Real World Capstone Design Course

Elmer Grubbs, Martha W. Ostheimer The University of Arizona

Abstract

Recent feedback from industry and our alumni indicates that graduating engineers need better preparation in solving open-ended problems, thinking "outside the box", working in teams, and in developing strong communication skills. In response to this feedback, as well as ABET Program Outcomes Requirements, we redesigned our senior capstone course to include real world and multidisciplinary technical projects proposed and sponsored by eleven companies, five University departments and the student satellite and solar car projects. Many of our industrial partners also participate as guest speakers in the class exposing ECE majors to real world professional topics including engineering design, the proposal process, design reviews, patents and intellectual property, ethics, quality and robustness issues, and considerations involved in designing for the environment. All students work in design teams of three to six students and prepare significant written documentation as well as three oral presentations during the two semester, four credit hour sequence of the course. Varied forms of assessment are used for the class, including a unique, well-designed rubric for the evaluation of the student's writing portfolios. The class is team taught by an ECE faculty member and the ECE Department's Technical Communication Expert. We believe that students' enthusiasm for the course results from both the uniquely collaborative design of this class and the real world application of all of the material provided in this innovative course.

1. Introduction

Many of today's engineering graduates lack the necessary skills to become contributing members in an industrial team environment immediately upon graduation. Most engineering schools have concentrated their efforts in preparing engineers to go to graduate school, or have simply neglected the more practical aspects of the profession, preferring to let industry train their engineers through co-op or on site training programs. Industry for its part, has been lobbying engineering schools, state legislatures, ABET and whoever else would listen, trying to get universities to prepare more fully engineering students for the day to day teaming, communication, and real world design tasks that the students will face upon graduation.

The culmination of this lobbying effort has been the Boyer report ¹, as well as a strong component of increased design, teaming, communications and exposure to real world topics, such as ethics, Design for Environment, etc. in the ABET 2000 Program Outcomes Requirements². Most engineering schools are now actively looking for ways to rework their curricula to include more design, teaming, and communications skills as well as assessment techniques for measuring the effectiveness of the changes made.

In the Electrical and Computer Engineering Department at the University of Arizona, we have taken the approach of redesigning our Senior Capstone Project class to include industrially sponsored projects to firm up our student's interdisciplinary real world design skills. Previously, students worked separately or in groups of two students each on projects designed and mentored by individual faculty. We had already integrated communications into the curriculum ³. This new industrially sponsored technique appears to be a natural approach, but perhaps has not been used much by engineering schools because of a perceived difficulty in forming these industrial links, or perhaps because of an unwillingness by faculty to partner with industry. In any case, the new ABET requirements have forced schools to take a more practical approach. At the University of Arizona, it became apparent after our first ABET 2000 visit that the old way of doing business was no longer adequate.

We thus designed the present capstone class, which relies on projects made available from industry, faculty from various components of the university as well as from students themselves to provide the practical design oriented education that present day students require. Students work in teams of from three to six people with a faculty mentor to advise each team. If the project is from industry, there is also an industrial advisor assigned to help each team. The projects are required to include open-ended ECE technical design problems, and as part of the coursework, the students are required to present a written design problem definition, a written and oral proposal, status report and final report. A design review is optional, depending upon industrial preference. Each student, as part of the requirements of the course, is required to turn in a portfolio of his or her writings, gathered from their undergraduate classes in the department. Grading in the class is based on a scale of fifty percent technical and fifty percent communications. The course is team taught by a faculty member with a technical degree and one with an English degree.

The course has been well received by the department, the college, the students and the industrial participants. Companies are using the course not only to get projects completed, but also to do recruiting for open positions. The department has benefited by forming new links to industry and receiving substantial gifts. Many students report that this course was the most valuable of all of their college courses.

2. Description of Course

This course is broken into two semesters with one unit of credit for 498A during the first semester and three units for 498B. Both 498A and 498B are taught each semester. During 498A, the projects are presented to the students by either industry, faculty or other university representatives, or by individual students. Each project is evaluated by the course instructors to be sure it meets the ABET requirements for an open-ended ECE technical problem with sufficient difficulty to require at least 150 hours of work by each student. Many projects have been multidisciplinary in scope, involving either the medical center, Optical Science department, Mechanical Engineering, the student satellite project or the solar car project, in addition to Electrical and Computer Engineering. Students fill out a form with their top four choices after the presentations, then they are placed on teams of typically between three to five students each by the technical faculty team teacher, and are assigned to a project. Occasionally larger teams are formed of up to nine people so far, for various more difficult projects.

