Capstone Project Selection and Evaluation Processes: More Fair for the Students and Easier for the ABET Evaluator

Jeffrey R. Mountain
Norwich University

Abstract

While the specific focus of an ABET on site evaluation of student outcomes may vary year to year, design outcome assessment (ABET c) tends to always be under scrutiny. Searching for evidence of addressing realistic constraints, as well as meeting any discipline specific program requirements, can be a time consuming process for the evaluator, particularly if the capstone sequence spans two or more semesters. Capstone courses are frequently used for final assessments of many additional student outcomes, requiring a significant amount of time to also be spent identifying the evidence used in those outcome assessments. Following adoption of a philosophy that making the evaluation task easier for the program evaluator will lead to a better evaluation, a documentation process used to select and evaluate capstone senior design projects has been developed and employed. The documentation uses a project request for proposal form which includes identification of the realistic constraints that should apply to the design. Detailed rubrics used for the evaluation of oral and written reports include criteria that can be directly mapped to the assessment of other, non-design student outcomes. At this institution, the grading process involves faculty evaluations of both the written and oral reports by faculty members that were not the project advisors; further strengthening the assessment while simultaneously mitigating differences in expectations among different project advisors. While the direct effect on the ABET evaluation cannot be directly determined, the existence of the documentation was proven useful in focusing an ABET evaluator's attention to the assessment and evaluation evidence necessary to conduct the program evaluation in a timely manner. Specific aspects of the relevant documents, the design project evaluation process, and an ABET evaluation scenario will be presented.

Keywords

ABET

Assessment

Senior Capstone Evaluation

Introduction

A substantial part of any EAC-ABET self-study report and on site evaluation is devoted to Criterion 3 - Student Outcomes and the assessment of Criterion 3 as a part of Criterion 4 - Continuous Improvement. Although the Criterion 3 heading has changed over the years, from Program Outcomes to Student Outcomes, the outcome statements themselves have remained unchanged since the 2010-2011 criteria [1-3]. During the on-site review, program evaluators will tend to focus on areas that cannot be verified by the self-study report. While many of the student

© American Society for Engineering Education, 2015

outcomes may require additional clarification during the on-site review, outcome c related to the design of a system, component or process, can only be verified by observation of evidence during the on-site review; typically a review of capstone design reports. Beyond the general student outcomes listed in Criterion 3, many individual program requirements specifically list design in a context that is appropriate to the individual discipline [1-3].

Due to the overarching nature of the capstone design course, it is not unusual for student outcomes other than outcome c to be assessed from student work generated during this culminating course [4-6]. While the assessment of multiple outcomes from a single course may be relatively efficient for the program faculty, the review of this student work by an ABET program evaluator during an intensive on-site review could easily result in missed or misinterpreted data, particularly when looking for evidence of the preferred realistic constraints, such as economic, social, political, manufacturability or sustainability [1-3]. A failure of the program evaluator to recognize the necessary evidence in a timely manner could lead to a less than satisfactory program evaluation. At the very least, some anxious moments between the program evaluator and the program leading faculty member will transpire.

One way to facilitate the review of student design work by an ABET evaluator is to use standardized documentation as a part of the normal project selection and course grade evaluation process that highlights the more difficult to identify design outcome identifiers. In addition, if other student outcomes are being assessed using the capstone design course deliverables as a data source, inclusion of documentation that indicates faculty evaluation of those student outcomes will make it easier for the ABET program evaluator to determine compliance with the criteria.

At Norwich University, the capstone senior project in the Mechanical Engineering program is conducted as a two semester sequence and assessment evidence for multiple ABET student outcomes is acquired from several deliverables that are evaluated as a part of the course grading process. This paper will present the project selection and evaluation tools and processes developed for the course. It will also outline our ABET continuous improvement process for student outcomes assessment and highlight how the tools and processes used as the normal course grade evaluation process provided a clear path between the student work and the outcome assessments.

ABET Outcomes Assessment Process at Norwich

At Norwich University, the stated ABET a-k student outcomes have been slightly modified to reflect their application to the Mechanical Engineering program offered at Norwich. Due to the unique nature of Norwich as a Senior Military Academy and the initial home of the Reserve Officers Training Corps (ROTC), each of the engineering programs at Norwich has adopted a local outcome related to the development of leadership skills. Table 1 provides a comparison of the ABET student outcomes and the corresponding student outcomes for the Norwich Mechanical Engineering program [7].

