

Capstone Design and Rehabilitation Engineering: A Great Team

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Introduction

The Capstone Design course at the University of South Florida (USF) has evolved over the past several years into nearly an ideal course arrangement. Students progress from taking an idea that has the potential to help individuals with disabilities to designing and building a prototype. They learn the design processes, develop ways to be creative, cultivate teamwork skills, and ultimately benefit the community. The course, based on a 15-week semester, gives students the opportunity to work on 'real-world' problems in a structured amount of time. The time constraints imposed on the students mimic the deadlines that industries must meet.

The Design Process

The student design teams experience all phases of a design project. Many authors summarize these phases in this way: 1) select a project, 2) clarify goals, 3) develop different conceptual designs, 4) formulate the embodiment design, and 5) finalize the detail design. The student design teams select a project from a list or develop their own project. Projects are usually assigned by an instructor, or in industry, by a supervisor. The students must then take the project idea and clarify its goals. These goals are continually updated and allow the students to compare the project definition with the functioning of the final design or prototype. During the conceptual design phase, the student teams develop their creativity through readings and lectures. The design teams must come up with at least five different conceptual designs. Then the students evaluate these design options and select the design concept that will be developed into a prototype. After the final design is agreed upon, detailed drawings, the necessary parts that are needed, and a list of materials are developed. The drawings are submitted to the machine shop, which produces the parts. The student teams then assemble a working prototype. Each week the instructors meet with the teams, and the progress of the design process, technical aspects, and the team processes, are discussed.

Project Topics

Project ideas for the Capstone Design course come from many sources, such as the ASME Design Challenge, NASA, local start-up companies, industries, and students who identify specific needs of disabled family members or friends. Students proposed four of the twenty-one projects that were completed. However, the majority of the projects for this course are provided by the Center for Rehabilitation Engineering and Technology, which will be described later.

A brief description of the projects topics from the 2006-07 academic year follows:

Fall, 2006

Piano Pedals Activator: A veteran of Iraq returned as a paraplegic. He could no longer activate the piano pedals when he played. The student team designed and built a device to allow him to activate piano pedals using solenoids and a “puff and sip” sensor.

Desktop Organizer: Many people have limited reach, and cannot utilize the desktop effectively. Two teams created different desktop systems. One team developed a unique gripping device that extended the reach of the worker. The other team developed a very different concept that had a turntable with drawers to organize the desktop and make it easy for the user to retrieve items.

Ballet Chair: Mixed ability dance is very active on the USF campus, and the students designed and put together a seat that would allow the mixed ability dancers to move in more graceful ways than a wheelchair allows.

Bead Thrower: A wheelchair bound veteran likes parades, and in Florida, that includes beads. The veteran wanted to be able to “throw” beads to the crowd, rather than drive over in his powered wheelchair and hand the string of beads to a person. Two teams developed very different versions of the “Bead Thrower”.

Trolley Track Modification: Tampa has a trolley system. There are places where pedestrians cross tracks that are not wheelchair or stroller friendly because of large gaps that exist. The wheels get stuck in these gaps. Instead of a mechanical device, the students used a polymer to fill the gaps. The trolley wheels would compress the polymer but the wheelchair and strollers would roll over the top. This has not been implemented due to railroad rules and regulations.

Walker/Crutch: A local woman has patented a device that gives an active person more freedom than crutches allow. The designs developed by this team made the device more portable and much more convenient.

Portable Bath Chair: Bath chairs that are currently available are not portable because they do not fold. This team designed a lightweight chair that could be used for a shower or bath. Its portability made it easy to use when traveling.

Height Adjustable Wheelchair: This was developed to assist a family in transporting their handicapped son. Essentially, a wheelchair-like device was developed that could lower and raise from 8 inches to 33 inches to transport him from the living room floor to the car and then to school and back.

Spring, 2007

Seating for Segway: Two groups worked on seating for the Segway personal transportation device. The seat allows paraplegics to ride the Segway instead of using a wheelchair, which increases the personal mobility of these individuals.

Scuba Assistant: Student teams developed a device to help handicapped scuba divers into and out of the water. This had the potential to tremendously improve the quality of life of these divers, because underwater experiences are so beautiful and awe inspiring.

