AC 2010-1735: A NEW FULL YEAR MULTIDISCIPLINARY ENGINEERING SENIOR DESIGN PROJECT COURSE: STRUCTURE, CONTENT AND LESSONS LEARNED

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A New Full Year Multidisciplinary Engineering Senior Design Project Course: Structure, Content and Lessons Learned

Abstract

A new full-year multidisciplinary senior design project course has been implemented at California Polytechnic State University. This course series utilizes externally sponsored comprehensive design projects to provide a hands-on and classroom environment in which students learn and apply the design process and systems engineering. The objective is to provide a realistic environment that enhances the cognitive learning of the students. The course also gives them a chance to apply the fundamental principles of science, engineering and mathematics towards the solution to technical problems that impact society and an appreciation of the strength of the multidisciplinary approach to solving these problems. This course brought students together from six of the college's engineering disciplines to tackle problems requiring multi-disciplinary talents. Over the course of the academic year, multi-disciplinary teams designed, built, and tested solutions to externally provided problems. The class lasted three quarters (approx: 30 weeks), and during the three quarters, student teams of four to six students designed, produced and tested prototype hardware for the external sponsors.

The first quarter of the course focused on team building, problem definition and conceptual design. This included a serious look at defining the engineering problem to be solved as well as an exploration of the student's full creative potential in generating solutions. By the end of the first quarter, the students produced a conceptual design and layout for their sponsor's review and approval. During the first part of the second quarter the students performed detail design work including supporting analysis, a formal design report and a complete set engineering drawings and schematics. The second part of the quarter focused on procurement and fabrication. The last quarter had the students building, testing and documenting a prototype. The prototype and a comprehensive final report, including test results were presented to the project sponsors at our annual Design Expo.

Background

A new college-wide, multidisciplinary senior engineering design course was offered in the Fall of 2008. Students from different departments across the college were involved and included Mechanical Engineering, Materials Engineering, Biomedical Engineering, General Engineering, Electrical Engineering, Computer Science and Software Engineering, Computer Engineering, and Industrial and Manufacturing Engineering. This course series provided students with an opportunity to work on an open-ended design project that required skill sets spanning numerous departments rather than just a single department. The teaching staff consisted of three professors from three separate engineering departments. For the 2008-2009 Academic year, the faculty came from the departments of Biomedical Engineering Materials Engineering, and Mechanical Engineering. The faculty considered the importance having an interdisciplinary set of instructors as well as a team-teaching approach to best model to the students the strength inherent in these approaches.

Course Structure

This course spanned three quarters, and each week students attended one lecture and two three-hour long labs. The first quarter of the course was focused on team building, problem definition and conceptual design. Students conducted background research and determined the engineering requirements and specifications that defined the engineering problem to be solved. Students were encouraged to foster their creativity and generate as many solutions as possible. They used conceptual models and decision schemes to narrow their solutions and developed project schedules to monitor and ensure completion by the end of the course. At the end of the first quarter, students performed conceptual design reviews and provided documentation of their efforts thus far for the instructors as well as their sponsors. During the first part of the second quarter the students completed the detail design work including supporting analysis and a formal design report with a complete set engineering drawings and schematics. The second half of the quarter focused on procurement of materials and fabrication of the prototype. During the third quarter, students completed their manufacturing and performed testing to ensure the solution met the customer's requirements and specifications. Students created vodcasts of their manufacturing efforts as a resource for future students to learn about manufacturing processes. The course culminated with the final prototype and a comprehensive final project report. Student delivered poster and hardware presentations to their sponsors at an annual Design Expo or at their sponsor site.

Course content is somewhat typical of a Capstone Design Course (see Eggert 2007)[1], but enriched by the viewpoints of three faculty and enhanced teaming activities. Responsibility for the instruction and lab activities was distributed between the three faculty with the goal of achieving the stated student learning outcomes (listed in the assessment section). All three faculty attended the lectures and labs to see the different points of view teaching the same topics and provide insight from their department's background. The students met weekly with their faculty advisor during a lab sections as to monitor their progress and provide feedback. The lecture and lab topics covered in order during the 30 weeks of the course are as follows:

Lecture	***Lab***
Design Process and Methodology	Background Research/Requirements/Specifications
Teamwork: Theory, Skills, Practice	Team Building Activity
Systems Engineering	QFD – House of Quality
Creativity and Idea Generation	Creative Problem Solving Experience
Conceptual Modeling	Shop Orientation/Hand Tools Experience
Idea Selection/Decision Schemes	Teamwork Revisited: Personalities, Communication
Project Planning	Engineering Economics
Safety and Risk	Basic CAD
Technical Report and Presentations	
Sustainable Design and Technology	Detail Design
Material Selection in Design	Teamwork Update/Peer Assessment/Roles
Design for Manufacturability	Design Verification/Test Plans/Engr. Statistics
Human Factors Engineering	
Intellectual Property & Patents	

