

AC 2010-362: REVITALIZING A CAPSTONE DESIGN SEQUENCE WITH INDUSTRIAL PROJECT MANAGEMENT TECHNIQUES

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Revitalizing a Capstone Design Sequence with Industrial Project Management Techniques

Abstract

The capstone design experience is a staple in many engineering programs throughout the nation. The purpose of these courses or sequences often includes the execution of an applied research project where students have a culminating design experience, and an opportunity to complete engineering design tasks. At _____, the objective of the capstone sequence in the Electrical Engineering Program is primarily focused on the design and execution of applied research or industrial sponsored projects. Over time, the faculty have assessed that the students struggle with elements of project execution such as planning and meeting intermediate deadlines. In order to improve the student learning, the faculty has revitalized the design sequence by incorporating project management techniques often found in the industrial setting.

The new additions to the sequence include a score card rating system and the inclusion of project management techniques and strategies. Student teams present the current state of their work during design reviews to faculty. A score card rating has been implemented in these design reviews to establish go/no-go guidelines and immediate feedback for the students. Students are instructed in project management techniques and the structuring of the sequence to pattern these techniques has been implemented.

This paper will briefly describe the current course structure and the assessment of the sequence. The score card rating of design reviews and the inclusion of project management techniques will be discussed. The effectiveness of the new strategies will also be presented.

Introduction

In the Electrical Engineering (EE) Program at _____, each student takes a senior capstone design sequence prior to graduation. Over time, it has been observed and assessed by faculty that students have difficulty adequately planning their project which often impacts the manner in which the project is completed. Through results of the assessment process, the faculty has decided to include project management techniques and a scorecard rating system to better aid and guide the students through this process. This paper will present the structure of this capstone sequence, the assessment of the sequence, the newly incorporated changes, and the results of these changes.

Capstone Sequence Structure

The main purpose of the capstone experience in the Electrical Engineering Program at _____ is to provide a forum for students to be involved in a culminating project experience in support of ABET Criteria 5.¹ The senior project experience is a two semester sequence comprised of a one credit hour fall course (EE 400) and a three credit hour spring course (EE 401). During the first semester, the class is focused on design methodology and decision-making. The course includes professional issues, and the planning and design phase of the project culminating with

oral and written reports. The objectives of this course are to further develop design skills, develop teamwork skills, learn to deal with situations in an ethical manner, and design and write the senior project proposal. Also in this course, students are placed on teams and assigned either industrial or applied research projects. The student teams initiate and plan the project during the fall semester and execute, monitor, and close the project during the spring semester. Each team has a faculty sponsor and industrial sponsor, if appropriate.

The second course in this sequence is EE 401. This course is constructed so that the student will assume the primary responsibility for the completion of the project. At the end of this course, students have completed a major capstone design experience and can demonstrate their ability to design, build, and test a system to meet specified criteria. Also, students exhibit their capability to communicate their project design and results in a written format and in an oral presentation.

Assessment of Capstone Sequence

The _____ EE program is a relatively young program producing its first graduates in May 2004. Prior to engineering programs, _____ was home to three engineering technology programs from which the new engineering programs grew. The three new programs in civil, electrical, and mechanical engineering at _____ received ABET accreditation in 2004. The EE program assessment plan is a multi prong plan which uses several instruments in program assessment.² These instruments include rubric scoring of student work, student self assessment, FE scores, and annual course review. During course review, the faculty discusses all of the courses offered during the previous year and the changes that need to occur in the courses to meet the assessment goals and to improve the next offering.³

The capstone design sequence is heavily assessed by the _____ EE faculty in support of the ABET Criterion 3 A-K program outcomes.^{1,2} Rubrics and course review are used to assess these courses. A summary of the major assessment results since the creation of the program are listed in Table 1 below. Throughout the years of offering these courses, the student performance has continued to improve. However, it has been noted that students continued to struggle with setting project milestones and to understand the project planning process.

