AC 2007-1247: THE IMPACT OF “SPECIAL NEEDS” PROJECTS ON STUDENT LEARNING

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The Impact of “Special Needs” Projects on Student Learning

Abstract
The Accreditation Board for Engineering and Technology (ABET) identifies design as an important element of the engineering curriculum. The faculty at the University of Tennessee at Chattanooga believes the concepts and principles of design are as fundamental to undergraduate engineering education as are those tools and topics traditionally thought as fundamental (such as mathematics, physics, chemistry, statics, and dynamics). One of the benefits of design is the hands-on activities or Project-Based Learning application it brings to the classroom. ABET also states that engineering programs must demonstrate that their students have the education to “understand the impact of engineering solutions in a global, economic, environmental, and societal context.” Many engineering programs use design projects as one means of addressing this outcome. This paper describes UTC’s process of using freshman hands-on design projects to address these outcomes. Of special interest is the impact of student projects that address needs of children with disabilities.

Introduction
The Engineering program at the University of Tennessee at Chattanooga (UTC) recently redesigned its freshman introduction to engineering design course (IED) to use Project–Based Learning (PBL) to excite students to independently learn, to create an environment for peer learning, and to increase student in-class and out of class participation. It is believed that these objectives are instrumental for exciting students about engineering, for increasing student retention, for motivating learning, and for improving students’ knowledge transfer capabilities especially in the application of engineering design.

To meet these objectives, the IED course instructional structure now culminates in customer supported projects. The instructors of IED recently received a grant from the Tennessee Department of Education (project Technology Designed to Benefit (TDB)) to design, prototype, test, evaluate and disseminate products, procedures and services that apply adaptive and assistive technologies to children with disabilities and their families and service providers. As part of this grant mechanical, civil, environmental, electrical, chemical, and industrial engineering students in the freshman year team with early interventionists to use a defined and unique customer to actively engage in the design process, especially to define the problem, application environment, and customer needs and build and test the prototype. Students are responsible for communicating with the requestor and customers, designing a device that meets customer constraints, safety and operational codes and standards, and budget restrictions, and testing the device with the customer (child).

This paper presents the PBL process initiated by the engineering program at UTC in the fall of 2005 that emphasizes the TDB projects. Descriptions of the course objectives as well as project outcomes from the 2005 and 2006 course offerings are provided. Student responses to the experience are emphasized and the outcomes of this experience on student learning are summarized.
Design at UTC

The elements of design are emphasized throughout UTC’s engineering curriculum, beginning with the freshman year. At least ten credit hours are devoted to teaching (to all engineering majors) design concepts in an applied, interdisciplinary setting. At the freshmen level the students are introduced to the foundations of design. At the sophomore level the students use design concepts to design, build, and test small structural and mechanical projects. At the junior and senior level the students use design concepts to solve real-life and open-ended interdisciplinary industry-based problems. The student project teams work with the sponsors and a faculty advisor to develop, test, and prototype a solution. In addition, students apply design concepts in a three credit hour discipline-based capstone course during their senior year. The structure of the design curriculum is shown in Figure 1.0.

![Figure 1.0: The Design Curriculum at UTC](image)

The goal of the design curriculum is to graduate students who understand and can apply the steps of the design process to various interdisciplinary and discipline-based applications. The first step toward meeting this goal is to introduce the steps of the design process in UTC’s 3 credit hour freshman level course Introduction to Engineering Design (IED). The design process emphasized at UTC is shown in Figure 2.0.

![Figure 2.0: Engineering Design Texts](image)

The freshman IED course uses short lectures and hands-on design exercises to emphasize the body of the design process—problem definition, conceptual design, alternative selection, and preliminary design (see the shaded portions of Figure 2.0). Concurrent with the design methodology is graphics design practice on sketching and solids modeling necessary for communicating the design. A major outcome of the course is a detailed design and prototype of a small team design project.

**IED Course Structure**

IED meets for 4 hours each week as two 2-hour class sessions. The first 2 weeks introduce the students to solids modeling and the concepts of graphical communication using a simple design project. During the next 4.5 weeks the students are introduced to and practice the
components of the design process through a larger class project. The last 7.5 weeks are devoted to the students applying what they learned about the design process and graphical communication to a small team project. The project culminates in a project prototype.

