Restructuring the Capstone Course Leads to Successful Projects

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Abstract

The engineering technology programs at Texas A&M University-Corpus Christi share a capstone projects course that allows students to use their problem solving skills and the technical knowledge they gain throughout their college experience to develop a device or system that meets some specific requirements. As a result of concerns raised during a recent ABET accreditation visit, the course was restructured in order to ensure consistency in the quality of the projects being completed by students. This paper describes the changes and briefly presents the progress that has been made since 2004 Spring Semester.

Introduction

An engineering capstone design experience has been defined as "the crowning achievement in a student's academic curriculum, and integrates the principles, concepts, and techniques explored in earlier engineering courses" [1]. Today, most engineering and engineering technology curricula include a senior capstone course [2-8]. Two major sources that led to this status are the Accreditation Board for Engineering and Technology (ABET) and industry [9]. While the process for conducting capstone projects varies between programs and disciplines, such projects normally take two or three semesters to complete and in the majority of cases, students are organized in teams of two or more [10]. A number of institutions have already used the capstone course as a significant assessment tool [11-13].

The engineering technology programs at Texas A&M University-Corpus Christi (A&M-CC) share a capstone projects course that allows students to use their problem solving skills and the technical knowledge they gain throughout their college experience to solve a moderately complex problem by developing a device or system that meets some specific requirements. This experiential learning activity brings the analytical knowledge and the practice of engineering in a hands-on meaningful project that involves product design, development, testing, and documenting. Until last year, projects were one-semester long and all students taking the course were advised by the instructor. As a result of concerns raised during a recent ABET accreditation visit, the course has been restructured in order to ensure consistency in the quality of the projects being completed by students. This restructuring affected another course, Project Management &

Justification, that was divided into two parts. In the first part, students learn about project management issues such as project selection, planning, scheduling, and control. In the second part, students select a project for the capstone course, propose a solution, and prepare a comprehensive project plan. Both courses, ENTC 4315 and 4350, are 3 credit hours each. Changes are summarized as follows.

1. Restructuring ENTC 4350 Capstone Projects (3 credit hours)
   (a) This course is now team-taught. The supervising faculty is responsible for quality of projects, presentations, and reports. They evaluate students' work and assign final grades.
   (b) The syllabus was revised. It shows all course activities (progress reports, presentations, report drafts, etc.) with dates.
   (c) Guidelines for preparing final project reports were developed.

2. Establishing Assessment of Capstone Projects
   The Capstone Projects course is a major part of the Continuous Improvement Plan (CIP). A Capstone Projects Evaluation Committee (CPEC) consisting of Industry Advisory Committee (IAC) members and ET faculty was established to ensure that the course is achieving its stated learning outcomes. The committee uses evaluation criteria that take into consideration course and program outcomes and use students' feedback, oral presentations, and written reports.

3. Revising ENTC 4315 Project Management and Justification (3 credit hours)
   (a) The syllabus was revised. This course now covers fundamentals of engineering economics, principles of project management, and planning for the capstone project (last four weeks). Students secure an advisor and prepare a complete proposal, including specifications, timelines, schedule, and budget. Throughout the semester, students use a project management computer program to plan, schedule, and track project progress.
   (b) Guidelines for preparing project proposals were developed.

We have completed the implementation of these changes. Students now start the planning phase for their capstone project during the last four weeks of the project management and justification course. All indications seem to support our belief that the changes we made make students better prepared for designing, implementing, and presenting successful capstone projects. The following sections provide details regarding the different components of the capstone course.

Capstone Course Contents

As can be seen in Fig. 1, the course is devoted to project development. FE review sessions are scheduled throughout the semester as will be discussed later. Evaluation of student performance is based on oral presentations, progress reports, report draft, final report, and a final exam.

Course requirements include three assignments to cover the following topics: (1) Professional, ethical, and social responsibilities; (2) Recognizing the need for, and an ability to engage in lifelong learning; and (3) Recognizing the need for timeliness, quality, and continuous improvement. These assignments consist of having students read handouts, perform library and Internet searches, and submit two-page reports that demonstrates their understanding of these issues.