Engineering Ethics	Ethics Case Study
Entrepreneurship	Ethics Case Study Conclusion
Product Liability	Update Presentations
Design with Quality in Mind	Teamwork Exercise
Industrial Design	
Cost Estimating	
Reliability	
Documentation/Product User Guides	
Global Perspectives in Engineering	BaFa, BaFa
Life Long Learning/Self Directed Learning	Pod Cast Screening
Resume, Interviews, and Corporate Culture	Mock Interviews

The deliverables required for the class were as follows:

Deliverables	***Timing***
Weekly Activities and Homework	Varied
Design Notebooks	Daily
Project Requirements Document	4th Week
Conceptual Design Report	10th Week
Conceptual Design Review	10th Week
Interim Design Report with Detailed Drawings	15th Week
Critical Design Review	15th Week
Ethics Memo and Presentations	20th Week
Manufacturing and Test Review	25th Week
Design Expo Poster and Hardware Presentation	30th Week
Final Project Report	30th Week

Projects

Potential projects for the course had to require expertise in three or more engineering disciplines in order to be consider as appropriate for this class. The three faculty members teaching the course were responsible for obtaining the projects. As this was the first year of the course, a small number of projects were chosen as the test bed. There were a total of six projects, and each faculty member was assigned the lead advisor for two projects. Students also had a technical contact from their project sponsor.

The six projects involved development of the following:
- power meter for a spin bike
- robotic plant trimmer to cut down plant growth on a solar farm
- second generation robotic finger spelling hand
- game that involves shooting foam balls at each other for people with development disabilities in order to encourage physical activity
- implantable anchoring device for spinal cord stimulation
- new neonatal medical device

Four of the projects were sponsored by industry, and two projects were service-learning projects with external customers. Each industry project sponsor provided a donation to the college and also provided funding for all of the necessary materials for the project. The donations were used to help fund the course, which included student travel to the sponsor site and funding for the service-based projects.

Students were provided a dedicated laboratory space in which they could work on and store their projects. Figure 1 shows students working on two of the projects, the robotic mower and the spin bike power meter. All sponsors of the projects were very satisfied with the final products. Two of the projects are being continued on as projects for capstone design courses, and two are being further developed by their sponsors.

Figure 1. Students working on the robotic trimmer and spin bike power meter projects.

Recruiting and Formation of Teams

Recruitment for the multidisciplinary senior design course began at the Design Expo the previous year. A flyer was created notifying students of the opportunity and was sent to each department for distribution to its students via email. There was some initial difficulty in recruiting students as the registration period for courses in the Fall began in the previous Spring. At the time for Fall registration, the multidisciplinary course had just been approved, and there were no projects to advertise. Little information was available to the students to help them choose between their capstone course and the new multidisciplinary course. In addition, each department had to decide on its own how the course would be counted in their curriculum, i.e. fulfilling their senior capstone design, senior project, or technical elective requirements.

Once the Fall quarter started, the projects had already been chosen, and information on the projects was distributed to the students. Presentations from the sponsors detailing their projects were given the first week of class. The faculty teaching the course went to each department to advertise the project opportunities and encourage students from all engineering majors to attend the sponsor presentations. The desired enrollment in the multidisciplinary course was 24 – 36 students, based on having 4 – 6 students per team. The final enrollment for the course was 29 students.

In order to form project teams, students completed a project preference form indicating their preference for projects. They also answered questions on the forms rating their expertise in domains such as machining, CAD, statistical data analysis, software programming, and electronic circuit development. Students also provided their resumes and evaluation of their thinking styles. Based on the information from the project preference forms, the faculty advisors formed teams by attempting to create as diverse of teams as possible.

Learning Outcomes and Assessments

Many of the basic learning outcomes for the course were taken from ABET criteria[2]. These provided a framework of outcomes that would be acceptable to each engineering department as replacement for their current courses. The learning outcomes for the course and assessments of each objective are detailed below:

1) *Apply a formal engineering design process to solve an open-ended, externally supplied engineering design problem*

Through the lecture and lab content, students learned about applying a formal engineering design process and simultaneously applied this knowledge to the open-ended projects by their project sponsors. The faculty advisors and project sponsors assessed their success in developing a solution. Project sponsors were given evaluation forms at the end of each quarter to evaluate the students' progress on the projects. Sponsors were asked to rate the students' quality of presentation delivery, preparedness, quality of presentation slides, completeness of presentation, design assumptions, conceptual design, and engineering knowledge. Sponsors were given a rubric to assess these areas.

