AC 2008-426: IT TAKES TWO TO TEACH CAPSTONE DESIGN

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Don Dekker is currently an Adjunct Professor of Mechanical Engineering at the University of South Florida. He is currently teaching three of his favorite courses Mechanical Engineering Laboratory I, Internal Combustion Engines, and Capstone Design. Before his retirement in 2001, Don taught at Rose-Hulman Institute of Technology. He first joined ASEE in 1974 and some of his ASEE activities include Zone II Chairman (86-88), Chairman of DEED (89-90), and General Chair of FIE '87. His degrees are: PhD, Stanford University, 1973; MSME, University of New Mexico, 1963; and BSME, Rose Polytechnic Institute, 1961. He became a Fellow of ASEE in 2007.

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Mr. Stephen Sundarrao is the Associate Director of the Rehabilitation Engineering and Technology Program at USF. His undergraduate and graduate education are in Mechanical Engineering and he has 15 years experience as a rehabilitation engineer and nearly 10 years experience managing a statewide program. He is certified by RESNA as an Assistive Technology Practitioner and Rehabilitation Engineer. He is currently on the Board of Directors of the National Mobility Equipment Dealers Association (NMEDA) and the Florida Department of Health's Disability Taskforce on Bioterrorism. He currently teaches the Capstone Design Course that develops 20-25 new innovative technologies for individuals with disabilities annually. His research interests include advanced vehicle modifications, ergonomics and mobility devices for individuals with disabilities. He recently received the Presidential Award from NMEDA and an award from the University of Miami for Course Development and Recruitment for their online training in AT. He is actively involved with the State VR program to develop policy and training for better integration of RT Services. He was recently appointed to the Advisory Board for the University of Michigan Transportation Research Institute RERC.

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Dr. Rajiv V. Dubey is the chair of the Mechanical Engineering Department in the College of Engineering at USF. He is also the PI and Director of the Rehabilitation Engineering and Technology Program. He received his Masters and Doctorate degrees in Mechanical Engineering from Clemson University. His research background includes Design, simulation and testing of haptic interfaces and assistive devices for persons with disabilities. His publications include rehabilitation engineering and robotic/telerobotic applications in healthcare. He has served on several review panels for the National Science Foundation and was the editor of the IEEE Journal on Robotics and Automation until 1997.

He has been distinguished by awards that include Favorite Professor in the College of Engineering Award from the Student Teacher Education Association, the University of Tennessee, Knoxville, 1987; National Science Foundation Research Initiation Award, July 1989; B. Ray Thompsan Professorship Award, University of Tennessee, 1998. He was recently honored as an ASME Fellow

It Takes Two To Teach Capstone Design

Introduction:

The Capstone Design course at The University of South Florids is a wonderful example of how two heads are better than one. In fact, two people are *necessary* to operate a Capstone Design course. Directing the student teams, grading tests and papers, and preparing discussions in a Capstone Design course is a full course load. In addition to these usual responsibilities, the instructor for a Capstone Design course is often required to visit industry and non-profit organizations to find the projects for students to develop. It seems commonplace for academic institutions to expect this extra effort from Capstone Design teachers, but this is unrealistic. Capstone Design is a wonderful course to teach because of the mature, motivated students and the exciting projects, but it shouldn't be a time-consuming backbreaker for the instructor.

Course Logistics:

The Capstone Design course is a one semester, 15 week class, which is organized into two sections of 25 to 30 students. This scheduling allows 100 to 120 seniors to take Capstone Design each year. The instructor of this course works with the Center for Rehabilitation Engineering and Technology, and the Center supplies suggestions for the projects. The Center suggests projects that they have collected throughout the State of Florida to improve the quality of life and/or the work life of people who need assistance or have some dreams that have not been realized. The student teams can also develop a project topic from their own ideas.