Boat Access: It is difficult for wheelchair bound people to board boats. Two teams developed quite different ways to afford access onto pleasure boats by people who are in wheelchairs.

Office Chair Brake: An individual has periodic spasms in her legs, and sometimes the office chair is pushed backward by the spasms. A brake system that kept the chair from moving and stopped the swivel motion was developed to help this office worker.

Wheelchair Height Adjustment: The father of a student is in a wheelchair, and he finds it inconvenient when he is not at the right height in restaurants, theaters, or even trying to reach something in the refrigerator. This team designed a mechanism for comfort and convenience of the user, which lowered the seat 5 inches and raised it 9 inches.

Pediatric Stander: Children with spina bifida need to “stand” to help strengthen their muscles and bones. This team developed a “stander” for children that was adjustable for the individual child and also allowed the child to move by using arm cranks. It was also foldable so it could be transported in a car trunk.

Ballet Chair: This semester the team developed a seat that acts like a joystick. When the person wanted to go forward, backward, left, or right, he or she would lean in that direction. The chair would respond accordingly.

Flight Simulator Mounting: A student works at a company that manufactures flight simulators. It is difficult to align the 800-pound brackets that attach the actuators that move the simulator to the simulator itself. This team developed a clever device to help position the mounting bracket on the simulator.

Solar Panel Orientation: This team developed a two-degree of freedom tracking mechanism to move solar panels to collect the maximum amount of energy. An electrical engineering student was also included on this team.

The Center for Rehabilitation Engineering and Technology

The Center for Rehabilitation Engineering and Technology is a national leader in research, education, product development and technology transfer integrated with service delivery for comprehensive Rehabilitation Engineering and Technology solutions. The Center is based at USF, and is funded by the state of Florida. It is unique in that it integrates potential services for disabled individuals with education, research, and development. Seven field engineers and six technicians travel throughout Florida to identify barriers of accessibility for individuals with disabilities. Some of these barriers that do not have existing commercial solutions are then referred to the Capstone Design course as projects for the students to select. These projects include devices for personal hygiene, wheelchair mobility, driving adaptations, recreation, and sports. They provide mechanical engineering students with a variety of problem-solving

situations, and potential solutions for helping disabled individuals improve the quality of their lives.

Mission Statement of the Center for Rehabilitation Engineering and Technology

To enable individuals with disabilities to achieve maximum potential across the lifespan through innovations in research, product development, education, technology transfer and dissemination in rehabilitation engineering and technology, resulting in independent living/community integration, better employment outcomes and improved quality of life.

Goals of the Center for Rehabilitation Engineering and Technology

Contribute new scientific and engineering knowledge and develop technologies to benefit individuals with disabilities. (*Research & Development*)

Strengthen graduate and undergraduate education in rehabilitation engineering and technology through interdisciplinary activities, access to facilities and industry partnerships. Provide continuing education opportunities for rehabilitation professionals. (*Education and Training*)

Provide technical assistance to agencies by developing standards, conducting assessments, recommending appropriate technologies and analyzing public policy. (*Service Delivery*)

Disseminate information on innovative methods of applying technology, scientific achievement, and psychological and social knowledge to facilitate technology transfer from research to practice. (*Dissemination and Technology Transfer*)

Target Population:

The following target populations have reduced functional capabilities of manipulation and mobility, and are dependent on attendant care for activities of daily living: developmental disabilities (cerebral palsy), progressive disabilities (multiple sclerosis, muscular dystrophy), traumatic injuries (spinal cord and head injury), aging population (Alzheimer's and mobility), and veterans returning from wars (amputees and poly-trauma injuries). Rehabilitation Engineering, and its ever-expanding technology, offers new opportunities for independence and improved quality of life for individuals in these target populations. USF's partnerships with industry, and the relationships with and access to the VA hospitals, rehabilitation facilities, and the disability community make it a unique and ideal location to bring this technology to fruition.

Program Resources:

The Center for Rehabilitation Engineering and Technology utilizes many resources to provide a variety of solutions to improve the life of disabled individuals. Some of these solutions are developed through the Capstone Design course, and others are developed within the Center.