The assessment process at Norwich evaluates each outcome in three different courses in the curriculum; an early introductory course, a mid-level course and a high level course using an outcome specific rubric. To reduce the workload associated with the assessment process, the twelve Norwich student outcomes were divided into three sets and each set is evaluated every

© American Society for Engineering Education, 2015

three years. This allows all of the outcomes to be assessed fully assessed twice during the normal six-year accreditation cycle with each completed assessment being composed of two formative assessments and one summative assessment. The foundation of the Norwich process is that each outcome is evaluated by a faculty expert using an outcome specific rubric.

Table 1: Comparison of the ABET and Norwich Student Outcomes for Mechanical Engineering

ABET Outcome Statement (2014-2015 Accreditation Cycle)	Norwich Mechanical Engineering Program Outcome Statement
(a) an ability to apply knowledge of mathematics, science, and engineering	1. Apply scientific and fundamental engineering knowledge based upon a strong foundation in advanced math, chemistry, physics, and the engineering sciences.
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	2. Design and conduct hands-on experiments, use mechanical/electrical hardware, and analyze and interpret data.
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	3. Design a component, system or process in the mechanical engineering field that meets performance, cost, time, safety, quality, materials, and manufacturing requirements.
(d) an ability to function on multidisciplinary teams	4. Function as a member of a multidisciplinary team and be able to assume leadership roles on the team.
(e) an ability to identify, formulate, and solve engineering problems	5. Identify, formulate, critically analyze, and solve engineering problems in energy conversion and transfer, materials and manufacturing, and mechanical systems design.
(f) an understanding of professional and ethical responsibility	6. Recognize and achieve a high level of professional and ethical conduct in all aspects of engineering work.
(g) an ability to communicate effectively	7. Formulate and deliver effective written and verbal communications of laboratory, analytical, and design project work to a variety of audiences.
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	8. Understand and incorporate non-technical considerations into an engineering solution including safety, environmental, social, economic, and global issues.
(i) a recognition of the need for, and an ability to engage in life-long learning	9. Recognize the need for mechanical engineers to engage in lifelong learning and begin the process by taking the FE exam.
(j) a knowledge of contemporary issues	10. Be knowledgeable of contemporary issues in mechanical engineering and related fields.
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	11. Utilize techniques, skills and modern engineering tools (including CAD/CAM) necessary for mechanical engineering practice.
	12. Develop broad based technical skills and knowledge, strong work ethic, integrity, and leadership skills that will lead to successful careers in a wide variety of engineering and non-engineering positions in industrial, military, government, and academic settings.

© American Society for Engineering Education, 2015

Although each course in the Mechanical Engineering curriculum contributes to at least one student outcome, measurements of individual outcomes to provide the formative and summative assessment data are collected in specifically designated courses where the contribution to the student outcome was particularly strong. For example, ABET Student Outcome c, related to a student's ability to design, has twelve different courses contributing to it, but it is only measured for assessment purposes in three courses: EG109 – Introduction to Engineering I, ME370 – Mechanical Systems Design, and ME468 – ME Design II; representing the two formative and one summative set of assessments.

While each course in the curriculum contributes to at least one student outcome, there are many courses that contribute to multiple student outcomes. In courses where the strong contributions were apparent, multiple outcomes were designated to be assessed. For example, ME468 – ME Design II contributes to eight of the Norwich student outcomes and is the designated measurement course for six outcomes listed summarily in Table 2. Due to the cyclic method of assessment described previously and the specific outcomes being assessed, each year at least one outcome is directly measured for a summative assessment in ME468, which is the final course of the ME capstone design sequence. Table 2 also indicates the year in the assessment cycle when the student outcome might normally be measured.