Figure 2.0: The Design Process (UTC Emphasis)

**IED Course Learning Objectives**

After completing the IED course, the students should know how to

- formulate a problem statement
- create project objectives
- distinguish between functions and specifications
- use idea generation exercises to generate alternative solutions to a problem
- use at least one proven means for deciding between design alternatives
- recognize and communicate constraints and codes and/or standards for a design
- recognize and apply ethical decision-making practices
- organize, participate in, and document team meetings
- participate as a contributing team member in the design and problem solving processes
They should also understand and be able to

- apply graphical 2-D and 3-D drawing principles
- use a 3-D drawing software package
- use the principles of good oral communications to effectively communicate ideas
- use Microsoft PowerPoint software to aid oral presentations
- use Microsoft Project for creating a simple Gantt Chart
- use principles of good technical writing to effectively communicate major ideas

**The IED Culminating Project**

The goal of the IED team project is to design a device for a specific customer. Since the fall of 2005 the projects consist of opportunities from (1) the TDB grant from the Tennessee Department of Education and (2) other UTC faculty needing small devices to support research or upper level courses or projects. The projects are completed per the process illustrated in Figure 3.0.

![Figure 3.0: IED Team Project Process](image)
As illustrated above, early in the semester a request for project proposals is sent to the grant participants and the faculty of the UTC College of Engineering and Computer Science (CECS). The course instructors select those proposals that best meet the needs of the course and the abilities of the freshman students (many students have yet to take an engineering course). Approximately nine projects are selected each semester (4 to 5 students per project).

Approximately five of the projects support the TDB grant. Molly Littleton, Director of the Assistive Technology Group at Signal Centers in Chattanooga, Tennessee and project team member, identifies possible projects from families and children with needs. She then, following consultation with the course instructors, submits proposals of those projects that can be completed by the freshman students. Ms. Littleton then acts as project consultant for each of the projects, helping the student teams contact the customers, including the therapists, teachers, and impacted children and families. The course instructors support the technical needs of the projects.

**Technology Designed to Benefit (TDB) Projects**

The focus of the IED TDB projects is improving assistive technology for toddlers and young children to help them be more independent at home and in the classroom. Projects support children, families, and counselors in Chattanooga as well as the surrounding counties. During the 2005 – 2006 academic year nine projects were completed and delivered to the children and centers. Four projects were completed during the fall 2006 semester and seven more are being supported by students during the spring 2007 semester. Following are descriptions of seven of the completed projects.

**Adaptive Mobility Device** – One of the first freshmen TDB projects (fall 2005) is the Adaptive Mobility Device, a modified tricycle to help a child with Prader-Willi syndrome to exercise. The tricycle, shown in Figure 4.0, was designed for a child weighing 40 lbs who is unable to walk unassisted but can sit and stand unassisted.

The Adaptive Mobility Device has three wheels – two wheels in the front and one wheel in the rear. The tricycle is 30 inches long and 26 inches wide. The bottom of the seat stands 18 to 20 inches off the ground. The wheels have a diameter of 10 inches and have steel rims and rubber tires. The tricycle does not include brakes; it is understood that the tricycle will be used only for exercise within the large activity room at Signal Centers. The bicycle frame and handle bars are made of light weight aluminum. The seat is adapted from a child’s safety seat with a 5 point safety belt.
*Springboard Communication Device System* — One of the spring 2006 TDB projects resulted in a means to position a Springboard communication system for use by a child of very small stature and limited freedom of movement. Prior to project completion, someone had to hold the Springboard device for the child while she used it. This limited the independence of the child at both home and in the classroom. Due to the child’s small stature there were no devices on the market that would hold her communication device while she sat in her classroom chair or her wheelchair. Thus, the child and teachers needed a custom-built mount system that adapts to the child’s wheelchair, her group activity wooden chair, and her floor activity.

The Springboard Communication Device System (SCDS) the students designed and produced is made of Lexan, aluminum, and Delrin (a high quality, smooth plastic). The overall physical appearance, as shown in Figure 5.0, resembles a tray on a high chair, except a Delrin “strip and track” is included down the center of the tray to allow the block that holds the Springboard device to slide. At the end of the long Delrin platform is a shorter piece of Delrin that swings under the tray to allow storage of the block and space for drawing or coloring. Both Delrin pieces have locking pins to hold the block and Springboard device in place.

