AC 2012-3439: ASSESSMENT OF PROJECT COMPLETION FOR CAPSTONE DESIGN PROJECTS

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Assessment of Project Completion for Capstone Design Projects

Abstract

The Capstone Design project has become a significant educational experience for the student in the preparation of their professional skills and the application of their growing technical expertise. The typical design process experience includes Problem Definition, Concept Generation, Preliminary Design, Detail Design, and Communication of Results. However, the end result of this process is ultimately Solution of the Problem which often receives little attention in the academic setting.

A successful Capstone Design program including companion design courses has been developed that has become an integral and important component of the Mechanical Engineering curriculum at the University of California, Santa Barbara. A variety of challenging projects are created each year to appeal to varied student academic and career interests. Students work in teams with the assistance of a faculty advisor to tackle a significant Mechanical Engineering Capstone Design project. The design experience and course experience includes defining the problems to be addressed with formal Design Requirements and identifying how the problems will be solved with a formal Project Plan. As the design and the project evolve, the course experience includes a Design Review and an Engineering Report. For those students that have not had the benefit of professional work experience or internships, these course deliverables provide an initiation and foundation for their professional engineering careers.

Objective assessment of the course deliverables is difficult for Capstone Design projects and courses. There is excellent published literature that provides guidance based upon learning outcomes and the design process. The design process within the Capstone course may be conducted in three assessments including Problem Scoping, Concept Generation and Solution Realization. There is some published literature regarding scoring rubrics that are helpful for assessing communication skills as demonstrated in a report or presentation for course grading purposes. However, there is a noted absence regarding the expectations and assessments regarding the final outcome of the design project, Solution of the Defined Problems (or Solution Assets).

Little attention has been given by instructors and as a result little guidance has been provided to the students regarding the expectations and assessment of Project Completion within the context of Solution Realization for Capstone projects. The Capstone project provides a unique experience regarding problem solving for the student. The students and teams should be held accountable in providing a formal definition of expected Project Completion outcomes and should provide objective evidence of problems solution and project completion. This paper will address the course deliverables and experiences of the demonstration and assessment of Project Completion as it has evolved. The evolution of the course deliverables now more clearly addresses Project Completion and Problem Solution. Students and teams have demonstrated the ability to define the problems that need to be solved and now must clearly provide objective evidence of solving the problems that have been defined. This assessment is conducted separate from the quality of communication skills typically assessed by a final report or design review.

Introduction

The Capstone Design Projects course is now required for all senior Mechanical Engineering students at the University of California, Santa Barbara and is taken in the final year for two units each quarter. This course was developed^{1,2} to provide the students an experience of working as a project team to address a practical and significant design and build project. The importance of individual roles and responsibilities while working as a team is emphasized.

Students work in teams of three to five with the assistance of a faculty adviser. Engineering deliverables in the form of Prototyping, Testing, Modeling, and Analysis are required each quarter. Engineering communication in the form of oral presentations, design reviews, and reports is addressed throughout the course and project experience. We emphasize a practical, hands-on experience, and integrate analytical and design skills.

The ME Capstone Design Projects include the following types of projects:

- 1) **Industry Partner** projects are supported by gifts to the program. Students have an opportunity to work on practical design projects and to interact with outside engineers.
- 2) **Research Partner** projects are supported by research or University funding to support current University research projects. Students have an opportunity to work with leading international researchers, graduate students, and research laboratories.
- 3) **Student Organizations and Design Competitions** include Engineers Without Borders and SAE design competitions.
- 4) **Student and Faculty Created Projects** include creative and challenging projects with an entrepreneurial perspective.

A variety of challenging projects are created each year to appeal to varied student academic and career interests. Student project selection and team formation can be a challenging and time consuming process that is critical to the success of the design project and course experience. Successful student teams should include enthusiastic, motivated and engaged students^{3,4}. This paper will not address how that projects are selected as this has been previously reported^{3,4}.

The typical design process experience includes Problem Definition, Concept Generation, Preliminary Design, Detail Design, and Communication of Results⁵. However, the end result of this process is ultimately Solution of the Problem which often receives little attention in the academic setting.