During the course of the semester, students learn about teaming, engineering notebooks, real world design to solve opened-ended problems, creativity, defining problems, giving oral reports and writing a simple proposal. Outside speakers lecture on design, proposals, and project scheduling. The output for the semester is a written problem statement, and an oral and written proposal. During the semester, the industrial representative, faculty member or student leader are encouraged to help the team to begin a serious design effort with at least an initial parts order placed. A part of the proposal is a Gantt chart and budget. All oral presentations, including a short individual practice presentation to help prepare for the team's oral proposal presentation are done during this lecture period. The only formal out of class time is during the second week of classes when the project presentations are being done. The students either meet fifty minutes in a large lecture setting each week, or in smaller groups in recitation, again once a week.

During the second semester, another lecture on creative problem solving is given as well as guest lectures on design reviews, patents, ethics, design for environment, and ergonomics and systems. A panel discussion with previous graduates who have been out two to five years is also scheduled. We include technical lectures on giving oral and written status reports, abstracts and technical reports. We have found that additional lectures on specific design techniques or on the design process during this semester are not welcomed by students. We let all additional design input be from the industrial advisors and faculty mentors. The students once again give us products consisting of oral and written status reports and a final report at the end of the semester, as well as any hardware and software that has been built. The class time is either a 75 minute lecture or the students are broken into smaller 75 minute recitation periods each week.

An important part of the process is learning to work in teams. Quite a bit of research has been done on how to form teams effectively and evaluate individual performance ⁴. In this class, we provide some rudimentary training to supplement what students have already learned in our freshman introduction to engineering class ⁵. We have members of the team evaluate each other member, and also have the faculty mentor do an evaluation once each semester. Each team then receives a grade on overall performance on a particular presentation. The individual team member's grade is then a percentage of the overall team grade, based on the individual evaluations. We also allow team members to be fired for lack of performance. They cannot be fired for incompetence; we stress this at the beginning of the semester, as many students feel incompetent when they begin this class. If a student is fired, they must find another team to accept them, or else they are dropped from the class.

Each written paper or report is graded by the technical mentor for technical content and by the communications team faculty for grammar, spelling, etc. The technical part is worth fifty percent and the communications part is worth fifty percent. For the oral presentations, the technical team faculty member also awards a technical content grade. As part of the grade, each student is required to turn in a portfolio of technical writings from their undergraduate courses. There are seven requirements that the writings must meet, four or five of which can be met from the 498 course itself. The requirements are "Graduates of the ECE Department shall be able to:

1. Write a procedural document explaining how something works, how to perform an

operation, or how to solve a problem.

2. Write a clear and succinct definition of an open-ended problem including a summary of known attempts to solve the problem.

3. Write a proposal to perform a project, undertake research, develop a program, solicit funding, or some combination of the above.

4. Write an abstract of a professional paper.

5. Write a letter or memorandum taking a clear position defending or selling an idea to an audience.

6. Document a project in a professionally written design report.

7. Explain technical information to a non-technical audience."

One of the difficult parts of this course has been to obtain the industrial projects. All of the larger companies in the area were contacted. Most have university relations departments, which circulated Emails to department heads asking for potential projects. Smaller companies were contacted individually, and some became participants because we had students in the class who were employed by them. We also contacted individual engineers, whom we either knew personally or had worked with previously. We contacted some grade schools and some charitable organizations to see if they needed network or web related projects done. Companies generally were enthusiastic about the opportunities to become involved with students and with the ECE department.

3. Results

The results of this change have been very gratifying. Each party involved has been extremely enthusiastic. We have assessed the students in several ways to get their feedback on the course changes. We have done an in-class anonymous survey, with a zero to three point scale on all relevant parts of the course. The sixty percent return rate gave an average of 2.5 or above on almost all of the categories. One notable exception was the guest speaker category for Fall 2000 (see figure one). In that semester we went to a large lecture hall to handle the 100 enrolled students. We believe that the decrease in enthusiasm for the guest speakers was probably a result of the larger class size and perhaps also affected by the fact that we made attendance mandatory for these lectures during that semester.

The department also conducted exit interviews with the seniors at the end of the first full year of the course. The answers to questions about the senior design class were unanimously positive, with also some thirty percent of the students specifically mentioning that senior capstone was a positive experience when asked for general feedback on the curriculum. We also measured the student's reactions to each guest speaker with an opinion form filled out at the end of each lecture. Except for a few students who were obviously upset that we had interrupted their naps, the scores were consistently three's with a small number of two's (again out of three possible).