*Vanguard Communication System Mount* — Another of the spring 2006 TDB projects resulted in a means to position a Vanguard communication device, which is larger than the Springboard device, on the wheelchair tray for a child with multiple disabilities. The specific problem was two fold: (1) the commercially available desk mount placed the communication device too close to the child for ease of use and (2) the commercially available mount did not securely mount to the wheelchair tray.

The student design for the Vanguard communication system mount, shown in Figure 6.0, consists of one-inch aluminum square pipe welded at two corners fitted to a commercially available mount. This attaches to the new tray made of clear half-inch acrylic using square pipe “slots” and a clamping device. A spring-loaded pin secures the mount to the table at the “slots”.

Figure 5.0: UTC Student Designed SCDS

Figure 6.0: Vanguard Communication System Mount
Etched into the tray is the child’s name flanked by two UNC Tar Heel logos (the child’s favorite college team). Around the front and sides of the tray are three North Carolina Blue half round pieces of wood used for barriers so that toys do not roll off the tray.

**Multi-Sensory Switch** — A third spring 2006 TDB project is the Multi-Sensory Switch, a pressure sensory switch for a multi-handicapped one-year old child. The child has vision and motor skills deficits. The project’s goals were to design a switch that (1) activates and illuminates brightly every time a child presses the touchpad, that (2) includes accessible slide switches that allow instructors to turn functions on and off, that (3) vibrates, and that (4) activates an externally attached toy.

The designed switch, shown in Figure 7.0, is oval in shape – 8 inches wide by 5 inches long by 3 inches high. The shell of the device is made of a polycarbonate plastic. The middle piece is painted blue with yellow dots. The top pad is translucent to allow light from LED’s to shine through. The top surface has extruded geometric shapes and curved lines to create texture.

The switch contains ten LED’s for effective lighting and four pressure sensors rather than one to provide a response no matter where the touchpad is pressed. The switch has three motors with offset weights to create vibrations. An electronic music box provides music when the pad is pressed. The switch has slide switches to turn vibrations, lights, and music on and off. Suction cups placed on the bottom of the switch keep it stationary. A 3.5mm jack is used to send a signal to a toy.

**Multi-Switch Mount System** – The Multi-Switch Mount System (MSMS) was developed Spring 2006 for a child at Signal Centers with multiple disabilities who frequently pulls or knocks mounted or placed switches off his tray. The MSMS secures two types of switches – a gum ball switch and two talking picture frames – to a tray that mounts to a wheelchair.

The MSMS, as shown in Figure 8.0, is made from acrylic and has an acetal dome to cover and secure the large gum ball switch. In addition, it has two smaller mounts that enclose the talking picture frame switches. The smaller mounts are made from a plastic material called Derlin. Both switches are positioned in a central position that allows the child to use them with ease. The big switch is on the child’s left and the smaller talking picture frames are on his right. The switches are positioned at 45 degree angles to the child to aid the child in using them.
Monitor Mount System – The Monitor Mount System (MMS) was developed during the Fall 2006 class. The MMS provides an adjustable mount for a 19” Elo Entuitive flat panel touch screen monitor and a cabinet for enclosing the computer hard drive, mount, and screen when the system is not in use. The monitor is needed for a family with 2 year old quintuplets who have a variety of abilities and disabilities. Thus, the computer monitor must move up and down so that the screen is visible and accessible to each child depending on what level is most appropriate. One of the children uses an adapted wheelchair for positioning.

The MMS, shown in Figure 9.0, is a wooden box measuring 24”x 24” x 23 1/8”. It is constructed from durable oak plywood, and is held together by steel screws. The box features two swing cabinet doors located on the front face. The rear face of the box has a rectangular cut section which houses the monitor mounting mechanism. The mechanism is composed of two steel pipes of 2” and 2.5” diameters. The pipes are machined so that they slide within one another smoothly. Both pipes have three holes drilled through them evenly spaced for vertical positioning. The three holes create three different operating levels for the monitor. Housed within the box is a fixed power strip with a surge protector. On the rear face of the box is a 1” diameter hole for electrical cable access.