Table 2: A summary of the student outcomes assessed in ME468 – Senior Design II

Summary of the Student Outcome	Typical measurement year in the three year cycle
Outcome 2 – Experimentation	1
Outcome 3 – Design	2
Outcome 4 – Teamwork	1
Outcome 7 – Communications	1
Outcome 8 – Non-technical Considerations	2
Outcome 12 – Leadership	3

Norwich University ME Senior Capstone Course: Project Selection and Grade Evaluation

The Mechanical Engineering Capstone course at Norwich University requires teams of 3 or 4 students to work on a project across the fall and spring semesters of their senior year. The students have already completed ME370 Mechanical Systems Design in the spring semester of their junior year. ME370 is a design methodology course focused on the new product development approach to design. Senior capstone projects are solicited from industrial sponsors and faculty members to ensure a sufficient number of projects are available to allow the students to have a choice of projects. In addition, students are encouraged at the end of ME370 to propose project topics of interest. In all cases, a project Request For Proposal (RFP) form is

© American Society for Engineering Education, 2015

completed in order to help initially define and select the projects. The basic information solicited on the 2 page form is presented in Table 3.

Table 3: Norwich ME Department Senior Capstone Design Request For Proposal Information

Information Requested	**Brief Explanation**
Project Title:	What the proposer would call the project
Contact Person:	Customer liaison or person proposing the project and their affiliation.
Background:	Brief reason behind the project being proposed.
Objective:	What is to be accomplished.
System Requirements:	Up to five, broadly stated requirements.
Deliverables:	Initial expectations of prototype, specialized documentation, or additional presentations.
Technical Requirements:	Specific skill areas that students will need to complete the project.
Customer Commitments:	What resources will the proposer commit to ensure project success
Additional Requirements:	What department resources (space, dedicated hardware/software etc…) required.
Anticipated Codes & Standards/ Realistic Constraints:	Known or anticipated applicable codes or standards. Includes spaces to identify the ABET list of realistic constraints; i.e. Economic (costs), Environmental, Social, Political, Ethical, Health & Safety, Manufacturability and Sustainability

The RFP forms are used as a starting point for negotiating an academically appropriate capstone project, regardless of project sponsor. Project content, scope, and provisions for adequate financial and support resources are typical points for negotiation. It is also common for both student and industry proposed projects to require faculty guidance regarding identification of potential realistic constraints, and occasionally some applicable codes and standards that might readily apply to a specific project. For ABET purposes, this provides an indication that some of their realistic constraints are being considered and that further evidence of those considerations should appear in the project documentation. It is well understood that project requirements,

© American Society for Engineering Education, 2015

including the applicable realistic constraints, may evolve as the project matures, but the final negotiated RFP establishes a suitable starting point for a project that will address the academic requirements for the course as well as meeting the sponsors design needs. The RFP also provides an indication of whether the projects involve mechanical systems, thermal/fluid systems, or a combination of both, which address Mechanical Engineering program specific portions of Criterion 5.

At the beginning of the fall semester, all of the approved projects are briefly described for senior students during the initial class meeting, and all of the RFP documents are posted for the consideration by the faculty and the students. Seniors "bid" on their top 3 project choices, indicating why they are interested in each particular project and what specific skills or motivations should qualify them to be assigned to the project teams. Teams consisting of three or four students are formed by the course coordinator. High priority is given to form teams to undertake externally sponsored and student proposed projects, provided there are a sufficient number of students who have indicated an interest in the project. Over the past 3 years, the only project to have a student team member that did not indicate a preference for that project was an instance where the student did not provide a list of preferences at all. In all other instances, student were assigned to a project that was either their first or second choice. Faculty mentor assignments were made based on allowable faculty workload, specific interests of the faculty or prior positive relationship with the sponsor.

The course grades for individual students are determined based upon the evaluation of several deliverables and observations. While most of an individual student's grade is determined by the evaluation of their assigned faculty advisor, a significant portion of the grade is determined by multiple faculty. These include the evaluation of three oral presentations during each semester, and the evaluation of the final reports at the end of each semester. The oral presentations are evaluated by all course faculty using rubrics that are specific to each stage of the project development. Each rubric identifies multiple criteria that are to be evaluated and descriptors identifying characteristic attributes for "Exceeding Expectations", "Meets Expectations", Below Expectations", and "Not Acceptable." Point values are uniformly assigned for each category of performance based on a criterion's value for a particular presentation. Other faculty and external sponsors who are able to attend the presentations are asked to provide feedback to the students using the same rubrics. All faculty rubrics are averaged to determine a grade for each presentation. The course coordinator collects all of the completed rubrics, determines the presentation averages, and maintains a record of the presentation grade along with electronic copies of the rubrics. The original rubrics are returned to the project advisors to provide feedback to the individual teams. In some instances, the presentation grade is assigned to a specific speaker, and in other instances the presentation grade is assigned to the team, depending on advisor preferences and their instructions to their teams. The rubrics also allow for minor grade adjustments when individual students distinguish themselves either positively or negatively relative to the rest of the team and these adjustments are figured into the grade assignment of the students, even if the presentation grade is considered a "team grade." External evaluator feedback is provided to the teams when available, but is not used to determine the course grade.

