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## **AC 2011-432: ASSESSING AND IMPROVING A CAPSTONE DESIGN SE- QUENCE WITH INDUSTRIAL PROJECT MANAGEMENT TECHNIQUES**

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# Assessing and Improving a Capstone Design Sequence with Industrial Project Management Techniques

## Introduction

The Western Kentucky University Electrical Engineering Program requires each student to complete a senior capstone experience. Project management techniques were incorporated as a result of the program assessment process. Throughout the years of offering these courses, the student performance has continued to improve. However, it was noted that students continued to struggle with setting project milestones and faculty had not given adequate intermediate feedback to students during the year. Therefore it was determined through the course assessment that more formal milestone development and appraisal should be incorporated into the courses. In order to address the concerns exposed during the assessment process, the following changes were implemented:

- Require each team to create a Project Management Workbook; and
- Implement Score Card Rating System for Design Reviews.

Embedded in this sequence are several mechanisms for students to report their work and to garner feedback from the faculty. These include status meetings, design reviews, and the project workbook. Project management techniques were incorporated into the design reviews through the score card rating system and the throughout the workbook. After these changes were implemented, faculty and student assessment were used to modify and revise this process. This paper includes a discussion of the initial changes to the senior project sequence, faculty and student assessment, and resulting revisions to the project management techniques.

## Additions to Senior Project Sequence

In order to meet the needs revealed in the assessment process, project management techniques were added to the project documentation and a score card rating system was added to the design reviews.

The Project Workbook is a document that contains the project planning and execution documents. The workbook contains three main sections:

- I. Project Management Plan;
- II. Requirements Documents; and
- III. Execution and Closing.

Each of these sections will be described below.

In the Project Management Plan shown in Figure 1, the students define the attributes of the project in an effort create a detailed statement of work. A more thorough description of the components of the Project Management Plan is provided in the referenced documents.<sup>1,2</sup>