There are the faculty, graduate and undergraduate students who work on projects. The disciplines that comprise this combined effort include engineering, physical therapy, rehabilitation and mental health counseling, visual and performing arts, and business.

The staff of the Center consists of seven engineers, six technicians and other support personnel. The staff personnel are located statewide.

The laboratories that the Center operates or has access to are the Rehabilitation Robotics Lab, Mobility and Adaptive Driving Lab, Motion Analysis Lab, Prosthetics and Orthotics Lab, and a CAD Lab. Other clinical facilities and laboratories that are available are at the VA hospital, the Shriners Hospital, and the newly established Orthotics and Prosthetics College in St. Petersburg.

The USF machine shop is staffed by three machinists and generates parts for the Capstone Design class and other Center projects. Rapid prototyping equipment is capable of producing models of the parts overnight. The Center for Rehabilitation Engineering and Technology provides the funding for the parts and materials necessary to construct the prototypes.

Industrial partnerships also add another dimension to the work at the Center. Some of the industrial partnerships are with companies at the USF Incubator and others are located throughout the state of Florida.

This combination of resources makes the Center for Rehabilitation Engineering and Technology uniquely capable of identifying and developing solutions to many of the barriers of accessibility for individuals with disabilities.

CAD

Many of the students have limited or no CAD experience, therefore, they are taught Pro-Engineer for eight weeks of the semester. This instruction provides the student teams with sufficient skills to complete their detail designs on Pro-Engineer or a similar CAD program. Those students who have experience with another CAD program can use whatever works best for them.

Part Production

Both the faculty and machine shop personnel collaborate with the student design teams on the manufacturability of the detail designs. The final parts are then either ordered through outside vending sources, or their descriptions are given to USF's engineering shop for them to make. After the shop completes its task, the student teams assemble all parts into their prototypes. Many of the prototypes are actually given to the disabled individuals with whom the design team worked to produce the product.

Project Costs

The projects do not have individual budgets, because each project is so very different. The students design their prototypes and then the faculty and students estimate the expected cost

involved in building them. If the projects are too large or expensive, scale models may be built to show “proof of concept”. The cost for each of the projects is shown below.

Fall, 2006

Piano Pedals Activator	\$1,419.41
Desktop Organizer	\$124.69 & \$325.49
Ballet Chair	\$1,207.62
Bead Thrower (Two Teams)	\$149.56 & 777.37
Trolley Track Modification	\$180.33
Walker/Crutch	\$232.80
Portable Bath Chair	\$109.75
Height Adjustable Wheelchair	\$278.00

Spring, 2007

Seating for Segway (Two Teams)	\$639.74 & \$381.26
Scuba Assistant	\$321.15
Boat Access	model constructed in machine shop
Office Chair Brake	\$1,712.72
Wheelchair Height Adjustment	\$196.85
Pediatric Stander	\$641.32
Ballet Chair	\$76.43
Flight Simulator Mounting	company supported the cost
Solar Panel Orientation	\$1,163.95

The expenses totaled \$4,805.00 for the fall semester and \$5,133.00 for the spring semester for a total of \$9,938.00. This relatively small amount reaps both tangible and intangible rewards.

Design “Guidemap”: The Class Notes

The class notes include chapters on the design processes, creativity, personality characteristics, teamwork, and the vocabulary of successful teams. These notes are authored by Don Dekker, PhD., and are updated versions of several papers he has written.

Creativity

For the design process to be effective, the students must be creative. It is extremely important to discuss creativity because students have seldom studied it and therefore may believe it is unimportant. They may be familiar with brainstorming as a way to elicit creativity, however, there are many other ways to teach students how to be creative. Edward deBono¹ and Doug Hall² both have written excellent books that provide a variety of techniques to enhance and to encourage creativity.

In the class notes, Dekker compares creativity to growing a garden:

<u>GARDEN</u>	=	<u>CREATIVITY</u>
Fertile Ground	=	Environment
Sunshine	=	Appropriate Language
Tools	=	Creative Enhancement Techniques
Weed and Spray	=	Quit Interfering with Natural Creativity
Water and Fertilizer	=	Develop a Creative Attitude

Each “gardening”/“creative activity” is described in detail in the notes. This is an effective analogy, because everyone can relate to gardening and how plants grow and survive.