The monitor arm is made from aluminum and is held together with tension springs. The arm provides 28” of horizontal adjustment and 14” of vertical adjustment. It also allows the monitor to tilt 70 degrees and swivel 360 degrees. The base of the arm provides 360 degrees of rotation. The box is supported by four ball bearing casters with locking brakes.

Through this project, the IED students designed a stable, flexible monitor with a mount system, and computer desk. Presently all of the quintuplets have easy access to a computer therefore helping foster their cognitive development while allowing for their individual needs.

Mobile Communication Stand – The Mobile Communication Stand (MCS) was also developed during the Fall 2006 class. The MCS was developed for a child at Siskin’s Children’s Institute who crawls across the floor because he is not yet able to walk. He uses a communication system to communicate to his teachers and peers but does not have a means to move the communication unit with him as he travels along the floor.

To aid the child the IED students designed and built a stand in the shape of Thomas the Tank Engine (see Figure 10.0) that holds the communication device securely and can be either pulled or pushed across multiple surface types. The stand is made of wood and uses three caster wheels for mobility. The mount has a 17” turning radius. A handle is included on the rear for pushing
and carrying the mount and an aluminum loop is included on the front for pulling. The communication system mounts at 45 degrees for ease of viewing.

![Image](image.png)

Figure 10.0: Mobile Comm Stand

The Thomas the Tank Engine Mount has provided the child with a significant way to gain more independence as he communicates and moves around. The IED students’ creative design helped to make using the communication system much more appealing and motivating!

**Learning Outcomes of the Projects**

Table 1 provides a summary of the number of UTC students and clients affected by the TDB projects since the Fall of 2005 as well the student reported project expense (each project had a financial resources of $700.00 to $900.00).

<table>
<thead>
<tr>
<th>Project</th>
<th># of UTC Students</th>
<th># of Affected Clients</th>
<th>Project Expense ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive Mobility Device</td>
<td>5</td>
<td>1</td>
<td>209.00</td>
</tr>
<tr>
<td>Remote Sensory Switch</td>
<td>4</td>
<td>unlimited</td>
<td>72.00</td>
</tr>
<tr>
<td>Dynamic Monitor Mount</td>
<td>4</td>
<td>1</td>
<td>186.00</td>
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<tr>
<td>Multi-sensory Switch</td>
<td>5</td>
<td>unlimited</td>
<td>375.00</td>
</tr>
<tr>
<td>Springboard Mount</td>
<td>9</td>
<td>1</td>
<td>325.00</td>
</tr>
<tr>
<td>Switch Mount</td>
<td>4</td>
<td>unlimited</td>
<td>164.00</td>
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<tr>
<td>Vanguard Mount</td>
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<td>1</td>
<td>550.00</td>
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<tr>
<td>Monitor Mount System</td>
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<td>5</td>
<td>886.00</td>
</tr>
<tr>
<td>Mobile Communication Stand</td>
<td>5</td>
<td>1</td>
<td>208.00</td>
</tr>
<tr>
<td>Mobile Monitor Stand</td>
<td>4</td>
<td>unlimited</td>
<td>390.00</td>
</tr>
</tbody>
</table>

UTC students were affected by the projects in a number of ways – some expected, some not. Some impacts are related to learning the design process. Other impacts are related to learning
about engineering’s impact on society. But still other impacts are associated with student motivation. The following summarizes these outcomes.

**Design Process Outcomes**

One of the more expected outcomes of the project experiences was what the students learned about the evolution of the projects and the communication of the project designs. For instance, some students learned that even though they designed their device on paper and in the 3D software, the prototype may not, due to constraints, exactly meet the portrayed design. This was true of the Adaptive Mobility Device team. The students’ design had a particular seat geometry and style that could not be duplicated due to time and budget constraints. The modified child’s seat was used. The redesign was tested with the child as the rider and was found to fit well except for the reach to the pedal and seat stability. The Adaptive Mobility Device will be proposed as a spring 2007 project to address this issue (among others).

Using real customers has also helped students to learn the importance of working closely with the customer. Previous to the fall of 2005, students developed projects of their own interest. They had no interaction with a customer who could examine their design and provide feedback. They also did not have to meet customer required constraints. Now, with customer supported projects, students learn that feedback and interaction with the customer is extremely important to create a successful outcome. Of particular importance of the TDB projects is the role of concept testing and testing with respect to customer needs. A few of the projects do participate in these activities as part of their design process though most experience this after the device is delivered to the customer (because they did not take the time initially). The result is that the students complete their projects following the end of the semester.