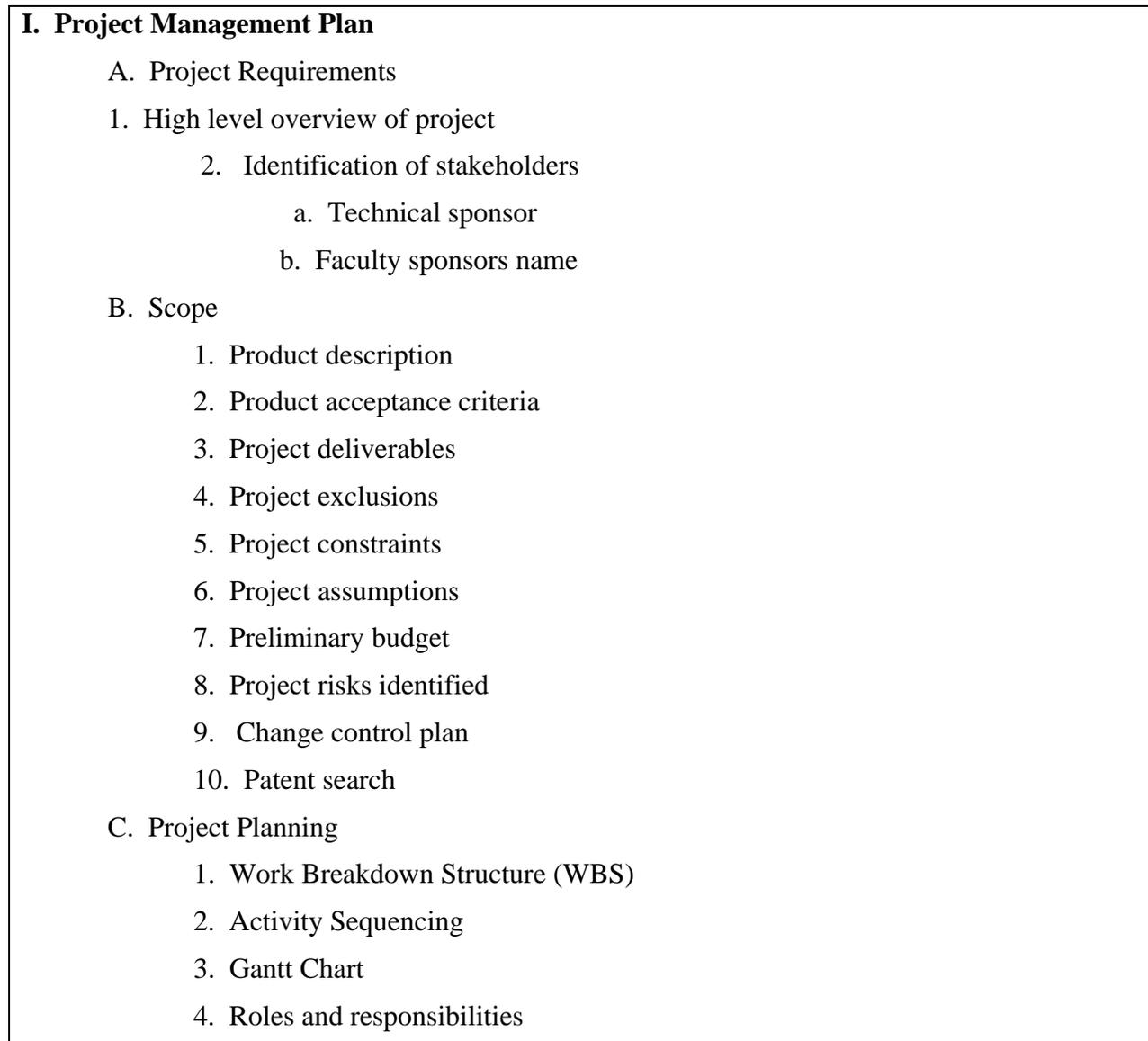


Figure 1: Project Management Plan of Project Workbook

The second part of the Project Workbook is developing the Requirements Documents shown below in Figure 2. In this section, the student design teams complete the design and analysis task associated with meeting the project deliverables.<sup>1,2</sup>

## **II. Requirements documents**

- A. Functional block diagram (hardware and software)
- B. Hardware and Embedded System Tradeoff Analysis
  - 1. Three possible solutions
  - 2. Pugh Matrices
- C. Software Design
  - 1. Software requirements specifics
  - 2. Software design document including flow chart
  - 3. Justification of embedded system solution
- D. Proof of Concept (Schematics)
- E. Agency Approval Requirements
- F. ABET Documentation
- G. Risk Management Plan
- H. Final Budget
- I. Demonstration of Design
  - 1. Test plan
  - 2. Test equipment requirements

Figure 2: Requirements Documents of Project Workbook

After the planning and design phase in the first two sections of the outline, the students complete the Execution and Closing section of the workbook at the end of the project sequence to document the execution and testing of the project design.<sup>1,2</sup> The components of this section are shown in the figure below.

### **III. Execution and Closing**

- A. Final design
- B. Design Results
  - 1. Input/output data, power requirements, etc.
  - 2. Statement about compliance with recognized safety codes if appropriate
  - 3. Statement of problems encountered in design and how problems were resolved
  - 4. Discuss design changes
  - 5. Schematics
  - 6. Actual schedule of events
  - 7. Cost of project
- C. Results of testing
- D. Conclusion
- E. User's manual
- F. Final presentation
- G. Spec sheets
- H. Status reports
- I. CD (includes all documentation, code, schematics, presentations, etc.)

Figure 3: Execution and Closing section of Workbook Outline

Design reviews occur throughout the year and are a forum for students to present sections of the workbook as completed and receive feedback from the faculty. From this feedback, the students are able to gauge the success of their project. A score card rating system was implemented to provide students with detailed feedback of the project status. 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. 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 meetings 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 student project teams.

Table 1: Score Card Rating System

<b>Rating</b>	<b>Comments</b>
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 project 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

### Assessment of Project Management Techniques

To assess of the additions to the senior project sequence, faculty and students were asked to complete a survey. On this survey, participants were asked to rate the effectiveness of the following items by considering the usefulness of each item in the completion of the senior project:

- Workbook structure;
- Completing sections of the workbook throughout the year;
- Design reviews; and
- Status reports and meetings.

The results of this assessment are shown in the table below. Each item was rated on a scale of 1-10 (with 10 being the highest and 1 being the lowest).

