AC 2008-2013: CAPSTONE DESIGN COURSES: CONTENT RECOGNITION

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Capstone Design Courses: Content Recognition

Introduction:

The Capstone Design course at The University of South Florida brings realistic design experiences into the academic environment. The course is completed in each of the two 15 week semesters. The students do all of the design phases: define the project, conceptual design, embodiment design and detail design, plus other experiences, such as report writing, making drawings, and presentation skills. In addition, the students read and discuss two engineering ethics case studies, are instructed in Pro-Engineer, and have lectures on several pertinent topics, such as patents and licensing, entrepreneurship, professionalism, and safety. The course instructors give some lectures, and guest speakers give others.

The content of Capstone Design courses can be categorized into the "Design Content," "Other Activities and Lectures," and "Life After Capstone." It should be made clear that there are many different approaches to take when a professor teaches a Capstone course or develops the Capstone experience for his/her students. These different approaches will depend upon the education and experience of the instructors, and the resources of the academic department. This paper is based on our experiences at The University of South Florida.

The Capstone Design course works with the Center for Rehabilitation Engineering and Technology. The Center, which is partially funded by the State of Florida, identifies 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. The Center for Rehabilitation Engineering and Technology was described in detail at the First Conference on Capstone Design.[1]

During the 2006-07 academic year there were 21 student teams that served about 100-120 students per year; two sections each in the fall and spring semesters. The total cost for their prototypes, including parts, machining, and materials, was approximately $10,000. During the 2007-08 academic year, there were 22 projects; their total cost will be known after the semester is completed. The monetary support from the Center for Rehabilitation Engineering and Technology allows the construction of these student prototypes, and the wrap-up of the student design experience. The 2006-2007 projects were described at the 2007 ASEE Annual Conference and Exposition.[2]

Some of the designs and student experiences continue beyond graduation. The University Patent Office handles the intellectual property of the Capstone teams. Several of the projects have been patented over the years. The Center has recently formed a company to commercialize these products. Currently three projects, which have received patents, are being commercialized, and some of the students have received their first royalty checks. This is a great postscript to an exciting Capstone Design experience. Another after graduation experience occurred when a student brought a company project back for the Capstone class to consider.

Design Content:

The design content follows the Pahl and Beitz[3] outline. Although Pahl and Beitz do not include prototypes, commercialization, or production in their design methodology, experience has shown that constructing a prototype is an excellent student activity that brings closure to their design process. Listed below are necessary phases a student team must complete in order to develop a "need" into a working prototype:

1. Recognize a need that the team wants to address.
2. Commit to the project.
3. Define and keep redefining the project scope including specifications.
4. Search for alternatives -- conceptual design.
5. Select the "best" alternative.
6. Elaborate on the concepts -- embodiment design.
7. Make drawings -- detail design.
8. Order commercially available parts.
9. Take drawings to the shop to be machined.
10. Assemble the prototype or other "proof of concept."
11. Present the project results orally as a team.
12. Write and submit a final written report.

The co-instructors think it is best to give the students an idea, not a well-defined problem, since during their educational experience they have already solved multiple 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 team members must 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 students usually use a "House of Quality" decision matrix or some other quantifiable method to 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.

In the embodiment design phase the students look at form, orientation, clearance, kinematics and dynamics, and heat transfer. They make sure their designs meet all the constraints. That is, they show that their designs will, in fact, work.

The students then enter the detail design phase. How much force? What diameter rod? What size bearings? What material? These are but a few of the myriad detail design questions that must be answered. The teams first discuss their drawings with the instructors and the machine shop personnel, then make changes to the drawings, and finally submit their drawings to the machine shop. The commercial parts are ordered through the Center for Rehabilitation Engineering and Technology. This does cost money, but it represents the "real world" of prototype production.

An alternative is to have the students make the parts in a student shop. This can be a worthwhile experience, because it teaches the students to use the equipment. However, there are some questions relating to liability if a student would be injured. Another difficulty is that one team may have students with machine operating skills, and another team may have little or no machining and fabrication skills.

When the design includes commercially available parts, they must be ordered so they can be included in the prototype. The students contact the supplier and determine cost, suitability, and availability. In short, they act as purchasing agents. This information is then given to the Center for Rehabilitation Engineering and Technology, and the Center orders, receives, and distributes the parts to the student teams.

The prototype is then assembled from the commercially ordered materials and the parts from the machine shop. The student teams derive a great deal of satisfaction doing this. They see whether or not the prototype works as designed. Often they have to make some modifications to achieve success. This is a satisfying ending to the design process for the student teams.