While it is disheartening at times, it has been very educational for the engineering students to realize the shortcomings of a particular design theory when it is put to actual testing. The design process cannot stop without testing and retesting, sometimes resulting in a small or large redesign. In fact this is sometimes one of the most important lessons learned.

At times a project has needed to be redesigned and improved by a different team the following semester. These students adapt the accomplishments of the previous design and modeling results to improve a design. They learn that sometimes customers change (grow, for instance, in the case of the TDB projects) and thus devices need to be adaptable as well as immediately useable. And with redesign the engineering students learn why actual beta testing is a crucial part of engineering a successful project.

One more exciting outcome of the TDB projects is that the projects come with financial support. This means that the students get to control a budget and determine how to spend the money to produce the desired product. This means they can make material and part decisions that will directly affect the outcome of their designs. They can then travel to the store and find and purchase the required materials. This step in the design process was not experienced by the students prior to the start of the TDB projects. They usually used scrap material to complete their designs and thus the students were not as proud of their final products.
**Societal Impact Outcomes**

The National Academy of Engineering recognizes that societal concerns are not easy to address due to their complexity. However, they believe that engineers must learn to recognize the role of societal concerns on design and manufacturing and the role engineering may play in society. The engineering students supporting the TDB projects have the opportunity to directly view and participate in how their designs have an impact on a single child, a child’s family, or an entire classroom of children with special abilities. The engineering students who participate in these projects express that they are motivated by knowing that what they are designing is improving the life of a child or the lives of a number of children. They realize that engineers can have a significant role in helping make a portion of our population, which not too many years ago had to live in isolated communities, have independent and contributing lives. The 7.5 week long projects provide an opportunity for the students to quickly experience how engineering and engineering decisions can impact our society.

**Motivation Outcomes**

Each semester approximately half of the IED projects are supported by the TDB grant. The students who choose to participate on these projects understand they will have a real customer who requires a product at the end of the semester. They also understand they have a generous budget to complete the project. The instructors do not put pressure on the students to control their budgets or to ensure they have a physical deliverable. The instructors understand that 7.5 weeks is a very short period of time to turn a list of needs, objectives, and constraints into a successful product. Interestingly, 80% of the projects result in a delivered product. More interesting is that the students, if they are unable to complete the project to the customer’s satisfaction, continue to work on the project into the next semester even though they have successfully completed the IED course and obtained their grade. The students also initiate and maintain all contact with the customers, visit the customer at their home or school, and deliver the completed project.

Also interesting is that the students are motivated to responsibly manage the project budget. They find project sponsors who donate either material or services. These sponsors – family, friends, and co-workers – find the projects interesting and worthy of gift support.

**Conclusions**

As the TDB project enters the second half of its second year, it is apparent that the program is successful. The children of special needs and their families are being served with devices that help the children become more independent thus significant impacting their lives. In this endeavor the UTC freshmen engineering students are making an immediate change in the lives of a particular child or a group of children. The customer supported projects are also helping them learn about the design process and engineering’s impact on society. Using this model with a freshman level course helps set the stage for a reality grounded, practical curriculum to begin the students’ engineering careers.

In addition, several local community organizations, through public relations activities and presentations, have become more aware of the contributions and impact that engineers can have
on society. This has resulted in several local organizations requesting assistance from UTC’s engineering program for projects that directly affect their community. This has further emphasized to the IED students the role engineering can play with respect to societal issues.

However, a formal quantitative assessment of student outcomes has not been completed. A voluntary survey is being conducted on how well the students believe they meet the course learning objectives. But the sample size is presently too small. The course instructors are considering means to ensure higher participation in the assessment survey.

**Future Considerations**

It is UTC’s goal to enhance this program to support more service-based projects from the local community, therefore not limiting the successes to young children. The outstanding needs of a minority population with disabilities in our society can provide a fertile field for the UTC engineering program to promote the education of the engineering students as well as foster the abilities of a person with disabilities to be integrated within society. Present grant and new grant opportunities could offer that possibility by providing money to support a significant expansion of this project to include older children and adults with disabilities. The steps necessary for initiating these enhancements have begun.

**References**


