Vetting Industry Based Capstone Projects Considering Outcome Assessment Goals

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One goal of capstone projects is that they simulate a challenging design experience similar to expectations of a BS graduate engineer. Consequently industry originated capstone projects are very valuable since they are based on real world problems and technical challenges. Capstone projects are also a critical part of the assessment process for most engineering programs. The challenge becomes how to evaluate the potential of an industry based project in providing assessment information. This paper provides an example of a vetting process used with good success to accomplish this complex evaluation process.

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Introduction

Capstone projects are a critical part of the assessment process for most engineering programs since they simulate a challenging design experience similar to expectations of a BS graduate engineer (Howe and Wilbarger, 2005). Consequently industry originated capstone projects are very valuable since they are based on real world problems and technical challenges (Fries, Cross and Morgan, 2010). The key issue in project selection is how to evaluate the potential of an industry based project in providing information applicable to accreditation assessment. Since the capstone project is a vital part of many Accreditation Board for Engineering and Technology (ABET) assessment plans (abet.org, 2010), high priority must be given to identifying projects that fit the assessment targets of a-k program outcomes (Engineering Accreditation Commission, 2010) (see Table 1). This paper provides an example of a vetting process used to accomplish this complex evaluation process with good success. The next sections examine the capstone process and how projects are solicited, identified, and reviewed.

Capstone Overview

The capstone design experience takes place over a two-semester sequence, ENGR 4010 and 4020. The course was developed by faculty using only modest influence from reviews of information from similar programs based on a diverse review of available literature (e.g., Chang and Townsend, 2008; Davis, et al., 2006). To assure integration of engineering standards and realistic constraints, we have worked with regional industry to identify sponsored projects which are representative of the expectations these clients have for design performance of entry-level engineers. This emphasis on real projects develops relationships between our regional technology base, our program, and our students. In addition, we are able to see firsthand the needs and expectations of local industry. This in turn allows us to apply this experience to analyze how our program courses provide the necessary foundation to meet industry needs in solving complex, yet entry-level, engineering design problems. Research shows that 71% of capstone projects, nationally, are industry related (Howe and Wilbarger, 2005).

Table 1 ABET Program Outcomes

Engineering programs must demonstrate that their students attain the following outcomes:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to 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
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Since we are a general engineering program, our goal is that capstone projects demonstrate interdisciplinary technical skills and problem solving (Redekopp, et al., 2009). Projects are selected using the internally developed, multi- tiered process described below and illustrated in Figure 1. Rizkalla, El-Sharkawy and Salama (2003) describe a more pedagogically based process.

- The first contact with the client is often made by our lead faculty member for industry outreach (Director, ECU Team Engineering). Once a potential project is identified, a brief abstract, or scope statement, is developed.
- This abstract is circulated to the capstone committee, which rates the project on the potential in meeting assessment outcome goals.
- If the project receives positive evaluations from the capstone committee, a faculty advisor is identified for the project. In general, the faculty advisor is selected based on identifying a fit between faculty interest and background and the requirements of the project. For example, a bio-processing related capstone project would typically involve a faculty member with background in that area.
- The faculty advisor meets with the client to be sure there is a thorough understanding of the scope and deliverables expected of the project. When the faculty advisor finalizes this understanding on project details, several iterative reviews have occurred to assure the project is a solid and achievable engineering design project. This process assures that the faculty advisor understands the skills required from the students and issues the students will need to address.
- This faculty member then becomes the advisor for this project for the 4010/4020 course sequence. The industry outreach faculty retains primary responsibility for industry relations the faculty advisor retains responsibility for the project.

The next sections of the paper focus on the first two steps in Figure 1 and their integration with project assessment.

Assessment Goals

As context for discussing the project evaluation process, it is critical to clearly define the assessment goals. The assessment plan for the capstone courses cuts across a wide range of outcomes. As in an “end of pipe line” quality control process, the goal is to examine many individual and integrated skills. Table 2 summarizes the assessment plan for the two semester capstone sequence

The assessment plan relies heavily on student work samples along with input from the advisory board and the client for the project. When looking under the surface of the assessment plan, the topical and operational characteristics of the project under consideration must present substantial potential for these essential outcomes:

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.
d) an ability to function on a multi-disciplinary team.
e) an ability to identify, formulate, and solve engineering problems.
f) an understanding of professional and ethical responsibility.

Table 2 Capstone Assessment Summary

ENGR 4010 Senior Capstone Design Project I	Student Work Samples: • Design proposal demonstrating formulation of problem and recognition of constraints (Outcomes c and g) • Assignment showing understanding of professional ethical responsibilities (Outcome f) • Assignment showing recognition of societal issues in design (Outcome h) • Assignment showing awareness of continuing education resources (Outcome i) • Application showing knowledge of contemporary issues in the engineering profession (Outcome j) • Student Course Survey
ENGR 4020 Senior Capstone Design Project II	Student Work Samples • Assignment showing awareness of continuing education resources (Outcome i) • Evaluation of Capstone Projects by Faculty and advisory board (Outcomes a, c, d, e, g, and k) • Student Course Survey

Project Solicitation

The project identification process for capstone proposals begins in January of each year. The solicitation is sent first to previous capstone sponsor in recognition of their loyalty to the program and its goals. Our first project sponsor has provided one or two projects every solicitation cycle since the capstone course’s inception. In support of this type of loyalty, a first-right-of refusal is granted to all alumni capstone sponsors. The second round of solicitations is sent to Engineering Advisory Board members and engineering alumni. Again, the intent with this round is to reward loyalty. This second round occurs in February. A final call for capstone projects goes out in March and is sent to all contacts within the department’s database.