During the 2006-07 academic year there were 21 teams, and the total cost for parts, machining, and materials for their projects was approximately $10,000. The co-instructor from the Center for Rehabilitation Engineering and Technology has the industrial contacts to schedule guest speakers, the expertise to give some lectures, and the authority to approve the monetary expenditures for the parts and equipment from the budget of the Center. He also has excellent contacts and invaluable expertise in the rehabilitation industry. These projects were described at the 2007 ASEE Annual Conference and Exposition.[1]

Team Activities:

The student teams need to work together and develop teamwork skills to do the required parts of the engineering design processes. The teams begin by selecting a topic, then they clarify their project definition, including specifications. Next, the teams search for different concepts, evaluate the concepts, select a concept, bring the design to form during the embodiment design phase, detail the design, and draw the parts. The design is taken to the machine shop, where the parts are found, specifically made, or ordered, and then the prototype is assembled. Of course, they must also write a report and make a professional presentation. All of this is completed in a fifteen-week semester. The students also they submit individual assignments, learn to work as a team, develop their design, and learn about the engineering design processes.

The following list summarizes the activities of a typical student team:

List of Team Activities

1. Select a "need."
2. Commit to the project.
3. Define the problem, complete with specifications.
4. Come up with 5 to 10 different conceptual solutions to the problem.
5. Select the best one or two concepts, using a decision matrix.
6. Elaborate on the design in the embodiment phase.
7. Complete the analyses and make drawings in the detail design phase.
8. Take the drawings to the machine shop.
9. Create a parts list and order parts through the Center.
10. Assemble the prototype, or Proof of Concept (Computer Model).
11. Orally present the project results as a team.
12. Write and submit a formal written report.

The prototype and the written report are each worth 25% of the grade, and the formal oral presentation is worth 15%.

Team Meetings:

The student teams receive help and direction in going through the design processes. Each week, every team meets with the two instructors to discuss their activities and progress. Each team must have a progress report which records what each team member did last week and what each team member expects to do during the next week. Some faculty might call this "guided design." It is definitely not a "sink or swim" technique the faculty use for teaching about the design processes.

Each week at the team meetings we try to ensure that the team does not fall behind. Listed below are the checkpoints the teams should be trying to reach each week. Since this is the laboratory portion of the course, there are some other items listed, like the Oral Presentations during the 14^{th} week of the semester.

Week	Checks:
1.	Form Teams, MBTI, Select Need
2.	Finalize Project Selection
3.	Conceptual Design Sketches
4.	More Detailed Design Sketches
5.	First Pro-E Drawings
6.	Presentation for Design Review
7.	Pro-E Drawings
8.	Review Drawings with Machine Shop
9.	Submit Drawings to Machine Shop
10.	Check with Machine Shop
11.	Pro-E Proficiency Exam
12.	Assemble – Get Materials
13.	Assemble – Get Materials
14.	Oral Presentations

15. Finish Report and Prototype and Submit

Individual Activities:

The students are individually required to write a one-page report in memo format (to, from, date, re) on each of the following readings or activities listed below. The students are asked to write about their **reaction** to the articles or sections, rather than summarize the material. These summaries in total are 25 percent of the course grade. Each memo is worth about 2 percentage points of the student's grade. The "Guidemap" is a collection of articles, written by the lead author, that have been revised to fit together in this booklet about design. The other articles have been collected from various sources and are applicable to design. This entire set of notes is available to the students either electronically on Blackboard or from Pro-Copy in a booklet format.

Reading & Writing Assignments:

"Guidemap"

1. Preface, Ch 1: Introduction, & Ch 2:Engineering Design Processes & Problem Solving Processes
2. Ch 3: Creativity and the Design Processes & Ch 4: Creativity in ALL of the Engineering Design Processes
3. Ch 5: Thinking Preferences and the Engineering Design Processes & Ch 6: Teambuilding Skills

"Articles"

4. "Ten Critical Factors in the Design Process" by: Crispin Hales, Hales & Gooch, Inc.
5. "MIS Project Teams: An Investigation of Cognitive Style Implications" by Kathy Brittain White, Univ. of North Carolina
6. "A Wheel Chair can be Fun: A Case of Emotion-driven Design" by Pieter Desmet & Eva Dijkhuis, Delft University of Technology
7. "Psychosocial aspects of scuba diving for people with physical disabilities: An occupational science perspective" by Cail Carin-Levy & Derek Jones, Queen Margaret University College