Personality Characteristics

The Myers-Briggs Type Indicator and the Herrmann Brain Dominance Instrument are both discussed in the Capstone Design course. They show students that each individual brings different strengths to the design team. Some students find it easy to be creative, but may find it difficult to meet deadlines and plan. Others may find it difficult to be creative, but find planning and decision making easy. These results help the students understand their team’s personality characteristics, creative abilities, management strengths and weaknesses, and their skill at working as team members. The students all know their MBTI types, so they can observe how they work together and, ultimately, learn to work better and smarter.

Teamwork

A very important part of a successful design project is the ability for students to be able to work effectively as a team. A section in the class notes discusses teamwork and the characteristics of high-performing teams. Another section addresses the “vocabulary” of teambuilding, since students are unable to discuss teamwork without the necessary words. During the semester the students also are asked to use the teambuilding vocabulary that was introduced to comment on the interpersonal characteristics of their design team.

In addition, during the fourth week, the students are asked to distribute a hypothetical monetary bonus of \$1,000.00 among the team members. If students receive no money, it is apparent they are probably not contributing to the project.

During the eighth week, a team survey form, adapted from Parker³ for student use, is completed. The survey asks how the teams are doing in 12 areas that are important for teams to perform well. These areas are: 1) Clear Purpose, 2) Informality, 3) Participation, 4) Listening, 5) Civilized Disagreement, 6) Consensus Decisions, 7) Open Communication, 8) Clear Roles and Work Assignments, 9) Shared Leadership, 10) External Relations, 11) Style Diversity, and 12) Self-Assessment. This questionnaire helps the students learn the various areas that are important when working in teams.

By doing different team evaluations throughout the course, the instructors have a chance to be proactive in helping the teams succeed, instead of merely giving the students the opportunity to “vent” at the end of the course.

The students complete a final team evaluation questionnaire during the last week of class. This questionnaire is a combination of the previous two, so they will have to evaluate each individual's performance during the semester.

Managing The Design Process

When students are left on their own with a design project, often they will focus only on producing the product. We, as teachers, want them to be able to transfer their experiences to the next project, and ultimately, to be able to be successful in industry. Therefore, we must not only teach them about the design processes, but also help them learn how to “manage” a design project through self-evaluation and check lists. The check lists that Hales & Gooch⁴ present have been modified and are used in the course to have the students evaluate how the team performed in each aspect of the design process.

Additional Topics

Both local and national guest speakers address the class and enlighten them on a variety of topics. Class time is spent discussing ethics, patents and licensing, entrepreneurship, designing for the handicapped, living with a handicap, designing for manufacturing, social impact and professionalism. Since most of the students are in their senior year, we also include the Career Center in these presentations to discuss resume writing and interviewing skills.

Capstone Continuity

Capstone Design at USF has a support structure in place because the Center for Rehabilitation Engineering and Technology is an integral part of the course. In addition to the monetary support for the prototypes, the Rehabilitation Program provides contact with and scheduling of the guest speakers. They also have contacts in industry and hospitals that provide information the student teams may need, and local machine shops to provide hardware when necessary. Since the Rehabilitation Program is statewide, contacts throughout Florida are available to assist these students.

At USF, there are two instructors who are involved with the Capstone Design course. One has many contacts in the community and the state, and possesses specialized rehabilitation knowledge. The other knows about design, creativity, teamwork, student teams, and getting the students excited about the projects. It is a synergistic situation to have two instructors working together.

Conclusion

Many of the prototypes are given to the disabled individuals with whom the design team worked to produce the product. Therefore, the financial support of the Center for Rehabilitation Engineering and Technology to build the prototypes is a crucial and integral part of the Capstone Design class. The USF Capstone Design course and the Center for Rehabilitation Engineering and Technology combine to make it possible for USF students to experience a complete design process that culminates with a professional presentation, a final written report, and, most

importantly, a working prototype. The relationship with the Center insures the stability of Capstone Design at USF, making it possible, if necessary, for a different professor to step in and teach the class. The students derive a great deal of satisfaction from working on these rehabilitation projects, and the recipients of the prototypes are excited and grateful. Student interest and commitment exceed normal expectations when the rehabilitation projects are used in the Capstone Design course.

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