Week Number	Topics and Activities
1	Course requirements Life long learning Professional, ethical, and social responsibilities Timeliness, quality, and continuous improvement.
2	Overview of projects (short descriptions by students) Project review I (with advisor)
3-5	Project development
6	Project review II (with advisor) Project development
7- 9	Project development
10	Project review III (with advisor) Project development
11-14	Project development
15	Report draft due First project presentation Revise report
16	Final project presentation Final project report due FE practice exam

Figure 1. Tentative Weekly Schedule

The course learning outcomes are stated as follows. "At successful completion of this course the students will have demonstrated their abilities to:

- Identify, analyze, and solve technical problems
- Apply creativity in the design of systems, components, or processes
- Use modern software and hardware tools
- Apply engineering methods and techniques to carrying out the project
- Apply project management tools for managing a project -- Microsoft Project will be used to develop a schedule of tasks necessary for the completion of the project
- Communicate effectively (oral and written)
- Recognize the need for, and an ability to engage in lifelong learning – Demonstrated by having students prepare a written document indicating their perception of the need and their future educational plans

- Recognize the need for quality, timeliness, and continuous improvement – Demonstrated by having students submit a written statement that addresses their understanding of this need
- Describe and demonstrate the concepts and importance of professional, ethical, and social responsibilities-- Demonstrated by written analysis of an engineering ethics case study."

Project Selection and Preliminary Proposal

The project selection task, which is key to a successful project experience, may represent the most challenge to both students and the instructor [5]. Advisors must be either part-time or full-time ET instructors. While students are asked to identify a problem they want to solve, the instructor must make sure that the selected project satisfies the capstone course requirements. Some students, especially those who choose work-related projects, have a good idea of what they want to do. Others, however, need the instructor's advice and guidance throughout this process. Students may select from a list of projects provided by the ET faculty, industry sponsored projects, or they may propose their own project. It is, however, the responsibility of the student to select a project and secure a faculty advisor.

Projects are sought from local industries. In a letter sent to potential industry project sponsors, the characteristics of a good project are listed as follows:

- Solvable in 200-400 man-hours
- Requires research and design
- Requires a team of 2-3 students
- Be a "back-burner" type of project rather than involved with mainstream production
- Material and equipment must be available by the first week of the semester (fall semester starts in late August and spring semester starts in early January)

The project selection process is carried out over a five-week period in the semester preceding the capstone course. During the fifth week of the semester in the Project Management and Justification course, students are given the following guidelines for preliminary project proposals.

- Project should be unique with a well-defined objective
- Project solves a real world problem (industrially sponsored, if possible)
- Task is moderately complex and of proper scope -- achievable, challenging, and appropriate for the capstone projects course

The preliminary proposal consists of the following:

- Cover page showing the project title, your name, date, course title, department, and advisor

- Project description:
  a) State the primary objective of the project
  b) Justify the proposed project (Better than what is currently available? New product? Less expensive? Etc….)
  c) Briefly describe the final product/operation
  d) Discuss basic plans for implementation
- Professional objectives (why do you want to do it?):
  a) State the project's relationship to your learning goals
  b) State the project's relationship to your career goals
- State and discuss potential problems.

Preliminary proposals are due during week 10 of the semester. The proposal is reviewed by the advisor and returned to the student. The final project plan and proposal is submitted to the instructor during week 15 of the semester. While students vary in their approach to select a project, the author has advised students to consider the selection process shown in Fig. 2. Here is a brief description of the major steps.

- Start by listing all the projects you can think of.
- Filter these projects by considering long term goals.
- Filter the new set of projects by considering short term goals. This will result in a list of projects consistent with both long and short term goals.
- Filter the new set of projects by considering the senior capstone course requirements.
- Finally, filter the last set of projects by considering available resources. These sources may include time, money, and technical knowledge.
- Select a project from the last filtered set of projects.