"Ethics"

8. Ethics Case 1: The Space Shuttle Challenger Disaster (Texas A&M)
9. Ethics Case 2: Choose different ethical dilemmas from the website: http://ethics.tamu.edu/pritchar/an-intro.htm

"Teamwork"

10. Team Performance Evaluation (Varney[3])
11. Team Performance Evaluation (Parker[4])
12. Final Team Performance

"Presentation"

13. Presentation Critique (View the DVD, and write a one-page critique.)

Pro-Engineer:

During the semester, the students have nine weeks of instruction in Pro-Engineer. They have not had any instruction in a CAD program except AutoCad when they were freshmen, so it is helpful when they interview for a job to have some knowledge of a CAD program. It also gives them the tools to model their design and submit drawings in Pro-E to the machine shop. These drawings can be electronically transformed into machine instructions. The instruction is done during the lecture period once a week for each section. One section receives Pro-E instruction and the other has the faculty lecture. The faculty gives each lecture twice to make this work. There is a Pro-E proficiency test, which is worth 10% of the student's final grade. A TA teaches the Pro-E portion of the course. The TA also makes up the proficiency test and evaluates the student's performance. If students are skillful with another CAD program, they may take the proficiency exam using another program.

Lectures:

There are really three kinds of lectures and activities that occur during the semester. Sometimes the entire class meets during the lecture period. Most of these periods have a guest lecturer, so the entire class meets together. The schedule of these lectures is shown below.

Week		Topic
1	Tuesday	Introduction, Course Outline, & Creativity, Course Instructor
1	Thursday	Design Synthesis and Design Methodology, Course Instructor
2	Tuesday	Product Evolution, Course Instructor
2	Thursday	Career Center, Ms Dianne Russell
12	Tuesday	Professionalism, Tampa Brass & Aluminum, Chris Leto & Paul Reshi
12	Thursday	Entrepreneurship, Dr. Michael Fountain
13	Tuesday	TRIZ – Creativity, Mr. Jack Hipple
13	Thursday	Patents & Licensing, Mrs. Valerie McDevitt

Other lectures are given twice each week to accommodate the Pro-Engineer instruction. These are given by the course instructors (CI 1 from academia), (CI 2 from the Center for Rehabilitation Engineering and Technology) and are listed below:

Week	Topic
3	Human Factors (CI 2)
4	Teamwork & Project Management (CI 1 & CI 2)
6	Tolerances, Fabrication, & Tools (CI 1)
8	Product Safety & Liability (CI 2)
10	Product Testing & Evaluation (CI 2)
11	Evaluating Cost & Mass Production (CI 2)

There are discussions or trips that occur during the semester, and these are shown below.

Week	Topic
5	Visit the Machine Shop (Trip)
7	Engineering Ethics Discussion 1, Challenger Case (Discussion)
9	Engineering Ethics Discussion 2, Other Cases (Discussion & Presentation)
14	Formal Student Presentations (Team)
15	Wrap-Up, Course Evaluations, Submit Report, Critiques, and Prototype (Team)

It can be seen that all of the lectures relate directly to the design process that the student teams are experiencing.

Center for Rehabilitation Engineering and Technology:

The uniqueness of the course is the active collaboration of academia with the Center for Rehabilitation Engineering and Technology, industry, Colleges of Health, Business, and Arts and Sciences. This provides the students with a real world product realization process. Without the support of the Center, the Capstone Design course would become a much more academic exercise for the students. The Associate Director of the Center is the key person actively involved in the design process, who provides this collaboration. The areas of support that the Center brings to Capstone Design are listed below. The Center has been described elsewhere.[2]

1. Develop a list of "Needs" from community partners, state institutions serving individuals with disabilities and field engineers of the Center.
2. Fund materials, machining labor and purchase commercial parts to build prototypes which demonstrate proof of concept.
3. Lecture on rehabilitation engineering and applied design topics
4. Share companies and other resources for obtaining parts and components during team meetings
5. Contribute manufacturing and fabrication experience to the team meetings
6. Provide contacts in the community to develop problem statement and identify partners
7. Provide laboratory space for students to work
8. Enhance the learning experience since the project is a solution to a real-world problem. The "need" is not made-up.