The student teams make formal oral presentations of their projects. 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 convincing and professional. The presentations are given during the 14th week of the semester, because the instructors think that having the presentation, the final written report, and the prototype all due during the last week puts to much stress on the students. The presentation is the only one that can be moved forward.

The final, formal design report follows the ASME guidelines for professional paper writing. The team reports range from 20-40 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.

It is necessary to go through all twelve phases of "Design Content" if the student team begins with a "need" and ends with a prototype. Some courses may not include some of these phases. For example, if a course ends its designs with a presentation and a written report, then commercial parts will not be ordered, taking drawings to the machine shop will not be done, and prototype will not be assembled. Other courses may have specific projects to work on, such as "Design a Recreational Center on a Specified Location." Then the students would not have to recognize the need, and they won't have to define the problem.

This "design content" list can be used to compare the content of Capstone Design courses at different colleges, or used by the instructor to develop and improve an existing course.

Other Activities and Lectures:

This listing is slightly different from the first one because some of these are student activities, while others are course lectures that are given to introduce the student to new topics or to reinforce and expand on topics.

Other Activities:

1. Ethics
2. 3-D CAD Program: Pro-Engineer, Solidworks, or Catia
3. Teamwork Skills

Lectures:

4. Resumes and Interviewing
5. Entrepreneurship
6. Patents and Licensing
7. Professionalism
8. Tolerances and Dimensions
9. Design for Safety
10. Design for "X"

According to ABET, ethics is an important part of a student's education. How we introduce our students to engineering ethics is left to the department. This ethics instruction can either be by a series of lectures or it can be structured as a student activity. At USF the students learn about engineering ethics through the use of case studies. The procedures for these case studies are listed below.

The first ethics case is the Space Shuttle Challenger Disaster. This is a case study written at Texas A & M by the Department of Mechanical Engineering and the Department of Philosophy. The assignment includes both individual activity and team activities as shown below:

1. Read the Challenger Case study. (individual)
2. Write a one-page summary of your thoughts on the Space Shuttle Challenger Disaster. (individual)
3. Discuss the case as a team. Write a one-page "Team Summary" of the team's conclusions. (team)
   (These individual and team activities should prepare the students to participate in the class discussion of the case study.)
4. Discuss the case in class. During the class discussion of the case, add handwritten notes to your individual summary about things you hadn't thought of before.
5. Staple the individual summaries to the team summary and submit as a team at the end of the discussion session.

The second ethics case follows a similar format and process, but each student team studies a different case. The instructor approves these cases, so there will be no duplications.

Additionally, each group reads a different case and then makes a 6-8 minute presentation, discussion, and team conclusions of their topic.

An article about a portable baby crib describes several tragic child deaths due to a faulty design. This can be used as one of the case studies. Other case studies may be found at the following web site. http://ethics.tamu.edu/pritchar/an-intro.htm.

Knowledge of a 3-D CAD program is becoming essential for a successful interview. There are eight hands-on lectures on Pro-Engineer. After this instruction, students can make drawings that can be sent electronically to the machine shop. The shop has the software to interpret the Pro-E drawings and convert them to the machine instructions. This saves time on both ends. The students also can make animations of their designs. They will sometimes use these animations as their "proof of concept." These drawings can be used to produce parts on a rapid prototyping machine.

When students are working on teams, they most likely do not learn teamwork skills on their own. This is because they have not been instructed in these skills. During the semester, the students are required to read articles about teamwork. The readings discuss Glenn Parker's[4] teamwork skills and abilities, Glenn Varney's[5] teams, and Tuckman's[6] phases of team development. During week 5, they are asked to complete a questionnaire based on Parker's teamwork skills. During week 10 they evaluate the team based on Varney's teamwork skills. The combination of the readings and the questionnaires provides the students with the vocabulary and experience to discuss team activities and to improve team interactions. This knowledge will be invaluable when they are employed.

Various lecture topics provide the students and student teams with useful information. All of them will not be discussed here because they can be changed easily, depending upon the college. In addition, different instructors will emphasize different topics, and this is where the professor can individualize the course. Included topics will depend upon the experience and education of the instructor.

The student teams are very interested in entrepreneurship, since many of the teams believe their project has produced a viable product. A speaker from the USF School of Business talks about entrepreneurship and what is involved in developing a product.

Patents and licensing are important topics at USF, because many of the student projects are patented. The Patents and Licensing Office obtains patents on promising projects. The University receives 55% of any profits, and the members of the student team receive 45% of the profits. This is a generous division of the rewards for the student teams, since they don't have to pay for obtaining a patent.

The owner of Tampa Brass and Aluminum discusses professionalism with the students. He emphasizes how important it is to behave ethically and professionally in business.