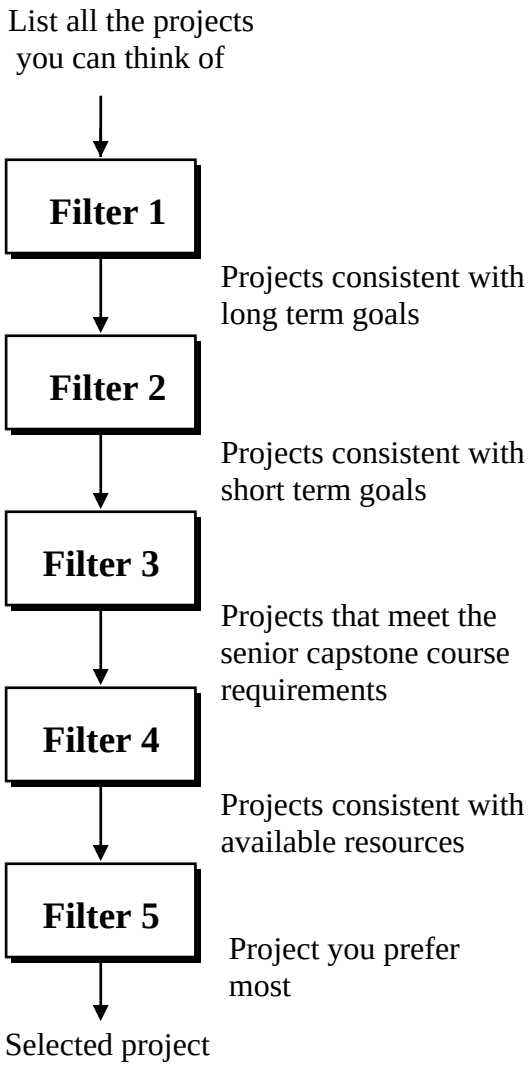

Figure 2. Project Selection Process

Simplified Project Development Process

Project management refers to managing resources to achieve established goals in time and within budget. The process can be complex and involved. For capstone projects, however, it may be simplified and presented as shown in Fig. 3. Here is a brief description of the major steps.

- State the objectives. This includes specifying performance, time, and budget.
- Identify available resources. This encompasses money, time, human (knowledge and availability), and material.
- Define the objectives. This involves restating the original objectives after considering the available resources to ensure that the goals are achievable.
- Analyze the problem. This includes an investigation of alternative approaches that achieve the desired goals. If the analysis does not generate at least one possible solution, redefining the objectives is necessary.
- Select the best approach. This consists of a comparison of the alternative solutions based on some selection criteria which may include such factors as performance, cost, time, size, speed, etc.
- Develop a plan. This considers all the phases that lead to the completion of the project. The plan should be comprehensive with a schedule of all the activities and their relations. It should also have a set of milestones.
- Implement the plan. This includes the design, construction, and testing of the product.
- Evaluate. This entails evaluating the performance of the product in meeting the original goals. If the results are not satisfactory, a review of the previous steps is required.
- Complete the project and its proper documentation.

