. Often a high level of technical expertise is not required, but rather an innovative use of common components to meet a very specialized need. Past projects used by the authors have been very diverse and have ranged from the design of a wheelchair accessible power tool bench for high school industrial arts to a pediatric mobile arm support.

This paper will discuss the use of these types of projects from the perspective of student learning and also as demonstrations of ABET criteria.

Examples of Typical Projects

To illustrate the differences between projects for the disabled compared to more traditional engineering projects the following examples are given. In each case the differences between these projects and more traditional engineering projects should be noted.

Case 1: Safety Considerations and Modifications for a Handicap Accessible Motorcycle

In this project students worked with a triplegic who owned a wheelchair accessible motorcycle with a sidecar. The motorcycle had been modified previously to accommodate the wheelchair by creating a chariot sidecar and the handlebars had been relocated so that it was controlled from the sidecar. The problem that the students were asked to solve involved the braking system. The braking system required that the driver be able to use both hands: The right hand operated the front brake and the left hand operated the rear brake. Because of his limited use in the left arm, the driver could not operate the rear brake and was operating the motorcycle using only the front brake.

The client, who was the driver, was able to define the problem for the students in this project but he did not have the necessary understanding of engineering principles and safety practices. He assumed that if a modification worked once, it would always work and was impatient with the rigorous testing that the students requested.

To solve the problem, students designed and oversaw the fabrication of a modified handle grip and bracket that replaced the existing bracket. This handle had a piston that actuated the master cylinder on the front brake as well as a cable pulley system that operated the mechanical rear brake. The students learned to co-ordinate between the manufacturer, the client, and the Rose-Hulman machine shop. They also had to insist upon following professional practice in all areas of design and testing and, for the first time, experienced pressure from the client to "just let it go." The students liked the client and developed new maturity in discreetly insisting on their standards. Because this project involved design, build and test, the students demonstrated EC 2000 Criterion 3 (c) completely.

What this project offered that the typical industrial project does not was the ability to work with a non-engineer for a client and the ability to empathize with an individual that has severe physical limitations.

Case 2: Design of a Safety Device to Aid Cerebral Palsy Patient

In this project students worked with a six year old child with Cerebral Palsy. In addition, the child had limited communication skills and could not recognize dangerous situations. The child was very active and was constantly getting into potentially dangerous situations. His parents had a Safety Chair that was designed to restrain him when they needed to do things such as cook, eat, or clean. The problem with the Safety Chair was that the child was able to rock the chair and "walk" it around the house at will. The family wanted some method of keeping the child safe for short periods of time and wanted to be able to use the device as he grew.

In this project, the family knew that they wanted something, but they were unable to give the students guidelines other than cost, space, and weight restrictions. The students had to determine all of the safety constraints because the parents did not have the expertise. Because the problem definition was so open-ended, the students had the opportunity and frustration of being more creative. The group decided to design a "damping base" that could be attached to the existing Safety Chair. This base would allow the child to rotate his chair 360 degrees, but would not allow him to move it along the floor. The key component of their design was a ball and socket joint. They decided to use Hind Joints which are used on automotive steering systems. Because the family had limited financial resources, the students contacted local companies and asked for and received donation of materials. The students then manufactured and tested their base and, after modifications, presented it to the family. The family was very pleased with the performance of the group.

This group learned how to define a problem in its broadest sense, how to use traditional components in non-traditional ways, how to ask for and receive charitable donations, how to empathize with the family, and how to communicate with non-engineers. In addition, they "were very thankful that we were able to give them something that they could use to improve their everyday lives."

Case 3: Pediatric Mobile Arm Support

In this project students worked with a two year old boy who suffered from arthrogryposis, a congenital disease that afflicts joints and muscles and restricts normal activities. The request that the student group received from the child's therapist was to help him move his arms. The group was initially frustrated by the enormity of the problem and considered solutions that were extremely complex (robotic manipulators) and unusual (helium balloons). After weeks of idea generation and rejection, the group decided on devices to help the child slide his arms along a surface.

The group made two devices, one for each forearm. Each device features a 4"x 4" copper plate, attached to his arms by U-shaped plaster supports, held together by Velcro straps. Four metal balls, similar to ball bearings, are attached to the bottom of the copper plates and allow the child to move his arms in any direction. The devices offered support and slight elevation for his arms. The elevation allows the child to use his fingers. When introduced to the device, "he squealed with delight and his eyes got real big", according to his therapist. The child has used the devices successfully for the last three years.

This group became personally involved with the child. "We wanted to do something to help him. He's such a great kid." The group received personal satisfaction from being able to help the child. The learning experience for this group included communicating with non-engineers, applying creativity to an open-ended problem, fabricating, and testing a device, and receiving personal satisfaction from helping a small boy. There were some drawbacks, however, with the project. The students were very frustrated because they could not think of a solution immediately. They were also concerned that their solution might be "too simple." They had a tendency to compare their project to more traditional projects and they felt that they weren't making enough progress.

Case 4: Creeping Trainer for a Physically Challenged Child

In this project students worked with a four year old girl who was unable to creep (crawl). She moved by scooting on her back or rolling because she had very poor muscle control in her arms and was unable to support her upper body. Her hands were very sensitive and she tended to kick her legs out from under her, making it difficult to keep her in the "hands and knees" position required for creeping. The problem statement presented to the students was "Help us keep her in the creeping position."

In this project the students could find available products that would meet a portion of the requirements but not all. There was a height-adjustable crawler available that provided upper body support, but did not limit range of motion of the legs. There were toys that children could use to scoot along the floor, but they had too much friction and did not limit the range of motion. The students decided to build a rolling platform that provided support for the child's upper body. Straps over the platform keep the child from being able to fall. It also had a plate with bungee cords attached that limited both the forward and backward motion of her legs. Due to the family's limited financial resources, the students obtained funding for the upholstery of the platform and the wheels and casters on the bottom of the platform.