Table 2: Assessment Results

	Students		Faculty	
	Average	Standard Deviation	Average	Standard Deviation
Workbook structure	8.42	1.38	8.67	0.58
Completion of sections of workbook throughout academic year	8.33	1.07	8.67	0.58
Design Reviews	8.75	0.87	9.00	1.00
Status reports and meetings	8.17	1.27	8.67	0.58

As seen from the table above, faculty and students both assessed these changes as useful to the completion of the senior project. Students were also given the opportunity to comment on several items. The following are student comments on the pace of senior project sequence:

- The sequence seemed rushed in the fall.
- The pace was fine.
- Even though we finished early, a faster pace might be needed the first semester
- The pace was set so that our team had to work diligently but it was nothing that couldn't be handled
- Just the right amount of work
- Course kept a good pace throughout the year. Faster at beginning than at end which I thought was good. Got the teams rolling in the beginning.
- It kept us on track to discuss everything weekly
- Everything came together well with the project
- Good pace
- The pace was okay for a two semester program
- Good pace for project to be completed

Students also provided comments on the positive and negative aspects of the capstone design sequence which are listed below:

- I learned a lot. It was a great learning experience.
- It did make sure everything was done.
- The project planning was very useful

- Lots of planning helps to prevent bad designs
  - I learned a tremendous amount about the project design sequence and working with a team
  - Working with a factory sponsor was a good experience for me.
  - I like the set organizational structure at the beginning of the year
  - There was a good flow of project. Everything was already lined out for us to do regarding the steps to take
  - Gives good experience designing a project from start to finish
  - Good experience for meeting deadlines and completing a project from beginning to finish
- Student also commented on the negative aspects of the capstone design sequence which are listed below:
- Some of the documents seemed repetitive
  - Some of the workbook stuff seemed repetitive and unnecessary
  - Parts of the workbook was overkill
  - Some parts of the workbook were unnecessary
  - Some work seemed unnecessary
  - Sometimes status meetings were unnecessary
  - Some redundancy in workbook
  - There is some redundant information that we have to provide in workbook

Faculty were given the opportunity to comment on same items. The following are faculty comments on the pace of senior project sequence:

- The students did a good job on moving projects forward toward completion.
- Groups had no major issues in completing projects.
- The students completed the planning portion of the outline during the fall semester and the execution and closing components during the spring semester.
- The students created a Work Breakdown Structure which broke the project into small tasks. These tasks were then sequenced and put into a Gantt Chart.

The faculty provided comments on the positive and negative aspects of the capstone design sequence which are listed below:

- Students deal with economics, vendors, and timelines.
- Students are required to use skills developed from many different classes.

- Students work on a team and interact with faculty and industrial sponsors.
- Some teams have difficulty working together.
- Some problems are difficult to solve during the time constraints of the course.
- The implementation of the Workbook outline and project management structure into the senior design sequence has resulted in a huge improvement in student time management and documentation.

Faculty noted that more faculty monitoring was required throughout the semester. Significant constant monitoring of student work and documentation was required by the course administrator and faculty team sponsor. It was determined to continue with the project management techniques with some modification and revision because of the extremely positive results. However, it was noted that it would be easier for faculty to score the rubrics if more than three choices available.

#### Refinements of Project Management Techniques

Through the assessment process and the implementation of the project management techniques, faculty decided to modify the techniques to be more effective. First more rankings were added to the score card rating system for design reviews. Now faculty can choose from five rankings; green, chartreuse, yellow, orange, and red; to provide students with accurate assessments of their project progress. The more detailed rankings have proven to be an effective modification to the design reviews.

Second, it was also determined that the Workbook Table of Contents should be modified for effectiveness and to remove redundancy in the required documents. The basic outline of the Project Management Plan remained the same except the second section of the workbook was divided into two sections:

- I. Project Management Plan
- II. Design Documents
- III. Supporting Documents
- IV. Execution and Closing

The major changes to the workbook structure will be discussed.

The required sections of the design documents of the workbook were simplified because of redundancy and for clarification. The table below shows a comparison of the original requirements compared to the new requirements.

