Integrating Rehabilitation Engineering into the Mechanical Engineering Capstone Design Course at the University of South Florida

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Capstone Design is one of the most important courses in the engineering curriculum. One of the more difficult things to do is to get the students really involved in the course. They are used to the lecture courses, where they take passively take notes and study for the tests. The Capstone Design experience at USF tries to provide the student teams with guidance, encourages them to work together as a team and design and produce a working prototype. To broaden the student's experiences, there are lectures about the design processes, creativity, teamwork, and other aspects of the design process. In addition, there are lectures by eight guests about several interesting topics to broaden the student's experiences. Working on designing and building a working prototype has been a wonderful for the ME graduates and prepares them for working in industry or academia.

Keywords: Capstone, Design, Rehabilitation, Prototypes

At Rose-Hulman Institute of Technology, Dr. J. Darrell Gibson taught the M.E. Capstone Design course. He scoured the area for industrial projects, academic projects and "rehab" projects. He used to say that the students who worked on projects that helped a child, always had a special interest in the project and the course.

For over 15 years, the Capstone Design Course at the University of South Florida has used rehabilitation projects as an integral part of the Capstone Design course. This is made possible through the cooperation between the Mechanical Engineering Department and CARRT, The Center for Rehabilitation and Robotic Engineering and Technology. CARRT is funded by the State of Florida, and has 15 employees in seven locations around Florida. There is an Engineer and a Technician at each location. They help people, who have a restriction or disability to return to work using commercially available technologies. Some individuals need special devices to help them. The CARRT engineers identify possible project ideas that have been collected throughout the State. These projects improve the quality of life and/or the work life of disabled people who need assistance, or who have dreams that they have not realized. Student teams may also develop their own project ideas. CARRT was described in detail at the 2007 Boulder Conference on Capstone Design[1], and at the 2012 ASEE Annual Conference[2]

The Rehabilitation Act of 1973 defines rehabilitation engineering as "the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities in functional areas, such as mobility, communications, hearing, vision, and cognition, and in activities associated with employment, independent living, education, and integration into the community."

At USF, the Pahl and Beitz[3] outline is used both to teach the students about the design processes, and to provide structure thorough out the semester. Although Pahl and Beitz do not include prototypes, commercialization, or production as part of their design methodology, the USF experience has shown that constructing a prototype is an excellent student activity that brings closure to their design process.

Pahl & Beitz Design Process

Select a "Need"
- Clarify the Task
- Specifications
- Requirements

Conceptual Design
- Establish Function Structures
- Search for Solution Principles
- Combine and Firm up Combinations
- Evaluate against technical and economic criteria

Embodiment Design
- Preliminary Layout
- Optimize form designs
- Check for cost effectiveness
- Prepare preliminary parts list

Detail Design
- Definitive layout & drawings
- Documentation & final parts list
- Solution

Listed below are necessary phases a student team must complete in order to develop a "need" into a working prototype. This more detailed version of this is necessary to guide the student teams through the design-build process. This schedule has evolved over several years. And yes, the course is a one semester course at USF. Although many Universities offer year long Capstone Design courses, the one semester course offers the students a taste of what industry will expect when they graduate, "work fast and effectively".

Capstone Design at USF-Team Activities

Activity	**Weeks**
1. Recognize a need	1-2
2. Commit to the project	1-2
3. Define and the project scope	2-3
4. Search for 5 to 10 alternatives	3-5
5. Select the "best" alternative	5-7
6. Continue to develop ideas in Solidworks	6-8
7. Continue to design in Solidworks and begin a bill of materials	7-9
8. Make final detail drawings & BOM	9-10
9. Order commercially available parts	9-11
10. Take drawings to the shop for parts to be machined	9-12
11. Assemble the prototype or other "proof of concept."	11-15
12. Present the project results orally as a team.	14
13. Write and submit a formal written report	15

The co-instructors think it is best to give the students an idea, not a well-defined problem. During their educational experience they have already solved many well-defined problems. It is always desirable to have the students commit to the project. When they have the opportunity to select a project that interests them, they are more committed. It often happens that students are more committed to the rehabilitation projects because they really like helping someone. It is important for students to learn to develop a loosely defined "need" into a problem definition that includes specifications. It is difficult to get the students to quantify the specifications, but this is an essential part of the process. As the student teams learn more about their topics, they improve their problem definitions and specifications. They are encouraged to upgrade these definitions on a weekly basis. The teams meet with the instructors for about 15 minutes every week. The instructors provide guidance and help the student teams.

The team members should learn some creative skills and apply them to develop 5 to 10 different conceptual designs. Each of these different concepts might possibly work. Often it is difficult to get the teams to do this because there is a very human tendency to take the first idea and "run with it." This ineffective technique will usually produce poor products, because the best solution is seldom thought of first. It is important that our students learn the creative skills to produce many new ideas.

The student teams are given a simple "House of Quality" decision matrix to help select the top one or two contenders from their conceptual designs. It is not acceptable for them to merely state, "we feel this is best." These decisions must be quantified.

Many universities have the students make the parts in a student shop. At this time USF does not have a student shop. USF does, however, have a lot of rapid prototyping machines available to the student teams at no or minimal cost. Rapid prototyping has many advantages in the early stages of the design process, because the teams can build "models" early in the design process and see how a new concept works or how it can be improved.

Formal oral presentations of their projects are required. Everyone must participate in the presentation, and they are expected to dress in business attire and to use Power Point. Often guests and recipients of their products are in attendance. Overall, the students are very professional. The presentations are given during the 14th week of the semester.

The final, formal design report follows the ASME guidelines for professional paper writing. The team

reports range from 20-50 pages in length, and support the final design with documentation. Some students have used these reports during job interviews to show what they are capable of producing.

Most student teams experience the entire design process, from conception to prototype during the 15 week semester. They teams are excited and satisfied with the results of their design process through prototyping. Examples of some of the past projects are shown.

Two projects will be discussed here. They are the Piano Pedal Actuator and the Dance Chair.

The Piano Pedal Actuator
This project was completed for a veteran who had lost the use of his legs. He is also a concert level piano player, however, if you cannot operate the pedals. The student team designed and constructed the actuator using solenoids that are actuated with a "puff-and-sip" actuator. The user was very happy with the output and recently wondered if a team could upgrade his device or construct a new one because electronics have become so commonplace in the last 10 years.

The Dance Chair
The Dance Chair was a collaboration with the School of Dance at USF. They wanted a device so a person who had lost use of their legs could still perform. The Capstone students decided to make the seat act as the joystick. This was a novel way to guide a wheelchair. They developed their own method to control the direction by the position of the seat. If you lean forward, the chair moves forward. If you lean forward and to the right, that is where the chair goes. This was a novel approach and did receive a patent. The Dance chair went through several modifications and actually performed at the Smithsonian Institution.

Figure 1. Piano Pedal Actuator

Figure 2. Dance Chair

References:

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