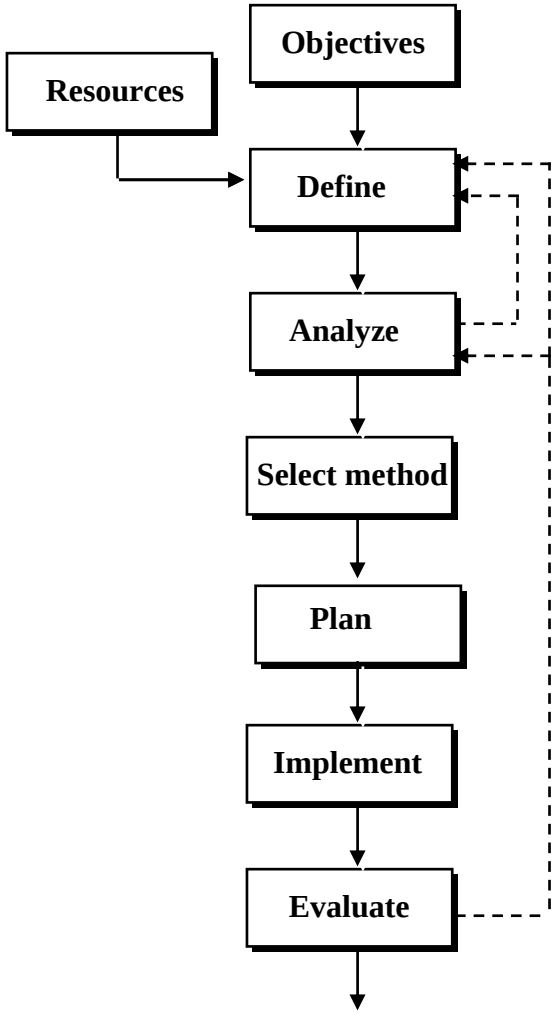

Figure 3. Project Development Process

Project Report

Students are required to submit a final report containing the following items.

Cover page
Table of Contents
Acknowledgments (if any)
List of Figures
Chapters

1. Introduction (2-4 pages)
2. Description of System Design (4-10 pages)
3. Test Plan and Results (3-8 pages)
4. Description of System Operation (2-4 pages)
5. Conclusion (2-3 pages)
6. References
7. Appendices.

Fundamental of Engineering Practice Exam

The final exam in the course is a FE practice exam. The exam consists of two parts, a two-hour morning session and a two-hour afternoon session. The exam is taken online through the Exam Café web site. The results of the exam are used to help with course and program assessment. To help students prepare for the exam, one-hour sessions to review the various FE topics are conducted throughout the semester. The topics are Statics, Mechanics of Materials, Math, Dynamics, Math, Circuit Analysis, Material Science, Fluids, Ethics, Engineering Economy, Chemistry, Thermodynamics, and Computers. In fall 2004, seven instructors volunteered to conduct sessions in their areas of expertise.

Oral Presentation

At the end of the semester, students deliver 20 minute oral presentations describing their projects and performing a demonstration. To help students prepare for this task, we discuss various approaches to technical presentations and present them with some general guidelines. All students participate in the evaluation process using the form of Figure 3. The lower part of the form (suggestions for improvement) is cut and returned to the speaker. The purpose is to make the speaker aware of areas needing improvement.

Experience with Implementation

In spring 2004, there were two projects performed by two teams of students. In fall 2004, there was only one project performed by a team of two mechanical engineering technology students. Their project involved the design and development of an air abrasion machine, LabJet, that has an integrated working enclosure with two chambers containing two micron of aluminum oxide abrasive media for dental laboratory usage.

This project was sponsored by American Medical Technologies. It is anticipated that the LabJet will be placed on the sponsor's product line and be utilized in the dental laboratory niche market segment. Fig. 5 shows the prototype of the machine.

ENTC 4350 Capstone Projects
Fall 2004

PEER EVALUATION FORM - Final Presentation

Speaker's name:_____ Topic:_____
Evaluator's name:_____

		Score (0-4 points each)
1.	Clarity of project description and goals (understood the main points)	_____
2.	Quality of presentation and supporting materials (interesting, complete, slides, graphs, handouts, transparencies voice, eye contact, confidence, enthusiasm, etc.)	_____
3.	Response to questions (clarity, accuracy, confidence, etc.)	_____
4.	Operation (demo) based on original proposal (take into consideration justifications for modifications/changes/deviations)	_____
5.	Technical value of project (originality, scientific importance, etc.)	_____

Total:_____(out of 20)

Figure 4. Presentation Evaluation Form

Evaluation of Learning Outcomes by Students

As part of our effort to continuously improve the course and methods of delivery we ask students to evaluate the course based on the course learning outcomes in the syllabus. Students are given a form with the list of learning outcomes and the following questions and instructions.

"Has this course met its objectives in teaching you the following techniques, skills and knowledge of the subject matter? How would you assess your own abilities in the following areas? Please use a 5 point rating scale with 5 being Confident and 1 being not at all." The results of fall 2004 are shown in Fig. 6. The number shown next to each outcome is the average score.