Table 3: Revision of II. Design Documents Scope Outline

<b>Original Section</b>	<b>Revised Section</b>
<p>B. Scope</p> <ol style="list-style-type: none"> <li>1. Product description</li> <li>2. Product acceptance criteria</li> <li>3. Project deliverables</li> <li>4. Project exclusions</li> <li>5. Project constraints</li> <li>6. Project assumptions</li> <li>7. Preliminary budget</li> <li>8. Project risks identified</li> <li>9. Change control plan</li> <li>10. Patent search</li> </ol>	<p>B. Scope</p> <ol style="list-style-type: none"> <li>1. Product description</li> <li>2. Project deliverables</li> <li>3. Preliminary budget</li> <li>4. Project risks identified</li> <li>5. Change control plan (to be provided)</li> <li>6. Patent search</li> </ol>

The project planning section remained the same except for the addition of the Activity Requirements Documents. This document is a table which lists the dates of design reviews and the proposed deliverables for the design review. The information in this table is gathered from the Gantt chart. The purpose of this document is to keep the students focused on the deliverables required at each design review and aid the faculty in locating the deliverables. The format for the Activity Requirements Document is shown in the table below.

Table 4: Activity Requirements Document Template

<b>Design Review</b>	<b>Date</b>	<b>Deliverables</b>
I	October	
II	December	
III	February	
IV	March	
V	April	

The second section of the outline was revised into two sections for clarity. The new outline is compared to the original outline in the table below.

Table 5: Revision of Requirements Documents Outline

Original Section	Revised Section
<p>II. Requirements documents</p> <p>A. Functional block diagram (hardware and software)</p> <p>B. Hardware and Embedded System Tradeoff Analysis</p> <ol style="list-style-type: none"> <li>1. Three possible solutions</li> <li>2. Pugh Matrices</li> </ol> <p>C. Software Design</p> <ol style="list-style-type: none"> <li>1. Software requirements specifics</li> <li>2. Software design document including flow chart</li> <li>3. Justification of embedded system solution</li> </ol> <p>D. Proof of Concept (Schematics)</p> <p>E. Agency Approval Requirements</p> <p>F. ABET Documentation</p> <p>G. Risk Management Plan</p> <p>H. Final Budget</p> <p>I. Demonstration of Design</p> <ol style="list-style-type: none"> <li>1. Test plan</li> <li>2. Test equipment requirements</li> </ol>	<p>II. Design Documents</p> <p>A. Hardware</p> <ol style="list-style-type: none"> <li>1. Functional block diagram</li> <li>2. Hardware Tradeoff Analysis (Pugh Matrix)</li> <li>3. Justification of hardware solution</li> </ol> <p>B. Software</p> <ol style="list-style-type: none"> <li>1. Embedded System Tradeoff Analysis (Pugh Matrix)</li> <li>2. Justification of embedded system solution</li> <li>3. Software requirements specifics</li> <li>4. Functional block diagram</li> <li>5. Software design document including flow chart</li> </ol> <p>C. Input/output data, power requirements, etc.</p> <p>D. Demonstration of Design</p> <ol style="list-style-type: none"> <li>1. Test plan</li> <li>2. Test equipment requirements</li> </ol> <p>III. Supporting Documents</p> <p>A. Compliance with recognized safety codes and standards</p> <p>B. ABET Documentation</p> <p>C. Risk Management Plan</p> <p>D. Final Budget</p>

The execution and closing section of the workbook was not modified.

## Conclusion

Assessment of student and faculty clearly showed where the sequence could be improved. These improvements removed redundancy from the required documentation. The changes to the design sequences have produced positive results. The student teams are more complete and thorough in the project planning process. Student project planning and execution continues to improve. The design sequences will continue to be assessed and refined.

## Bibliography

<sup>1</sup>Wilson, Stacy and Michael McIntyre. "Revitalizing a Capstone Design Sequence with Industrial Project Management Techniques," Proceedings of the ASEE National Conference, Louisville, KY, June 2010.

<sup>2</sup>McIntyre, Michael and Stacy Wilson. "Introducing Project Management Theory into a Capstone Design Sequence," Proceedings of the IEEE Annual Global Engineering Education Conference, Madrid, Spain, April 2010.