Session XXXX

The Evolution of a Capstone Design Course to Include Outcomes Assessment

Paul Ricketts, C. I. Ricketts, and Leon Cox

Department of Engineering Technology
New Mexico State University

Abstract

This paper outlines the format of a senior capstone design course in Mechanical Engineering Technology (MET) designed to address ABET requirements for assessment of program outcomes. Summarized are the rationale followed and the steps taken as the course was changed to redirect the focus of graduating seniors toward good overall design practice and demonstrated relevance of their educational experience to the capstone design process. The course modifications also allowed the MET faculty to implement the course as an efficient tool for assessing program outcomes. Implementing the course as one of several primary assessment tools, directly addressed issues from a prior accreditation cycle and helped contribute to a recent positive review by a visiting ABET team.

Introduction

The general requirements contained in ABET's *Criteria for Accreditation Engineering Technology Programs* (1) has historically not required that engineering technology programs implement a capstone course, however, some specific program criteria do require some form of a capstone design course. At New Mexico State University (NMSU), the MET program has had a senior capstone course as a requirement since the 1995-1996 academic year. The course was added to the curriculum with the intent that students should demonstrate the skills and abilities meant to be acquired from their four-year educational experience. In particular, it was expected that graduating seniors would demonstrate the ability to draw from completed academic coursework and synthesize the ensuing skills in a relevant and meaningful way within a design environment similar to that typically encountered in industry. Although the ABET Mechanical Engineering Technology criteria have not yet specifically mandated such a requirement, the prospective benefits of such a course are numerous.

Initial Capstone Design Course

The initial capstone design course developed for MET students had the following characteristics:

- To help better motivate them, students were allowed to propose and commence design projects of their choice. Many students did seem to become more motivated by the idea of choosing a project topic of interest to them and enrolled in the course with a project already in mind.

- The students were tasked with finding a faculty member who would agree to mentor them on their project. It was the faculty member's responsibility to provide technical expertise when needed and to ensure that students stayed on schedule in completing project milestones. Additionally, the students were required to find two faculty members to serve on the end-of semester, project evaluation committee.

- While the students were encouraged to work in teams, they were also allowed the option of working individually; if they could justify a project of appropriate scope.

- To obtain approval of their project choice, students were required to submit a one-paragraph proposal of the work to be accomplished. Included as part of the assignment was a Gantt chart showing major project milestones and completion dates. They also had to identify which courses from the curriculum that they would draw from in completing the project.

- To help keep the project on schedule, students were required to submit biweekly progress reports in the form of one-page memorandums.

- At midterm, the students orally present a summary of work completed and an intended plan of action for accomplishing yet outstanding tasks.

- At the end of the semester, the students made oral presentations highlighting project results and submitted a project final report.

Disadvantages Identified for Initial Capstone Design Course

During the first years of the course offering, faculty members became concerned about how inconsistently students appeared to be performing in terms of project completion and documentation. The following describes the areas identified as needing to be addressed: in order to have the course better serve students with a positive and beneficial capstone experience.

- All too often, students selected projects that could not be completed within the time constraint of an academic semester, *i.e.*, they almost invariably underestimated the total time needed. Furthermore, unanticipated factors – several outside students' prior experience – often resulted in unexpected delays. Examples included: fabrication time, parts delivery time, waiting on other project team members, and the tendency to prefer the more comfortable work routine of focusing on deadlines of other courses; instead of those requisite to capstone project success.

- Because projects were open-ended and the course lacked rigid deadline enforcement, students generally tended to put off project tasks, in order to meet the more frequent absolute deadlines of concurrent courses having the traditional structure of homework and exams. By mid-semester, it was rare for teams to be close to 50% completed with their projects. In fact, it was very common for them to have accomplished only 10-20% of the tasks necessary to successfully finish a project.

- Some students would invest inordinate amounts of time (and in some cases their own money) brainstorming, designing, modeling, or fabricating; at the expense of project documentation. This left course instructors in an awkward predicament when assigning grades: particularly for cases in which project realization in the form of a high-quality tangible product was achieved; but without a satisfactory final report or acceptable oral presentation.