Table 1: Summary of Assessment Results for Capstone Design Courses

Year	Assessment Result
2004	Project timeline developed in fall semester, project driven by timeline
2004	Students noted progress in logbook through year. Logbooks found to be ineffective.
2005	Faculty noted the need for more formal project milestones through the year
2005	Students submitted weekly progress reports rather than logbooks
2006	Established monthly design reviews as well as continued weekly meetings.
2007	Course restructured with firmer deadlines so that students had a better understanding of their final grade.
2008	Incorporated three design reviews and project deadlines into sequence
2009	Include project milestones in fall and spring semester
2009	More emphasis placed on project and time management

Changes to Design Sequence

In order to address the concerns exposed during the assessment process, it was determined by the faculty that the following major changes should be implemented in the design sequence:

- 1) Include more project management topics into the first semester of the sequence;
- 2) Require each team to create a Project Management Workbook;
- 3) Allow student team to set deliverables and dates for design reviews; and
- 4) Implement a Score Card Rating System for design reviews.

First Semester Topical Outline

In the past, the first course included a variety of topics which were chosen to aid students in their project and to foster discussions of professional issues. As mentioned previously, the student teams begin planning their projects during the first semester of the design sequence. The new course outline for this semester is shown in Table 2 below. New topics in project management are discussed throughout the semester. These topics are indicated by bold font in the table below. The weekly deliverables for each team are the various components of the project management workbook to be discussed. The student presentations are italicized in the table below.

Table 2: EE 400 Course Outline

Week	Discussion Topic
1	Course Outline, Resume Writing
2	Project Requirements (High level overview and Stakeholders), <i>Status Meetings</i>
3	Scope (Product description, Product acceptance criteria, Project Deliverables), <i>Status Meetings</i>
4	Scope (Project exclusions, constraints, assumptions, Preliminary Budget, Project Risks, Change Control Plan), <i>Status Meetings</i>
5	Scope (Patent search), <i>Status Meetings</i>
6	<i>Design Reviews</i>
7	Project Planning (Work Breakdown Structure), <i>Status Meetings</i>
8	Project Planning (Activity Sequencing, Timeline, Roles and Responsibilities), <i>Status Meetings</i>
9	Standards, <i>Status Meetings</i>
10	ABET Discussion
11	<i>Status Meetings</i>
12	<i>Status Meetings</i>
13	<i>Status Meetings</i>
14	<i>Status Meetings</i>
15	<i>Design Reviews</i>

Status Meetings and Design Reviews

Embedded in this sequence are several mechanisms for students to report their work and to garner feedback from faculty. These include status reports, status meetings, and design reviews.

Status reports are short weekly reports in memo format that the students submit to the faculty outlining their progress during the week and action items for the upcoming week. Status meetings are short weekly meetings between the project team and the faculty in which the status reports are discussed. Design reviews are more formal meetings where the project teams prepare a presentation outlining their progress since the last design review. Status meetings are attended by the faculty member serving as the course administrator while the design reviews are usually attended by the majority of the EE faculty.

Student teams begin weekly status meetings approximately three weeks into the first semester of the project sequence. At these meetings, the student teams update the faculty on their progress and satisfaction of project timeline activities. These status meetings continue weekly during the spring semester. Prior to each progress meeting, the team must submit a status report. Also, approximately five design reviews are scheduled for each team during the academic year to detail the status of their project to the faculty via formal presentation. During the design reviews, the faculty evaluates team progress toward the established project milestones. Failure to meet the milestones will affect the final grade.

Project Management Workbook

In order to add more structure and rigor to the student planning process, each team is now required to complete a Project Management Workbook.⁴ The workbook is composed of three main sections to be completed during the sequence. These sections include the Project Management Plan, Requirements Documents, and the Execution and Closing. The first two sections are created during the fall semester of the sequence. During the second semester, the first two sections are modified as appropriate and the third section is written. At the end of the sequence, the students have created a complete document outlining their project work. Each of these workbook sections will be described below.

Project Management Plan

The Project Management Plan is composed of the Project Requirements, Scope, and Project Planning. In this section of the workbook, the project teams basically define and outline the project specifications. The Project Requirements include a high level project overview and the identification of the project stakeholders including the faculty and technical sponsor. The section of the notebook labeled Scope is a compilation of the following information: product description, acceptance criteria, deliverables, exclusions, constraints, assumptions, preliminary budget, project risks, change control plan, and patent search. The Project Planning section includes the work breakdown structure, the sequence of activities, the project timeline, and the definition of roles and responsibilities. At the completion of this section, the project teams have done the necessary research and planning to begin the solution of their design problem.