There is excellent published literature^{6,7} that provides guidance based upon learning outcomes and the design process. Common design phases, processes, and products for Capstone projects has been described⁸ and provided a foundation for the course experience. Classroom learning activities have also been described⁹.

There is some published literature regarding the review and assessment of design projects. However, there is a noted absence regarding the expectations and assessments regarding the final outcome of the design project, Solution of the Defined Problems (or Solution Assets). An attempt to assess design outcomes¹⁰ has been described in an attempt to measure the “goodness”

of a design outcome. A Customer Satisfaction Survey and Design Quality Rubric were used. Although of limited use these instruments fail to capture and assess the Solution Assets with Solution of the Problem. The use of scoring rubrics for the assessment of senior design projects¹¹ has been described. However, use of these rubrics are focused more upon "...streamlining the assessment process, resulting in a reduction in faculty assessment workload." The assessment of the quality of student design reports¹² using rubrics has been described. These rubrics, however, are limited to evaluating reports and indicated that refinement was necessary. An attempt to assess creativity in design assessment¹³ has been the focus of interesting research but does not yet provide practical assessment methodology. The use of Management By Objective (MBO) has been reported¹⁴ and provides good insight into the use of students establishing self goals and evaluation of goal achievement. The use of scoring rubrics that are helpful for assessing communication skills as demonstrated in a report or presentation for course grading purposes has also been reported¹⁵.

Literature of particular interest describes assessments for three performance areas in Capstone Engineering Design¹⁶. The authors defined four areas of performance:

- 1) Personal Capacity
- 2) Team Processes
- 3) Solution Requirements
- 4) Solution Assets

Assessment instruments have been developed for three of the four performance areas with Solution Assets remaining to be addressed.

This paper is intended to address the development and evolution of the course deliverables as they relate to the design process, the course experience and Project Completion. Difficulties were encountered and addressed over the years regarding the assessment of the final outcomes of the design projects. The evolution of the course deliverables now more clearly addresses Project Completion and Problem Solution. The Capstone design project provides a unique experience regarding problem solving for the student. This paper will provide examples of course deliverables and provide some guidance for other programs to consider.

Capstone Design Projects Course Outcomes and Objectives

The Capstone Design Projects course is typical for a course of this type. The topics covered by the course include:

- Formation of Teams
- Development of a Project Plan
- Design Research
- Development of Concepts and Designs
- Design Development
- Prototyping
- Design Analyses
- Testing and Evaluation
- Final Design
- Engineering reporting including presentations, design reviews, and technical reports

The course grading was originally in-progress grading for the Fall and Winter quarter. A final grade was determined in the Spring quarter after completion of the project and all course deliverables. After determination of the final grade, this was reflected retroactively for the Fall and Winter quarters. This created administrative issues and created an atmosphere of delayed achievement with a negative impact upon the course. In-progress grading was abandoned after the second year of experience in favor of well defined course deliverables with team grades and individual grades determined each quarter.

The development of standardized course deliverables for each academic quarter with a variety of challenging projects was required in the academic setting. Common design phases, processes, and products for Capstone projects has been described⁸ and provided a foundation for the course experience and the development of course deliverables (see Table 1 and Table 2).

Table 1. Common Design Phases, Processes, and Products for Capstone Projects⁸

Design Phases	Design Processes/Activities	Design Products
Problem Scoping	Analyze Product Opportunity	Product Opportunity Proposal
	Clearly Define the Problem	Problem Definition
Concept Generation	Generate Alternative Concepts	Concept Variants
	Select Concept	Concept Selection
Solution Realization	Design Product	Final Design
	Communicate Design	Final Design Communication

Table 2. Design Process and Solution Assets assessment instruments⁸

Design Phases	Design Process Assessments	Solution Assets Assessments
Problem Scoping	Problem Scoping Process	Problem Definition
	- analyzing product opportunities - defining the design problem	- communication of problem definition - quality of the problem definition
Concept Generation	Concept Generation Processes	Selected Concept
	- generating alternative concepts - selecting a concept	- communication of the selected concept - quality of the concept
Solution Realization	Solution Realization Processes	Proposed Solution
	- designing product solution - validating product solution	- communication of the design solution - quality of the solution

The academic ME Capstone course activities are the same for all projects and project types:

Fall Quarter Activities

- Project selection, Formation of Teams
- Design Research
- Prototyping, Testing, Modeling and Analyses
- Development of Concepts and Designs
- Development of Project Plans
- Development of Product Design Specifications
- Project Presentation

Winter Quarter Activities

- Design Development activities
- Project Planning Activities
- Prototyping, Testing, Modeling and Analyses
- Preliminary Design Review
- Engineering Project Report

Spring Quarter Activities

- Design Development Activities
- Project Planning Activities
- Prototyping, Testing, Modeling and Analyses
- Complete Project Binder
- Completion of Design Project
- Poster Competition

Course Deliverables

The initial development of our Capstone Design Program has been described¹. The initial emphasis was on creating challenging projects. The course was created to provide the students an experience of working as a project team to address a practical and significant design and build project. The importance of working as a team with individual roles and responsibilities within the team was emphasized. A broad selection of projects, common course deliverables and common expected completion dates would provide a structured format for the student efforts and faculty evaluations.

The conceptual basis for the course experience is simplistically depicted in Figure 1.

Team Dynamics

Figure 1. LEARN BY DOING!

This very simple figure is used to graphically reinforce the critical aspects of the Capstone Course experience for the students. The basis of the course experience places an emphasis upon **“Team Dynamics”** through performance and achievement. The students and teams are advised at the start of the course that excellence may only be achieved by excelling at both **“Design & Build”** and **“Plan & Communicate”**. The **“Design & Build”** deliverables include the engineering deliverables of Prototyping, Testing, Modeling and Analysis. The **“Plan & Communicate”** deliverables include engineering communication including project plans, design specifications, presentations, design reviews, and reports. The project and course deliverables are completed as a team. The students and teams are advised at the start of the course that the best way to ensure success is through teamwork. The team must demonstrate achievement with the design and build of their end project and must communicate their results and achievements. A clear distinction is established at the very start of the course between **“Design & Build”** and **“Plan & Communicate”**.

As may be seen by reviewing the Fall, Winter, and Spring course activities, The Fall activities place a heavier emphasis upon **“Plan & Communicate”** course deliverables. The Winter activities witness a transition with equal emphasis between **“Plan & Communicate”** and **“Design and Build”**. The Spring activities place a heavier emphasis upon the **“Design & Build”** course deliverables.

The design process within a Capstone course has been described and may be conducted in three assessments⁹ including Problem Scoping, Concept Generation and Solution Realization. Within this context, the Fall activities may be best described as Problem Scoping, the Winter as Concept Generation and the Spring as Solution Realization.

The course deliverables for the Fall quarter include the development of a Project Plan document, a Product Design Specifications document, the start of a Project Binder that includes copies of all documents, reports, drawings, and meeting minutes. A Project Presentation is conducted at the end of the quarter with the students and teams presenting the results of the efforts regarding the Problem to be addressed, how the Problem will be addressed, and the Concept Generation for Solution of the Problem. Templates are provided for the students and teams for the Project Plan

document, Product Design Specification document, Meeting Minutes, Presentation, and Binder. Templates are also provided for the generation of formal Test Methods and Test Reports.

The course deliverables for the Winter quarter include a Preliminary Design Review mid-quarter that addresses the proposed Solution of the Problem with a selected design that is critically reviewed by independent faculty and all project sponsors. An Engineering Report is required at the end of quarter that addresses the probability of success or feasibility of the proposed Solution with the expectation of finalizing their design before the final build in the Spring. The Project Binder is also assessed. Templates and guidance are provided for the Design Review and Engineering Report.

The course deliverables for the Spring quarter include Completion of the Design Project, completion of the Project Binder and a Poster to be displayed at the annual Poster Competition event. The emphasis in the Spring has always been Solution Realization. The experience of a Design Review and an Engineering Report was previously addressed in the Winter quarter. The course emphasis for the Spring was established with a focus on Solution of the Problem in terms of focused student and team efforts and achievements. This was a very deliberate decision from the very beginning of the course. Formal engineering communication of the Completion of the Project has been captured through development of a poster. An unstructured final project review is conducted with the team prior to the Poster Competition through review of their completed Prototyping, Testing, Modeling, and Analysis engineering deliverables. The time, energy, and stress associated with conducting a formal Design Review or generation of an Engineering Report was eliminated in favor of focus upon Solution Realization and Solution Assets.