- While students for the most part had good intentions, they were often not able to demonstrate that they had drawn from their educational experiences to complete their chosen projects. Specifically, they neither demonstrated knowledge in technical subject areas and in the technical design skills area; nor did they consciously integrate curriculum-based skills into project activities.

- During a Fall of 1999 visit by an ABET re-accreditation team, the capstone course was identified as lacking the ability to demonstrate that students were familiar with current industrial practices. It was also noted that the integration of prerequisite coursework needed to be evident and correspondingly resulting skills needed to be demonstrated in the documentation of design projects.

- With the transition by ABET to a re-accreditation process requiring an outcomes assessment model, it was not possible to retain the existing course structure toward achieving that end.

Addressing the Disadvantages

During the course of several brainstorming sessions in the summer of 2001, the MET faculty came up with options to address the capstone course structure, such that the issues identified above could be remedied. The intent of implementing the changes was to provide a more rigorous and focused course structure that better allowed students to demonstrate their knowledge and skills gained during their educational experience; as well as to imbed the underlying framework needed to utilize the course as a major outcomes assessment tool.

The changes included:

- Providing students with a checklist of tasks that should be completed during the semester to successfully complete a design project. While not all items on the list would be required from all students and projects; the list can be used as a means of identifying items that may be inadvertently overlooked. Appendix A contains the recommended project task checklist.

- Requiring that an economic analysis be done for any project, where ever relevant.

- Exposing students to the patent search process by requiring that they perform patent searches whenever they elect to work on projects that have the potential for innovative design.

- Making sure that students follow current industry practices as these apply to a particular design. Appendix B contains the current industry practices handout for students.

- Setting clear expectations for what constitutes acceptable standards for teamwork, timeliness, and project documentation in the form of a final report (see Appendix C).

- Instead of allowing students to propose their own design projects, faculty members developed a set of design projects related to the NMSU specific program educational objectives and program outcomes. One of the requirements for the four-year ABET specific program criteria for MET [1] is for the program to demonstrate that graduates possess “technical expertise having added technical depth in a minimum of three areas”; selected from a list of nine general areas.

To meet this requirement, the NMSU MET program was tailored to provide added depth in the areas of 1. mechanical design, 2. the thermal sciences, and 3. manufacturing processes. These are the areas that are evaluated as part of the program’s outcomes assessment plan. Moreover, since one characteristic that an engineering technology education should have, is a focus on providing a laboratory component: experimental techniques was added to the list of areas from which students could select a design project. The students are typically given brief project descriptions in all four areas, and asked to select three of them to complete - in teams - during the semester. Having students work in multiple areas allows the course to be easily used as an assessment tool to better monitor the quality of the educational experience. The current outcomes assessment evaluation form is attached in Appendix D.

Results and Conclusions

The changes developed in 2001 were not incorporated into the capstone course until the Fall 2002 semester. In the seven ensuing semesters, there has been significant improvement in the quality of the projects completed by students. The faculty carefully formulated projects to be smaller in scope than the ones previously attempted by students. This scaling back has enabled the students to successfully complete the projects within the allotted time constraints of one semester. Additionally, students demonstrate that they can apply in practice; both the theoretical and the practical knowledge gained from an applied technical curriculum. They consistently show an ability to integrate multiple curriculum topics (*i.e.*, synthesize) in such a way that a minimum acceptable level of competency is demonstrated. During the Department’s Fall 2005 re-accreditation visit by ABET, the visiting team was satisfied that acceptable progress had been made with regard to correcting deficiencies identified during the previous visit. It was thus demonstrated that the capstone course could serve as a viable outcomes assessment tool.

Cited References

1. *Criteria for Accrediting Engineering Technology Programs (2005-2006)*, ABET Inc. 2004

References

Duff, J. M., Schildgen, T. E., *Establishing Outcomes for Senior Capstone Projects in Industrial Technology*, Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition.