Requirements Documents

The second section of the Project Management Workbook is the Requirements Documents. These documents are the next step in the progression of project planning. This section includes the following documentations:

- Functional block diagram for both the hardware and software;
- Hardware embedded system tradeoff analysis with three possible solutions and Pugh Matrices;
- Software design which includes the specifics of the software requirements, software design documentation, and the justification of the embedded system solution;
- Proof of concept which includes schematics;
- Agency approval requirements;
- Risk management plan;
- Final budget; and
- Test plan and the test equipment requirements.

Once this section is complete, the project teams have thoroughly planned for the execution and implementation of their project. Also, the teams will have generated documentation necessary to guide them through the completion of their project.

Execution and Closing

The Execution and Closing section simply documents the execution of the project. This section includes the following:

- Final design including schematics, layouts, power requirements, and software documentation;
- Statement about compliance with recognized safety codes;
- Explanation of problems encountered in design and resolution;
- Discussion of design changes;
- Actual schedule of events and cost of project;
- Results of testing;
- Conclusion; and
- User's manual.

Deliverables and Dates for Design Reviews

The five design reviews are planned during the academic year. The first design review occurs during the fall semester at the completion of the first section of the Project Workbook. At this design review, the students present the documents in the Project Management Plan to the faculty. The faculty then provides students with feedback to their plan. From this feedback, the students modify their plan accordingly as they develop their Requirements Documents. From the project timeline, each team also sets the deliverables for the remaining fall semester design review and the three spring semester design reviews. At the second design review in the fall semester, teams present the second section of the Project Management Workbook, the Requirements Documents, and the status of the first set of deliverables. During the second semester of the sequence, each team has three design reviews in which they discuss the execution of the deliverables defined during the project planning process in the Requirements Documents. Teams are allowed

flexibility in scheduling the dates of the spring design reviews within a specified window of time.

Score Card Rating System

During the design reviews, each faculty member is provided with a rubric customized to each project team with the specific deliverables for that particular design review. The faculty then rates each deliverable according to the score card system in Table 3.

Table 3: Score Card Rating System

Rating	Comments
Red	Major problem with checklist item No fix identified Specification change required to resolve issue Required to resolve to continue project Could cause failing grade for project
Yellow	Minor problem with checklist item Fix identified Specification change not required to resolve issue Required to resolve issue to continue project Could cause an incomplete grade for project
Green	No issue with checklist item
Blank	Checklist item does not apply to this project

Shortly following the design review, the teams are provided with their rating for each deliverable and any additional faculty comments. Any item that receives a yellow or red rating is discussed weekly at each progress meeting and revisited at the next design review to ensure that the issue is corrected. If red or yellow items are not corrected satisfactorily, students can receive a failing grade for the course. By incorporating the score card rating system as part of the design review feedback, the design reviews have become a no/no-go gateway for the student project teams.

Effectiveness of New Strategies

The changes to the design sequences have produced positive results. First, the student teams now provide more complete planning documents. By requiring the teams to complete the first two sections of the workbook in the fall semester, the teams have thoroughly understood their design project and have planned the execution of the project according to project management techniques. Through this process the students take ownership in their projects more quickly than in the past. One of the challenges of these courses is to have students focused and on task for a full academic year with relatively few intermediate deadlines. By requiring a variety of project documents at intervals throughout the semester, teams seem to stay more focused and on task. These changes have added more structure and definition of expectations for students. Incorporation of the project management topics has also produced better quality of work from the student teams. These changes have made it easier to determine when a student is not fully participating as a team member.

The only issue resulting from these changes is that more faculty monitoring is required throughout the semester. Significant constant monitoring of student work and documentation is required by the course administrator and faculty team sponsor. These new changes will continue to be used in the design sequence because of the extremely positive results. However, it has been noted that it would be easier for faculty to score the rubrics if more than three choices were available. In other words, “shades of colors” would be useful on the score card rubric instead of simply three choices.

Conclusion

Through the assessment process, the faculty in the _____ EE program made several changes to the capstone design sequence in order to improve student performance and to meet the assessment goals for the sequence. These changes include incorporating project management topics into the course outline, requiring a Project Management Workbook, allowing teams to set design review deliverables and dates, and implementing a score card review system to the design reviews to provide timely feedback to the project teams. These changes have been extremely successful and will continue to be refined in future sequence offerings.

Bibliography

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