All project teams are expected to prepare and maintain an electronic copy of a Project Binder that includes Meeting Minutes, copies of Presentations, Design Specifications, Project Plans, Design Reviews, Engineering Reports, design output such as drawings, test reports, and analyses. The final Project Binders at Project Completion are delivered to all sponsoring partners, labs and researchers at the completion of the projects with all software, prototypes, samples, and end products.

There has been some evolution of the course deliverables. This evolution has been based on addressing improvements in the engineering deliverables of Prototyping, Testing, Modeling and Analysis (PTMA) and ultimately Project Completion. There have been no changes regarding the original intent of the Fall, Winter, and Spring activities regarding Problem Scoping, Concept Generation and Solution Realization. There have been improvements in the templates and instruction provided for the engineering communication deliverables including Product Design Specification, Project Plan, Presentation, Design Review, the Engineering Report, and the Project Binder. There has also been minor re-weighting of these communication deliverables. The driving factors for changes and course evolution have been based upon addressing improvements in Solution Realization and Solution Assets.

Originally, the course did not provide for scoring and formal appreciation of efforts regarding the engineering deliverables of PTMA. The only evaluations and scoring for course grading purposes was based upon the communication deliverables that were required each quarter and that were assumed to be supported by the engineering deliverables. However, improvements

were needed, particularly in the Fall, with increased efforts and achievements in the engineering deliverables. In the professional setting and for the better student teams, the engineering deliverables that are needed to support the communication deliverables are understood and straight-forward. However, in the academic setting, unless there is a formal weighting and scoring for grading purposes, the best way to ensure efforts and achievements is to require output and to evaluate and score the output with a grading impact.

We have seen minor changes in the weighting of PTMA each quarter. As has been previously described, the course and the projects transition from Problem Scoping to Concept Generation to Solution Realization. The Fall quarter places heavier emphasis on the Plan & Communicate, the Winter an equal balance of Plan & Communicate and Design & Build, and the Spring with a heavier emphasis on Design & Build. Conceptually this has never changed. However, to ensure satisfactory attention and performance by all teams each quarter regarding the engineering deliverables associated with Design & Build, formal scoring of PTMA was originated. At present the scoring for PTMA for grading purposes is 15% of the Fall grade, 20% of the Winter grade, 50% of the Spring grade (Project Completion).

The evaluation and scoring of the engineering deliverables of PTMA is conducted separate and distinct from the communication deliverables that are required each quarter. Evidence of Prototyping must be provided by the teams in their Project Binders and end items produced. Evidence of Prototyping activity must also be captured in their Meeting Minutes in their Project Binders. These efforts must be supportive of their intentions regarding Concept Generation and Solution Realization. Evidence regarding formal Testing must be provided by the teams and documented in the Project Binders with formal Test Methods and Test Reports with templates that are provided. Evidence of Modeling and Analysis must include the generation of drawing and analytical models that must be supportive of Concept Generation and Solution Realization.

As stated previously, the emphasis in the Spring quarter has always been Solution Realization. The course emphasis for the Spring was established with a focus on Solution of the Problem in terms of focused student and team efforts and achievements in terms of Design & Build. This was a very deliberate decision from the very beginning of the course. Formal engineering communication of the Completion of the Project has been captured through development of a Poster and their Project Binder. The students and teams have always had the freedom to conduct an unstructured final Project Completion review. These reviews may be conducted at an appropriate location chosen by the team. This could be a university lab, industry partner conference room, or other locations. We have had reviews conducted at the beach for a solar-powered project and automotive garages for vehicles. It was desired to eliminate the stress of conducting a formal Design Review and to eliminate the time and efforts required to generate a final Engineering Report. The desire has always been for the students and teams to focus upon the fabrication and completion of their end items. The final Project Completion review may be conducted in a lab setting with display of the end items, review of test reports and analytical considerations. The final review may also be conducted in conference room setting with PowerPoint slides capturing achievements with the end items on display. The teams are allowed the freedom to conduct this review without the formal structure that had previously been required for the Project Presentations and the Design Reviews. As might be expected, an unstructured review has encountered several difficulties over the years and has evolved. It has also been

extremely rewarding as an instructor to witness Project Completion reviews conducted with professional skills and expertise by a student team that will graduate within weeks and will no longer be regarded as students but professional engineers.