End of semester final reports are also graded using detailed rubrics. Report relevant criteria are evaluated using descriptors identifying the same levels of performance relative to expectations as

© American Society for Engineering Education, 2015

was used for the oral presentation rubrics. Each report is evaluated by two of the faculty advisors. Neither grader is an advisor for the team being graded. The purpose of this is two-fold: a) the written communication value of the report is better assessed by someone who is only vaguely familiar with the project and b) no student team has a specific advantage or disadvantage due strictly to their assigned faculty advisor. The team report grades are determined by an average of the two evaluator grades.

At the end of each semester, the course faculty meet to determine and assign the final semester grades for each individual. The portion of the grades that are evaluated strictly by the advisor, along with the presentation and report grade averages and the student peer evaluations are reviewed. Several deliverables evaluated by the faculty advisors, such as individual weekly progress reports and student design notebooks, contribute to individualizing the final grade averages. During the last semester, a portion of the final grade is determined by project success, which is determined by the course faculty and subjectively accounts for the satisfaction of the external sponsor if applicable.

Project Grade Evaluation and ABET Assessment

It is a common technique to differentiate between the assignment of a course grade and the assessment of student outcomes. Embedded assessments, however, are also well established methods for using a portion of a student's coursework to determine the level of mastery of a particular student outcome. In the process previously described, the rubrics used to evaluate the oral and the written communications associated with the capstone projects are distinctly different than the rubrics used to assess the ABET student outcomes. Student course grades include many factors that are not directly related to specific student outcomes, but are considered important points of student learning. While the outcome assessment process is predicated on the evaluation by a faculty expert using an outcome specific rubric, it is felt that evaluation data provides a much stronger assessment of outcome attainment when it was based on the opinions of multiple experts. The rubrics used to evaluate the Norwich University ME capstone oral and written communications include embedded assessment evaluations and the grading process includes a review by multiple faculty experts.

As an example, ABET Student Outcome 2 regarding testing and experimentation is specifically addressed in the second semester final presentation rubric by a "Prototype Testing" criterion with descriptors and point values identified with Exceeding Expectations, Meets Expectations, Below Expectations and Not Acceptable. In addition, a specific chapter of the final written report is to be "Analysis and Testing" and the rubric provides detailed descriptors to assist in the identifying which of the four levels of achievement have been attained.

Other rubric criteria addressed the evaluation rubrics directly address conceptual and detailed design content in both oral and written communication formats and a final report section criterion devoted to "Manufacturing, Economic and Life Cycle Assessment." These grade related criteria provide evaluation data from multiple experts that directly relates to assessment of ABET Student Outcomes 3 and 8 regarding design and non-technical considerations. The overall presentation and report evaluations are used to assess ABET Student Outcome 7 related to communications. Separate outcome assessment rubrics for oral and written communications are used in Norwich's Student Outcomes Assessment process.

© American Society for Engineering Education, 2015

While the assessment of teamwork and leadership are not as apparent in the body of student work, they are primarily evaluated by the individual team advisors and discussed by the course faculty during the final grade determination meetings at the end of each semester. During the years when those Student Outcomes are assessed, it is relatively easy for each team advisor to assess each student teamwork and leadership mastery using the appropriate Student Outcomes rubric.