Usually, the students have not studied dimensions and tolerances since they were freshmen in college. Most of this information has not been kept up to date in their skill set, so they need a review of dimensions and tolerances.

Of course, safety is a very important consideration whenever a product is designed. When the public is involved, safety is paramount. Design for "X" is a term that refers to the many specifications that we need to design for when a product is produced. Manufacturing, and cost, are two of the very important "Xs" whenever a product is being designed. However, others, like "lightweight", might be used when designing aircraft.

Life after Capstone:

The Capstone Design experience can continue to be a part of the student's life after he/she graduates. Capstone is normally thought of as a "terminal" experience for the students in the university. It is very unusual for courses to have any relevance after graduation. A few of the ways Capstone can continue are discussed below:

1. Student designs are patented.
2. Designs are further developed for production.
3. Students receive royalty checks.
4. Capstone comes full circle when graduates suggest new ideas for projects.

Many of the designs from Capstone have been patented. The Office of Patents and Licensing gives a lecture to the class. Although all of the student teams are encouraged, some with very promising designs are urged to discuss them with the Office. Filing the team's formal report as a provisional patent application is usually the first step. This buys time until the patent application can be filed.

The Center for Rehabilitation Engineering and Technology may further refine a design to prepare it for production. Sometimes the Capstone students in Industrial Engineering will refine and improve the Mechanical Engineering prototypes and designs for production. Other students may continue working on the project through a special topics course or even an MS thesis.

Occasionally the students who develop these new designs and products form a new company. However, this is unlikely, since recent graduates most often do not have the money and time to accomplish this.

A University "incubator" that nurtures start-up companies might help the student teams develop their designs.

The Center for Rehabilitation Engineering and Technology is taking a different approach. The Center has recently formed a company to develop rehabilitation products. This company, Rehab-IDEAS (Institute for the Development of Engineering and Assistive Solutions), is currently commercializing three of the patented designs from the M.E. Capstone Design course.

One product is a beach and rough terrain platform that allows a person in a power wheelchair to explore rough terrain. See Figure 1.

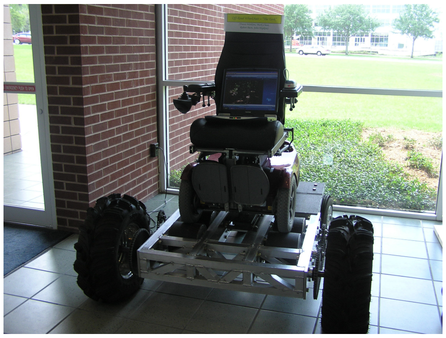

Figure 1. Beach and Rough Terrain Wheelchair Platform

Another design being developed is a mechanism that takes a backpack or briefcase from the side of a power wheelchair to the back of the chair. See figures 2 and 3. This is helpful, because when the backpack is on the side of the chair, it cannot fit through doorways.

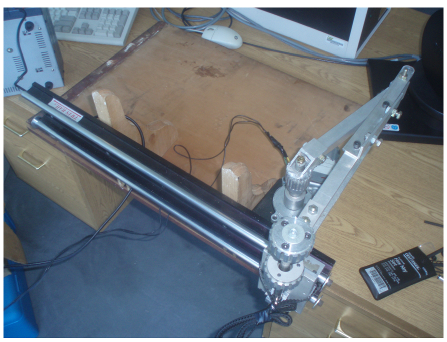

Figure 2. Backpack or Briefcase Mechanism

Figure 3. Backpack or Briefcase on Powered Wheelchair

The third device is a folding writing table for wheelchairs. This makes it much easier for students in wheelchairs to take notes and to eat lunch.

Rehab-IDEAS obtains start-up financing, and because of this, some of the students have received royalty checks for their products. Rehab-IDEAS also is a source of employment by members of the student teams, and other students may be employed as well to work on developing the products.

Graduates can suggest new ideas that are used for Capstone Design projects. This is a very different way that Capstone Design continues to be a part of a graduate's life. This fall, one of our recent graduates brought us an industrial project that required the student team to develop a "robot" to go into a pipeline for 300 feet and determine the condition of it. This is a "closing the loop" experience for both the graduate and the class.

Conclusions:

Teaming with the Center for Rehabilitation Engineering and Technology is a synergistic combination that improves the Capstone Design course because it brings stability and additional knowledge to it. The course consists of three essential and intertwined parts: (1) The Design Processes, (2) Other Activities and Lectures, and (3) Life after Graduation. When these three parts of the course are optimal, the course then provides the senior mechanical engineering students with a Capstone Design experience that gives them an accurate and exciting introduction to design processes and product development.

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