Review of Completed Projects

The Capstone project provides a unique experience regarding problem solving for the student. The students and teams should be held accountable in providing a formal definition of expected Project Completion outcomes and should provide objective evidence of problems solution and project completion. The students and teams have defined the problems to be solved and have documented their Design Requirements in the form of a Product Design Specification. They have defined the Purpose, Scope and have documented how they will solve their defined problem with a Project Plan. They have generated various proposed solutions and concepts, have selected a proposed solution and have critically defended their selection at a Design Review. They formally documented their engineering efforts and achievements with an Engineering Report that addressed the feasibility of their proposed solution and finalized their design prior to final build. The dilemma for the course has been developing a methodology that provides for expectations and assessments regarding the final outcome of the design project, Solution of the Defined Problems (or Solution Assets).

The Project Completion reviews were conducted the first few years with little to no guidance provided to the students and teams. The teams were instructed to provide objective evidence of meeting or satisfying their Product Design Specifications and to conduct a review of this evidence in the form of Prototyping, Testing, Modeling, and Analysis. There was such a wide variation in the quality of the reviews that significant improvements were desired. The reviews have ranged from some teams attempting to conduct a single performance trial during the review to professional quality conference room presentations. For grading purposes, Project Completion review has remained about the same at about 50% of the Spring quarter grade. However, their engineering deliverables (or lack of deliverables) would also indirectly impact their Poster and Project Binder scores. Lack of well defined scoring rubrics and lack of proper guidance has been problematic.

The process has evolved to now include a Project Completion Requirements (PCR) document that is generated by the team. A preliminary document is generated by the team at the end of the Fall quarter. A final PCR document must be reviewed and approved by the instructor at least one month prior to the end of the Spring quarter. The teams begin to understand the expectations for project completion simultaneous with Problem Scoping, Concept Generation and Solution Realization activities.

It is important that the students and teams have self-defined the expected outcomes and have defined the objective evidence that will be generated and presented for review for the Solution of the Problem. As noted previously, in the academic setting, unless there is a formal weighting and scoring for grading purposes, the best way to ensure efforts and achievements is to require output and to evaluate and score the output with a grading impact. The preliminary PCR submitted in the Fall is worth 10% of the Fall grade and the final approved PCR is worth 5% of the Spring grade. It is important to note that the instructor must review and approve this document in the

Spring. It is not a simple matter of submitting a typical course assignment. There must be agreement resolved by the team and the instructor regarding the expected outcomes and the objective evidence to be presented.

Project Completion Requirements

The development of the Projects Completion Requirements has evolved from a simple handwritten document generated during a meeting with the team to a template that is now completed by the team. The current template may be reviewed in Appendix 1.

There are many concerns that must be addressed and include the following:

- Performance requirements as specified by the Product Design Specifications
- Objective evidence that will be generated and presented
- The repeatability or reliability of the test data that is to be obtained. Will a single trial or data point be satisfactory? Will statistical validity be required?
- The documentation of the design that is satisfactory for the partner or sponsor

The team must clearly define the end item that will be designed and fabricated. Will this be a proof-of-concept that may be destroyed through testing? A functional prototype capable of limited testing? Or a production ready system capable of being installed on a production floor.

The team must clearly identify what will be produced in terms of hardware and software. Will software code be generated to control the end item of system?

The team must clearly identify what will be verified through testing and what will be obtained through analysis. Is physical testing possible? What is the accuracy of the testing? Is analysis more applicable and can these analytical models be verified through testing? Is test equipment available? Are custom designed test fixtures required?

One concern that was addressed was the improvement in testing and the documentation of testing. Formal Test Methods and Test Reports are now required for all projects. Templates have been provided.

All testing that is performed that is to be used as objective evidence must include:

- Use of formal Test Methods
- Use of formal Test Reports
- The minimum number of trials for any data point is three

Another concern was the absence of satisfactory documentation of the design. Many completed projects produced a single prototype that could not be replicated from the documents provided by the team. Many of our Industry partners were disappointed with the end documents.