Neff, Gregory, Scachitti, Susan, & Higley, James, *Counting Down to 2004: Some Insights and Strategies for Satisfying TC2K While There is Still Time*, Proceedings of 2003 ASEE Annual Conference.

Neff, Gregory, Scachitti, Susan, & Higley, James, *Counting Down to 2004: Some Insights and Strategies for Satisfying TC2K While There is Still Time*, Proceedings of 2003 ASEE Annual Conference.

Lin, P., Broberg, H., *Reassessing Capstone Courses to Support TC2K Accreditation*, Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition.

Neff, Gregory, Scachitti, Susan, *The Assessment Cookbook: Recipes for Successfully Meeting TC2K Criteria*, Proceedings of 2002 ASEE Annual Conference.

Bilbeisi, S. D., & Steve E. O'Hara, 2001 *Utilizing a Capstone Design Project for EC2000 Assessment*, Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition.

Shaeiwitz, 1998, *Classroom Assessment*, Journal of Engineering Education, ASEE, Vol. 87, No.2.

Authors

PAUL H. RICKETTS
Paul Ricketts is a Professor in the Department of Engineering Technology at New Mexico State University. He has degrees in engineering technology, mechanical engineering, and industrial engineering, and is an active member of ASEE, ASME and ASHRAE. Professor Ricketts is a registered professional engineer in New Mexico.

C. I. RICKETTS
Dr. Ricketts is an Associate Professor in the Department of Engineering Technology at New Mexico State. He has degrees in mechanical engineering and mechanical process engineering and is an active member of ASEE and ASME. His interests lie in areas of experimental methods, applied fluid mechanics, and applied thermodynamics.

LEON COX
Leon Cox is an Associate Professor in the Department of Engineering Technology at New Mexico State University. He has degrees in industrial engineering, and is an active member of ASEE and IIE. Professor Cox's research interests are in the areas of computer integrated manufacturing and quality control.

Appendix A

Project Task Checklist

The following is a checklist of most of the tasks that each group should accomplish by the end of the semester. Note: Not all items will be required of each team or each project.

Submit Project Proposal

Identify Design Criteria

Develop Performance Specifications

Identify any Assumptions that Must be Made

Develop a Gantt Chart

Participate in Project Brainstorming Experiences

Identify Which Academic Courses Will be Drawn from for Successful Project Completion

Conduct Literature Search of Related Journal Publications

Perform Design Calculations

Identify Design Alternatives

Perform Economic Analysis

Identify any Important Safety Considerations (OSHA requirements)

Identify Relevant Codes & Standards

Conduct a Patent Search

Ensure that Project Deadlines are Met

Submit Progress Reports in a Timely Manner

Submit Outline of Final Report

Participate in Midterm Presentation

Generate Technical Drawings

Write and Submit Draft of Final Report

Either Test (if built) or Evaluate (paper design) Final Design Concept

Participate in Final Presentation

Write and Submit Final Report

Appendix B

Examples of Standard Industry Practices

Market Considerations
- Market Analysis
- Economic Analysis

Engineering Analysis
- Detailed and accurate drawings
- Design Calculations
- Design Criteria
- Alternative Designs
- Design for Manufacturability
- Investigation and application of appropriate codes and standards
- Patent Search (www.uspto.gov, www.isinet.com)

Project Management
- Gantt Chart
- Journal
- Progress Reports
- Meeting Deadlines
- Teamwork (www.facstaff.bucknell.edu/rich/engr100/teams/Teamwork.htm)

Manufacturing
- Feasibility Study

Safety
- OSHA Requirements

Report
- Oral Presentation
- Formal Written Report

Appendix C
Final Report Checklist

The following is a checklist that includes most of the major aspects that should be covered in your final written report. Depending upon the nature of the project, some items will be optional, although it would be best if you sought the advice of the MET faculty before making any final decisions about what to exclude.

Project Goals/Objectives

Design Criteria/Constraints

Performance Specifications

Assumptions

Materials Selection

Identification of Courses Drawn From

Design Calculations

Codes & Standards (if none, then document)

Design Alternatives

Bases for Selection of Design Implemented

Economic Analysis

Technical Drawings (can someone use the drawings to built the product?)