The items on this list will be discussed in the following paragraphs.

This collaboration provides continuity to the Capstone Design course in a department or college. If the professor stays in a community for many years, they will build a network of alumni, friends and industrial contacts. These contacts will be useful in developing the list of projects for the course. However, at times faculty relocate and others move up the ladder to administrative positions. When this happens, the new person selected to teach the Capstone Design course may or may not have these contacts. If the course is connected with a group like the Center for Rehabilitation Engineering and Technology, the project needs will be available to the new instructor. The list of needs saves the new instructor a tremendous amount of time. In some cases if have heard about, it takes all summer to develop the list of projects.

The Center provides the finances purchase the parts, purchase materials, and to machine the parts. These parts all go into the prototypes. It might be possible for the company or the department to fund the construction of the prototypes. However, the Center uses these prototypes to improve the quality of life for people in the State of Florida, so it funds the projects.

There is a lot of specialized knowledge about rehabilitation that the usual academic professor would not necessarily know. Having the instructor from the Center to both lecture on rehab topics and be able to pinpoint companies in the area and other specialized resources is a big benefit to the students and the academic instructor. This would hold true in any specialized technical area that some projects might require information. Rehabilitation engineering is only one of many specialized areas.

The manufacturing and fabrication experience of the Center is invaluable during the team meetings. Academic faculty are not known for their manufacturing experience.

The contacts in the community talk with the student teams and help them refine and define the problem they are tackling.

Many departments do not have the space for students to keep their materials and assemble the prototype. The Center provides some secure laboratory space for this activity.

The students really like working on a project that will produce a solution to a real problem.

To summarize, the Center provides money, specialized rehabilitation knowledge and space. This money, knowledge, and space tremendously improve the student's experience in Capstone Design.

Commercializing the Capstone Design Projects:

A new company, Rehab-IDEAS (Institute for the Development of Engineering and Assistive Solutions), has been formed within the Center for Rehabilitation Engineering and Technology to help develop the designs and bring the resulting products to the marketplace. Rehab-IDEAS needs manpower, and members of the student teams may be employed, or other students may be employed, to work on developing the products.

Rehab-IDEAS is currently developing three of the designs from Capstone that have been patented. One is a beach and rough terrain platform that allows a person in a power wheelchair to explore rough terrain. Another is a mechanism that takes a backpack or briefcase from the side of a power wheelchair to the back of the chair. This is helpful, because with the backpack on the side of the chair, it can't fit through doors. The third is a folding writing table for wheelchairs. This would make it much easier for students to take notes and to eat lunch.

This company gets start-up financing, and some of the student teams have received royalty checks. This is a great "postscript" to an exciting Capstone Design experience.

Conclusion:

As can be seen, there are a lot of normal classroom activities for the academic instructor to evaluate in addition to working with the student groups. Meeting with the student groups is equivalent to teaching a course with a laboratory, which takes more time than a lecture course. The active collaboration between the Mechanical Engineering Department and the Center for

Rehabilitation Engineering and Technology ensures continuity in the Capstone Design course. In fact, the faculty member who developed the course moved up the academic ladder. An Adjunct Professor took it over for a couple of years, and then “retired” again. The current Adjunct Professor and lead author took it over in the Fall of 2006. The course has been individualized with each faculty teaching based on their interests and experience. However, the collaboration has provided a continuity that would have been difficult, if not impossible, to do in any other way. It is like teaching two classes if the instructor has to teach the course and develop the contacts to provide the projects.

There is a synergy when the Center for Rehabilitation Engineering and Technology and the Capstone Design course team up that provides the senior mechanical engineering students with an excellent Capstone Design experience. It does, however, take two instructors to do this. As the old song says, “It Takes Two to Tango,” and it also takes two to make Capstone Design excel. This collaboration ensures that the Capstone Design course continues, and that the students receive the best design education possible.

Bibliography:

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