All teams must now provide a Documentation package that is reviewed and approved prior to the review by the partner or sponsor that may include:

- Instruction Manuals
- User Manuals

- Drawing Packages
- Software or source code

Lastly and most importantly, Safety must be addressed by all teams. There must be at least one clear deliverable that addresses Safety. Will safety guards be required to prevent injury? How will activation be accomplished? How will materials be handled or disposed?

Each team must identify at least ten items or specifications for review and the formal evidence that will be produced.

Example

One of the 2010/11 projects involved the design and fabrication on an Atmospheric Dispersion Corrector (ADC) Instrument for a local telescope company.

The Purpose of the project as defined by the students in their Product Design Specification (PDS):

A major problem for ground-based telescopes is atmospheric dispersion, which is the prismatic effect seen to increase at greater angles with respect to straight up. As the sky is viewed closer to the horizon, the wavelengths of light become increasingly dispersed due to this effect. The function of an ADC is to correct for the dispersion caused by the atmosphere, allowing the light from an observed object to be focused into a small area such as a spectroscopy slit. ADCs accomplish this by rotating two circular prisms in the telescope's light path to specific angles depending on the position of the telescope. Adjusting the relative angle between the prisms alters the correction strength of the ADC.

The purpose of this project is to design and build a prototype ADC for a telescope being designed by XXX. The prototype will be functional, but will use cylindrical aluminum blanks in place of the precision prisms to be used in the final product. Testing methods and criteria must be developed to demonstrate that the ADC is performing within specifications.

The original Performance requirements as defined by the team (Table 3) in their PDS:

Table 3. Team PDS Performance Requirements

Requirement	Value
Prism rotation accuracy	1000 arcseconds (0.27 degrees)
Prism maximum rotation	Unrestricted (360 degrees)
Prism separation (axial distance between prisms)	0-2 mm
Max length (mounting flange to outside prism)	190mm
Max diameter	200mm
Max axial prism deflection	0.001 inch
Lifetime expectancy	73,000 rotations over 20 years
Maximum maintenance frequency	Semiannually (2x per year)
Max rotation speed	5 RPM
Approximate manufacturing cost	USD 4000
Max weight	15 lbs

The Project Completion Requirements (Table 4) as defined by the team in their PCR template:

Table 4. Team PCR completed template

	Specification	Description	Value	Verification Method (Test Procedure)	Trials
1	Angular Precision	The rotational accuracy of the prisms	0.27°	An encoder attached directly to the prisms to verify correct prism location [TP1]	3
2	Radial Runout	The Radial runout the cell holder	0.001"	Measurement of Radial Runout in Cell Holder [TP2]	3
3	Dust seal	There should be no dust between the flange and nearest prism.	0	Apply powdered sugar to the seal locations and then visibly check the ADC interior [TP3]	3
4	Home Position	The ADC must be able to locate home position after power down and up.	N/A	Locate home position after restarting the controller [TP4]	3
5	Gap size	Optics requires that the two prisms to have a consistent gap size.	2lbs	Load bearing to failure, checking that extra force exceeds cell mass [TP5]	3
6	End prism to base distance	Optics requires that the top prism surface to be 183mm from the ADC mounting surface.	183mm	Measure the distance from the top prism surface to the bottom mounting surface [TP6]	3
7	Diameter of ADC	The ADC has a geometric envelope requirement, this checks the diameter.	200mm	Gauge fit the diameter using a tube [TP7]	3
8	Length of ADC	The ADC has a geometric envelope requirement, this checks the length.	190mm	Measure the outer dimensions of the ADC [TP8]	3
9	Deflection	The ADC cannot deflect (axially) under any gravitational loading.	0.001"	Measurement of ADC structural deflection under gravitational orientations [TP9]	3
10	Drawings	The ADC must be able to be manufactured.	N/A	A complete set of part drawings will get approved by LCOGT	N/A
11	Assembly Instructions	Assembly manual for the ADC	N/A	An assembly manual will get approved by LCOGT	N/A
12	Manual	Detailed information about the operation of the ADC, specifically its electronics	N/A	A manual will get approved by LCOGT	N/A

The team completed multiple test reports to document all results. The team conducted a professional quality project review with a PowerPoint slide presentation at the Industry partner facility.