A group of university and industrial representatives were used to grade the student's portfolios. We graded them in the seven areas outlined previously on a scale of from one to six for each selection, using a rubric designed for holistically scoring the portfolios ⁶. Figure two shows the scores for the first class evaluated. We were excited to see the reasonably high scores in the first six of the areas, thus demonstrating the writing skills of our students.

Because of the student's enthusiasm for the course and the fact that we appear to be meeting ABET requirements in a more appropriate way, the department and many of the faculty also have reacted positively to the course changes. Many look upon this class as a way to form better university industrial links as well, although, frankly some faculty still see little use in increased industrial contact.

The companies, for their part, have generally reacted positively as well. Eleven companies have participated so far, many with multiple projects. The large majority of the projects have been successful, although some of the projects have had to have their desired outcomes modified as the year has progressed. Those companies that have been most successful have been the ones that invested the most in terms of sacrificing the time necessary to mentor properly their teams of students. In each of these cases they have effectively multiplied the time invested by a factor of four or five by using the student groups. Those groups that were left on their own, struggled to get the job done. Some students obviously did only "C" work as well, hoping just to graduate, so not all of the projects could be termed successful. It should be noted that one large computer company donated all of the equipment used in the project to the department after the project was over, with a total of hundreds of thousands of dollars for the grant.

4. Conclusions and Recommendations

By the metrics that the authors created and used, this modification to the senior project class appears to have been successful. Students, the instructors, local industry, the department, and much of the faculty all appear to be happy. We are hopeful that ABET will also be pleased during the next program evaluation. Except for a major amount of work expended, there appears to be no downside at all. We would highly recommend that changes similar to these be made at all engineering institutions. Real industrial projects, teaming, emphasis on communication skills, multidisciplinary projects, assessment, more faculty with industrial experience, all seem to be contributors to the future direction of engineering curricula across the country. At the University of Arizona, some effort will be made in the coming years to integrate this approach at the college level as well.

References

2. URL: http://www.abet.org/eac/2000.htm

Lonsdale, E.M., Mylrea, K.C., Ostheimer, M.W., *Professional Preparation: A Course That Successfully Teaches Needed Skills Using Different Pedagogical Techniques*. Journal of Engineering Education, April 1995, p.187-191.
Felder, R.M., Brent, R., *Effective Teaching*. North Carolina State University, 2000, p. E-8 - E-12.

^{1.} The Boyer Commission on Educating Undergraduates in the Research University, *Reinventing Undergraduate Education: A Blueprint for America's Research Universities*. New York: State University of New York at Stony Brook, 1998.

Johnson, V., *Becoming a Technical Professional*. Casas Adobes Publishing, Tucson, Az., Chapter 2.
Ostheimer, M.W., Strickland, R.N., *Evaluation of Student Writing Outcomes using a Portfolio Assessment Process*. ASEE-PSW Section Spring 2000 Conference Proceedings, p. 168 - 172.

ELMER GRUBBS

Elmer Grubbs is currently a Senior Lecturer in the Electrical and Computer Engineering Department at the University of Arizona. He received his B.S. and Ph.D. from the University of Arizona and his M.S. from Arizona State University in Electrical Engineering. He has over twenty years experience in industry, as well as fifteen years experience in teaching in Engineering and Engineering Technology, with several years as a Department Chair.

MARTHA OSTHEIMER

Martha Ostheimer is currently an Adjunct Lecturer in the Electrical and Computer Engineering Department at the University of Arizona. She received a B.A. in English and a M.F.A. in Poetry from the University of Arizona, and has been teaching in the ECE department for ten years, in Technical Writing courses as well as in the Senior Capstone class.

Class Elements

- <u>2.52</u> Teaming Experience
- 2.52 Interfacing with an industrial sponsor
- 2.67 Working on an open-ended design problem
- 2.08 Exposure to "real world" topics from guest speakers
- 2.39 Project scheduling experience
- 2.55 Preparing a written design proposal
- 2.48 Preparing an oral design proposal
- 2.30 Documenting design work in an engineering notebook
- 2.33 Evaluating design progress in oral and written status reports
- 2.55 Documenting a project in a professionally written design report
- 2.73 Preparing a final technical presentation on a design project

Figure One



Assessment Results for ECE's Seven Writing Outcomes Fall 1999 (Averaged over multiple readers)

Percentage portfolios vs. Outcomes B = Competent, A = Highly Skillful, D = Less Than Competent

Figure Two