Figure 5. Prototype of the LabJet

Average Rating	Course Learning Outcomes
4.5	Identify, analyze, and solve technical problems
5.0	Apply creativity in the design of systems, components, or processes
4.5	Use modern software and hardware tools
5.0	Apply engineering methods and techniques to carrying out the project
5.0	Apply project management tools for managing a project -- Microsoft Project will be used to develop a schedule of tasks necessary for the completion of the project
4.5	Communicate effectively (oral and written)
4.5	Recognize the need for, and an ability to engage in lifelong learning – Demonstrated by having students prepare a written document indicating their perception of the need and their future educational plans
4.5	Recognize the need for quality, timeliness, and continuous improvement – Demonstrated by having students submit a written statement that addresses their understanding of this need
4.5	Describe and demonstrate the concepts and importance of professional, ethical, and social responsibilities-- Demonstrated by written analysis of an engineering ethics case study.

Figure 6. Rating of course learning outcomes by students

Students were also asked to answer the following two questions. Their answers follow.

1. What was good about this course and should not be changed?
   "The ability to apply theoretical knowledge to solve a practical problem. The review sessions were very helpful and taking the practice FE exam was good"

2. How could this course be improved?
   "Improvement could come from making the course into a competition between teams of students when class size is sufficiently large"

Capstone Projects Evaluation Committee (CPEC)

As mentioned earlier, CPEC was established to ensure that the course is achieving its stated learning outcomes. CPEC consists of IAC members and ET faculty and performs its function by

(a) Evaluating each student's oral presentation
(b) Evaluating each project report
(c) Analyzing results of the "Capstone Exam"
(d) Analyzing results of the "Student Self-assessment of Course Outcomes"
(e) Analyzing results of the "Course Matrix"

The course matrix, which is not described in this paper, is part of the program CIP. CPEC uses the results of evaluating the oral presentations, project reports, capstone exam, student self-assessment of course outcomes, and results of the course matrix to determine if the course is achieving its stated objectives. The committee, as a group, assigns a rating (1 to 5) to each learning outcome according to the following guidelines.

5 = outcome is 91% to 100% achieved
4 = outcome is 81% to 90% achieved
3 = outcome is 71% to 80% achieved
2 = outcome is 61% to 70% achieved
1 = outcome is less than 60% achieved

CPEC recently evaluated fall 2004 projects. The results are show in Table 1. As you can see from the table, most course outcomes were broken into two or more categories to allow a better assessment by the committee. Overall, the committee was very satisfied with the improvements that have taken place since last year.

Course Outcoms	F04
Identify, analyze, and solve technical problems	
Students are able to identify and define the problem.	5
Students are able to analyze the problem.	5
Students are able to present/choose a workable/acceptable solution.	5
Students are able to present and discuss results	4
Apply creativity in the design of systems, components, or processes	
Apply creativity in the design of components	4
Apply creativity in the design of processes	4
Use modern software and hardware tools	
Use modern software tools	5
Use modern hardware tools	5
Students are able to apply engineering methods and techniques to carrying out the project	4
Apply project management tools for managing a project	5
Communicate effectively (oral and written)	
Presentations are appropriate for technical and expert audiences.	5
Reports are clear, readable, and complete	4
Recognize the need for, and an ability to engage in lifelong learning	
Recognize the need for lifelong learning	5
An ability to engage in lifelong learning	5
Recognize the need for quality, timeliness, and continuous improvement	
Recognize the need for quality	5
Recognize the need for timeliness	5
Recognize the need for continuous improvement	5
Have the ability to understand professional, ethical, and social responsibilities	
Have the ability to understand professional responsibilities	5
Have the ability to understand ethical responsibilities	5
Have the ability to understand social responsibilities	5

Conclusion

This paper describes the new structure of the Capstone Projects and the Project Management & Justification courses in order to ensure consistency in the quality of the engineering technology capstone projects at A&M-CC. All indications seem to support our belief that this new approach provides students the opportunity to design, implement, and present successful projects. This paper describes the changes and briefly presents the progress that has been made so far.

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