Conclusions

The evolution of the course deliverables now more clearly addresses Project Completion and Problem Solution. Students and teams have demonstrated the ability to define the problems that need to be solved and now must clearly provide objective evidence of solving the problems that have been defined. This assessment is conducted separate from the quality of communication skills typically assessed by a final report or design review.

A template has been generated (Appendix 1) that is provided to the students. A preliminary document is required to be generated and submitted by the student team in the Fall quarter. Instruction is provided in form of a general lecture in the Fall quarter and again in the Spring.

A final document is generated by the student team that is reviewed and approved by the instructor at least one month prior to expected project completion. This document is referenced by the student team to provide objective evidence of project completion.

The team completes an unstructured Project Review that must address all of the items identified in the Project Completion Requirements. A simple scoring rubric (Appendix 2) is used to assess the reviews.

The use of Project Completion Requirements has significantly improved the overall quality of the completed projects and the Solution Assets. The use of formal Test Methods and Test Reports with the provided templates has improved the quality of the efforts and supportive evidence. Requiring a Documentation package with considerations for drawings, user manuals, instruction manuals, assembly instructions, software code, etc has also been a significant improvement that is much appreciated by the partners and sponsors.

The students and team are now well aware that the project is not complete with the last tightened screw or final brush stroke. They must provide objective evidence that they have solved the problem that they originally defined at the beginning of the project, Solution Realization.

Future Efforts

Improvements have been observed with the process. However, there is still confusion with the student teams in the Fall quarter during regarding the difference between Product Design Specifications and Project Completion Requirements during the Problem Scoping phase. This becomes clearer for them as they approach the Solution Realization phase in the Spring. However, a certain level of confusion remains for the weaker teams even in the Spring. Improvements are still needed with the level of instruction and guidance to be provided by the instructor and improvements may still be needed with the template.

The efforts to improve assessment of Project Completion and Problem Solution have evolved. There is a lack of noticeable and measurable outcomes related to these changes and the impact of these tools and templates. Indeed, this paper would be significantly strengthened with measurable outcomes. It is now impossible to objectively assess with measurable outcomes the impact of the changes that have been implemented. It is intended, however, that for the 2012/13

Capstone Projects that measurable outcomes will be developed though survey instruments with the project partners and the student teams regarding the level of satisfaction related to Project Completion and Problem Solution. It is intended that the results of these continued efforts with measurable outcomes will be reported in the future.

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Project Completion Requirements

PCRxxxx

[Team Leader], [Team Member], [Team Member], [Team Member], [Team Member]

REV. DATE [MM/DD/YYYY]

Requirements				
Specification	Description	Value	Verification Method	Trials
1	Must reference formal Test Procedures			
2				
3				
4				
5				
6				
7				
8				
9	Must be at least one measure of Documentation			
10	Must be at least one measure of Safety			

Notes:
 [Insert additional information here.]

Reviewed

Date

Appendix 2.

Project Completion review scoring rubric:

Score:

90 to 100	Excellent review, high performance team, project completion, sig achievements
75 to 89	Good review, good performance and achievements, lacks some aspect
below 75	Problems are noted in the review and performance, poor achievements

	Max pts	
<u>Prototype</u> - Project Completion - Performance vs. Design Req - Innovation, Degree of Diff	50	50 Excellent efforts, complete, comprehensive, 40 Well done, minor deficiencies, not as comprehensive 30 Good efforts but missed significant achievements 20 Weak efforts, poor achievements
<u>Testing</u> - Test Methods, Test Reports	25	25 Excellent efforts, supportive results, comprehensive 20 Well done, not as comprehensive or supportive 15 Good efforts but minimal support or weak methods 10 Weak efforts, poor achievements
<u>Modeling/Analysis</u> - Drawing Package - Computer modeling - Analytical methods - Assembly instructions - User manuals - Software code - Safety issues	25	25 Excellent efforts, Professional quality supportive doc 20 Well done, not as comprehensive or supportive 15 Good efforts but minimal support or weak quality 10 Weak efforts, poor achievements