2) *Work effectively on an interdisciplinary engineering team*

Students worked in teams of 4 – 6 people for 30 weeks. They were presented with teaming theory, skills, and practice based on Tuckman's ideas of Team formation[3]. Specific activities included an afternoon of team forming at the University's leadership training facilities led by experts in team formation. Other activities included a qualitative feedback exercise in which each team member prepared feedback for each of the other individuals on the team, delivered the feedback, and wrote a personal development plan so that the students could conduct peer and self-assessment of their teaming skills and practice. Each quarter the students received feedback on their effectiveness in a group. The students were also instructed on the ideas of Social Styles[4] and how perceptions of personality can impact team function.

3) *Develop, analyze and maintain an engineering project schedule*

Students were required to create Gantt charts detailing their project schedules. The Gantt charts were updated periodically to reflect the true state of the project. In addition, teams conducted weekly meetings with their faculty advisor to inform them of their progress.

4) *Formally define an engineering problem*

Students were required to generate a project requirements document detailed the problem and the need for a solution. They included any relevant background information and converted the customer's requirements into engineering specifications.

5) *Apply structured decision schemes to select appropriate engineering concepts in a team environment*

Students applied decision matrices during the conceptual design phase to narrow down the solutions to focus on and choose their final solution to pursue. This information was presented in their written documentation, design notebooks, and oral presentation of the conceptual design review and critical design review.

6) *Apply current industrial design practice and techniques*

Students were given lectures on current industrial design practices such as DFX, FMEA, and TQM, and as part of lab activities, applied to their project.

7) *Communicate and present engineering design project results orally, graphically and in writing*

Throughout the entire course, students are required to provide both oral and writing communication of the details of their progress on the project. This is presented to both the instructors and project sponsors and feedback is given based on a grading rubric.

8) *Understand engineering code of ethics and be able to make ethical decisions*

Students were presented with the engineering code of ethics and discussed various ethics case studies. Each team performed an ethics case study and presented their analysis of the case to the class. In addition, students performed a lab activity in which they were introduced to a series of ethical situations. Discussion of the ethical situations highlights the assumptions that are used in making judgment.

Conclusions

The first year of the college-wide, multidisciplinary senior design project course was a success. By using teams of students from different disciplines, students were able to take a multidisciplinary look at the problems that needed to be solved and create successful solutions to sponsored projects. This also provided an opportunity for sponsors to provide valuable industry feedback to students on their progress. Students were able to obtain a well-rounded interdisciplinary design experience focused on real world engineering problems.
In order to increase the success of the course, there are several recommendations that could be implemented. The majority of students belonged to the home departments of the instructors. This was partly due to the ease which faculty could promote the new course within their own department through their colleagues and own classes. In addition, due to the late approval of the course, student recruitment started late. Now that the course is firmly established, recruitment

can begin earlier. Visits by the instructors to the capstone design courses or senior project courses of other departments before registration could bring more visibility to the course.

One difficulty encountered by a college-wide senior design course is in trying to satisfy each department's curriculum requirements, since each department has different requirements. Some departments at our university require their students to take a capstone design class, while others require students to only complete individual senior projects. Other departments require their students to do both activities. As this was the first year, each department had to decide within how this would replace or substitute classes in the student's department, and final approval for some departments was not until well after the course had begun. This process has been completed and is no longer an issue for future classes.

Another issue was that several of the projects were covered by a non-disclosure agreement, and students on some of those projects were unable to present or demonstrate their projects to others in the class. During these presentations, valuable feedback was provided by the instructors as well as the rest of the students in the class. Due to the wide variety of student backgrounds, the students provided a wider variety of feedback for their peers than seen in our respective departments. Students on those projects lost an opportunity for valuable feedback and were unable to show their work off to their peers.

Due to the success of the college-wide multidisciplinary course, a second round of this course is currently underway. The department's represented by the faculty teaching the course will be rotated each year so that all departments have an opportunity to participate.

1. Eggert, R., "Engineering Design: Are We Teaching the Right Stuff," Proceedings of the 2007 ASEE Annual Conference and Exposition," June 2007, Honolulu, Hawaii.

2. Criteria for Evaluating Engineering Programs, Engineering Accreditation Commission, ABET Inc, 2006.

3. Tuckman, B., "Developmental sequence in small groups", Psychological Bulletin, 63, 384-399. The article was reprinted in Group Facilitation: A Research and Applications Journal Number 3, Spring 2001 and is available as a Word document: http://dennislearningcenter.osu.edu/references/GROUP%20DEV%20ARTICLE.doc. Accessed September 30, 2007

4. Knight et al., "Expanding Understanding of First-Year Student Retention and Team Effectiveness Through Social Styles Assessment," Proceedings of the 2007 ASEE Annual Conference and Exposition," June 2007, Honolulu, Hawaii.