In this project, students learned that scheduling can be very difficult when working with a disabled child. They learned how to communicate with the child, the therapist, and the machine shop fabricating the device. They learned that there are lots of products on the market, but those products do not necessarily meet the needs of a client. They learned that to use bungee cords in a creative manner. Finally, they learned the satisfaction of helping a child with severe disabilities.

Case 5: Wheelchair Accessible Power Tool Bench

In this project students worked with a local middle school shop teacher. All students in his middle school are required to take an industrial technology class, but students who were confined to a wheelchair were unable to use the power tools on the current bench layout.

Initially, the students perceived the construction of a table as being trivial; however, as they considered the special needs of the disabled, they realized that there were many functions that should be considered. First and foremost, the table must be accessible for someone confined to a wheelchair. When the table is not being used, it needs to be moved and stored easily so that there is more room in the shop. The table needs to be easily adjusted to various heights and should be able to carry the load of the tool and the workpiece and a person leaning on the table for support. In addition, the table needs to minimize vibrations and deflections so that the user will be comfortable and feel that the table is sturdy. The table must have sufficient work space and not take up too much room in the shop. Finally, the table needed to be durable and offer all reasonable safety precautions.

The students designed and constructed a two level, adjustable height worktable with its own power supply and kill switch. The group felt that the kill switch would be a good safety feature because a person in a wheelchair has limited mobility in the event that there is a problem.

The students constructed and tested a prototype table. After initial testing on the Rose-Hulman campus, the students tested the table on site at the middle school. The disabled students were excited when they were allowed to use power tools on the table.

In this project students learned that designing a seemingly simple object requires a lot of consideration. The group had to work with the shop teacher and the disabled students - so they had two customers with slightly different perceptions. The shop teacher was interested in function, safety, and ease of set-up/storage. The students were interested in the table being sturdy and looking cool. All materials were purchased by the shop teacher after the students completed requisition forms. The group was not prepared for the "red-tape" associated with a large educational system and quickly realized that a part requested on Friday would not be in on Monday. This group also learned how a table can give a disabled student a sense of belonging, and they were pleased that the disabled students were able to learn to use power tools.

Conclusions

After supervising capstone design projects with both industry and service learning projects for more than ten years, the authors have recognized that there are some distinct opportunities that service learning projects offer; especially when compared with traditional industrial design projects.

1. <u>Problem statements are not given in engineering terms</u>. In the service learning projects the problem statements are often ill-defined and rarely specified in engineering terms. This requires that students cast the problem in a technical form.

2. Projects are almost always design, build, and test. In the service learning projects, the client is looking for something to improve his/her everyday life. This "something" is usually a physical device that the client does not have the skill to produce. This requires the students to take responsibility for the final product. In industrial projects, the company is typically looking for one or more designs detailed so that the company can construct prototypes. Typically, the companies do their own prototyping. The prototyping and subsequent testing may or may not be shared with the student group.

3. Students must communicate effectively. The students must communicate with disabled clients and usually medical personnel. Students, as seniors, have become familiar and comfortable with technical jargon. They must set aside their jargon in order to talk to their clients and they must learn to listen and understand medical terms. In addition, many students choose to find funding for their client and they must ask local groups for money. Asking for donations is a new experience for most engineering students.

4. Students work with a greater variety of outside groups. When working on an industrial project, students usually work with the company and potential suppliers for their proposed design. In service learning projects, students must work with a variety of different groups. From the examples shown above, the students might be working with the end user, the end user's family, the medical therapist, vendors, machinists, and funding sources.

5. Students develop empathy for those with disabilities. For many of our students, this is their first opportunity to work the disabled. The students often voice how much they have taken for granted. They realize that for their clients even the simplest task is enormous. The groups see their client as an individual who is trying to cope with a serious problem.

6. Students gain great personal satisfaction from helping others. As they develop empathy for their clients, the students want to help them. In some cases, the group knows that their client will only get worse as the disease progresses. In other cases, the group knows that the client will not live a normal life span. This knowledge gives an urgency to their work: they want to help right now. Being able to see a person use their design and improve the quality of their life provides enormous satisfaction to the groups. They feel that they have made a difference for someone, and they see the results of their work.

7. Student reflection is more global. All students who take the capstone design course are required to write a section entitled, "Lessons Learned." In this section, students are asked to reflect on the quality of their learning experience in the course. For the industrial projects, students tend to be very detailed, for example, "We should have used a different fastener." or "The production department was not helpful." In the service learning projects, students tend to discuss their role in the project. "I was happy that we could make a difference." or "I have a new perspective on engineering."

8. Students mature. In the service learning projects, students are the “experts” for the first time in their technical career. With industrial projects the students are seen as novices who might offer help to the company. In the service learning projects, the students are seen as the experts who will make a difference. They are the ones with the technical background who can make the decisions.

There are some drawbacks associated with service learning projects. The students do not get to work with and be mentored by a practicing engineer. The technical requirements are generally not as in-depth as an industrial project. However, the merits of the service learning projects balance the drawback. Students must communicate with a variety of technical and non-technical participants to achieve their goals. This requires that they must listen and explain in ways that are very different from what they have done in college. This communication meets the essence of ABET EC2000 (g). In addition, groups follow the design process from concept to delivery and thereby satisfy ABET EC2000 (c). Students get to experience the essence of engineering - “using their knowledge and skill for the enhancement of human welfare.”[ASME Code of Ethics for Engineers]

BIOGRAPHICAL INFORMATION

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