Patent Search Information (if none, then note and justify)

Gantt Chart

All Progress Reports

Brainstorming Experience

Test or Evaluation of Final Design

Safety Considerations (OSHA requirements, for example)

Appendix D

Program Outcomes Assessment Evaluation Form

Graduates should possess the skills needed to perform successfully in industry, business, and government. A capstone course requiring successful completion of team projects is required of each student. A committee of faculty members reviews the written reports and oral presentations. The outcomes/skills below will be assessed to identify strengths, weaknesses, and trends. Adjustments will be made within the curriculum - when necessary - to strengthen any identified weak areas. At least 70% of the students will demonstrate a minimum proficiency in each of the assessed areas.

Student's Name ____________________________________ Date __________

Demonstration of			**Better →** **Min ↓**			**Not Applicable**
Manufacturing Processes						
Modern Processes:	1	2	3	4	5	
Measuring Tools:	1	2	3	4	5	
Machine Tools:	1	2	3	4	5	
Quality Systems:	1	2	3	4	5	
Process Improvement Methods:	1	2	3	4	5	
Mechanical Design						
Kinematic Analyses:	1	2	3	4	5	
Stress Calculations:	1	2	3	4	5	
3-D Models:	1	2	3	4	5	
Standard CAD Drawings:	1	2	3	4	5	
Engineering Materials						
Appropriate Use:	1	2	3	4	5	
Thermal/Fluid Systems Design						
Applications of Principles and Concepts:	1	2	3	4	5	
Experimental Methods						
Perform Successful Laboratory Experiment:	1	2	3	4	5	
Use of Measuring Instruments:	1	2	3	4	5	
Gathering Data:	1	2	3	4	5	
Data Presentation:	1	2	3	4	5	
Data Analysis:	1	2	3	4	5	
Conclusions:	1	2	3	4	5	
Recommendations:	1	2	3	4	5	
Safety						
Relevant Safety Issues:	1	2	3	4	5	
OSHA	1	2	3	4	5	

Demonstration of			Better → Min ↓			Not Applicable
Computer Software						
Word Processing:	1	2	3	4	5	
Spreadsheets:	1	2	3	4	5	
Graphing:	1	2	3	4	5	
Presentation:	1	2	3	4	5	
Mechanism Analysis/Design:	1	2	3	4	5	
Data Acquisition:	1	2	3	4	5	
Computer Assisted Manufacturing:	1	2	3	4	5	
Project Management:	1	2	3	4	5	
Progress Reports	1	2	3	4	5	
Project Management						
Scheduling:	1	2	3	4	5	
Planning:	1	2	3	4	5	
Economic Analysis:	1	2	3	4	5	
Progress Reports	1	2	3	4	5	
b. Current knowledge, adapt to emerging applications:	1	2	3	4	5	
Use of modern tools such as calculators, computers, software						
c. Conduct/Analyze/Interpret Experiments:	1	2	3	4	5	
See previous page						
d. Application of Creativity in Design:	1	2	3	4	5	
Alternative designs						
Justification for final selection						
e. Functioning Effectively on Teams:	1	2	3	4	5	
Peer teamwork evaluation form						
f. Identify/Analyze/Solve Technical Problems:	1	2	3	4	5	
Clear/concise problem solutions						
Consideration of relevant problem solving topics/issues						
g. Effective Communication:	1	2	3	4	5	
Oral Presentations						
Written Reports – grammar, spelling, technical writing						
h. Recognize need for, and ability to engage in lifelong learning:	1	2	3	4	5	
i. Professional/Ethical/Social Responsibilities:	1	2	3	4	5	
j. Diversity/Knowledge of Professional/Societal and Global Issues:	1	2	3	4	5	
k. Quality/Timeliness/Continuous Improvement:	1	2	3	4	5	
Professional looking work						
Meeting deadlines						
Consideration of alternatives						