How These Tools and Techniques Assist During an ABET Onsite Evaluation

As is typical of an ABET onsite evaluation, course notebooks containing representative student work are prepared for the evaluation team. The student work accumulated represents high, medium and low, but passing, grade levels of achievement. During the most recent ABET onsite evaluation, the program evaluator had been instructed to look specifically for evidence of the student work that was specifically used for the assessment of student outcomes. While the year of record for Norwich would have normally included only the local "Leadership" related outcome as being assessed in the Capstone Design course, the PEV was reviewing the general and program specific criteria related to design. It was certainly beneficial to direct the PEV's attention to the RFP forms that were archived with the ME467 – ME Design I course materials to provide indications of anticipated codes, standards and realistic constraints, as well as the rubric evaluations of the written reports and the student reports themselves. It also was beneficial to direct attention to the specific sections of the final report rubrics that would be used to assess the other design related student outcomes in other cycle years.

Although not included in the course notebook, hardcopies of the oral presentation rubrics were quickly provided from the digital copies of the rubrics archived for grade determination meetings. Providing these additional documents, along with indicating specifically where to find the evidence of graded student work that would be used for the assessment of student outcomes made it easier for the PEV to locate and document his evaluation of program compliance with the ABET criteria.

Conclusions:

This paper has described the process used by the Mechanical Engineering Program at Norwich University to select and administer their senior capstone design projects. A general description of the forms and rubrics used to define and evaluate certain key aspects of the projects was provided. A linkage between the key project criteria, their method of evaluation, and the ABET requirements for design was provided along with examples of of evaluation data being tied to outcome assessments. Finally, a scenario where the Request For Proposal forms and the presentation and report evaluation rubrics provided a means to expedite the onsite ABET evaluation was intimated.

There is a certain additional workload associated with the ABET accreditation continuous improvement process. Due to the summative nature of the culminating capstone design experience, it is frequently used for the assessment of multiple ABET Student Outcomes. Regardless of the specific schedule used to assess the student outcomes, design is often a program specific criterion to be addressed as a part of Criterion 5 – Curriculum. Consequently, ABET Program Evaluators are very frequently required to review faculty evaluated capstone

© American Society for Engineering Education, 2015

design related student work and identify evidence linking the evaluated student work to the compliance requirements of ABET Criterion 3 – Student Outcomes and ABET Criterion 5 – Curriculum. By the strategic use of Request For Proposal forms to initially define and select the capstone design projects, and the use of rubrics, evaluated by multiple faculty experts, containing criteria that address design and other outcome topics, a direct connection between student work and assessment of student outcomes can be made. The embedded assessments are considered strong, direct assessments, and the evaluation by multiple faculty provides a strong evaluation process. Using these tools and this method for administering the senior capstone design course both facilitates the gathering of student outcome assessment data and the onsite evaluation by an ABET program evaluator. It seems reasonable that processes which make it easier for the evaluator to determine a program's compliance with the ABET criteria should lead to a more satisfactory evaluation.

References

1 ABET "2010-2011 Criteria for Accrediting Engineering Programs", October 2009.

2 ABET "2014- 2015 Criteria for Accrediting Engineering Programs", October 2013.

3 ABET "2015-2016 Criteria for Accrediting Engineering Programs", November 2014.

4 Davis, D., Beyerlein, S., Thompson, P., Gentilli, K., McKenzie, L., "How Universal are Capstone Design Course Outcomes?", *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition,* Nashville, TN, June 2003.

5 McKenzie, L.J., Trevisan, M.S., Davis, D.C., and Beyerlein, S.W., "Capstone Design Courses and Assessment: A National Study," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition,* Salt Lake City UT, June 2004.

6 Davis, K.C., "Assessment Opportunities in a Capstone Design Course," *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition,* Salt Lake City UT, June 2004.

7 Norwich University Mechanical Engineering ABET Team (Mountain, J., Friend, R., Wight, G., and Kelley, M.),"Self-Study Report for the Mechanical Engineering Program at Norwich University", pgs. 23-24, Norwich University, Northfield Vermont, 2014.

Name of the paper's First Author

Dr. Jeffrey R. Mountain has an earned doctorate in Mechanical Engineering from the University of Texas at Arlington. He is currently chair of the Mechanical Engineering Department at Norwich University in Northfield Vermont. He has over 20 years of university teaching experience and has been an ASEE member for over 16 years, affiliated primarily with the Engineering Design Graphics, Educational Research and Methods, Mechanical Engineering and Design Engineering Education divisions of ASEE. He is a registered professional engineer in Texas and is the Honors and Awards chair for the Design Engineering Division of ASME.

© American Society for Engineering Education, 2015