Sponsors proposing projects are asked to draft a simple abstract that briefly describes the project including final project deliverables, general constraints and identification of the sponsor’s point of contact for the project. Project details are not expected at this point since students assigned to approved projects are required to develop a project scope or charter for sponsor's approval during the first semester of the project.

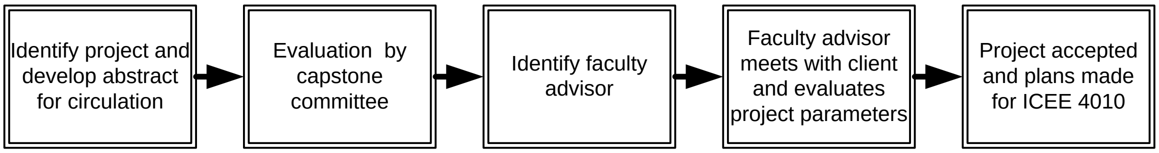

Figure 1: Capstone Process

Proposals from sponsors are submitted by the first part of May. While this is a busy time for faculty with end of semester milestones pressing, it represents a convenient time to conduct a formal review of capstone proposals prior to the summer break.

Project Vetting

Upon receipt, the proposals are vetted by the department's Capstone Committee. This committee is comprised of the faculty members who are the concentration coordinators (concentrations include: mechanical engineering, industrial and systems engineering, bio-process engineering and bio-medical engineering), the capstone design course(s) coordinator(s), the department chair and the Director, ECU Team Engineering. The latter faculty member has sole responsibility for acquiring capstone projects and leads industry outreach and liaison efforts.

Using a form listing the ABET Outcomes that are assessed via the capstone course, the vetting jury is asked to consider each proposal on its individual merits relative to its ability to support evaluation of the list of outcomes. A sample completed form is included in Appendix A. Course objectives supersede the need to consider ABET outcomes related to communications, interdisciplinary teams and modern tools.

The capstone committee jury examines two questions when considering each proposal. How does the project proposal support the outcome? What is needed to strengthen the proposal? Members of the committee are asked to review each proposal relative to these questions and assign a numerical ranking to each outcome based on the perceived strength of the proposal. This process is designed to achieve two objectives: 1) identify where students might struggle in developing a charter/scope description and 2) what is needed to remove any recognized weaknesses in the ability to objective 1.

The questions/objective approach gives every proposal an opportunity for success. Forms are returned to the Director, ECU Team Engineering for compilation of evaluations and primarily to address, with the proposal sponsor any items where more information might be needed prior to a committee discussion of the relative merits of each proposal. During the committee's proposal review meeting, each project is reviewed individually with consideration given to matching projects to the goals and objectives of the concentrations represented in the rising class of juniors. Again, projects proposed by previous sponsors are given first consideration and remaining capstone project opportunities are allotted to new sponsors. Each proposal is discussed by the committee and proposals who meet the objectives satisfactorily and with the highest compiled scores are selected for use beginning in the fall term.

Assessment

Considerable literature relate capstone projects and ABET assessment. Biney (2007), for example describes the role of student documentation in ABET accreditation. Welch and McGinnis (2012) consider the assessment protocol for considering teamwork related to outcomes attainment. Peretti, et al., (2004) consider assessment process within the capstone for communications. Miskimins, Graves and Van Kirk (2006) develop an assessment protocol for outcomes a-k. Wang, Fang and Johnson (2008) explored assessment of lifelong learning via the capstone. There is a paucity of literature examining the role of capstone selection and outcome assessment. Our efforts have been directed at relating assessment criteria to project selection in order to provide some assurances that the final project results have the potential to satisfy assessment needs, i.e., capacity is evaluated before projects are executed and force-fit.

Assessment data is collected per our assessment plan. The assessment plan is an annually produced document that varies year-to-year which outcomes are to be assessed across the curriculum. However, the focus of capstone based assessment planning is outcomes c-f as indicated above.

Data is collected at both the end of the first semester of the two semester sequence and at the end of the second. Table 3 shows student survey data across the two semester sequence for the last two years. The table reflects strong support that the capstone projects are meeting assessment requirements. This is supportive of a sound project selection process.

Table 3: Student Survey Results (1 strongly disagree; 5 strongly agree)

Outcome	2009	2008
c) …design…to meet desired needs ….	4.06	4.19
d) [effective teamwork]	4.17	4.44
e) …engineering problem solving.	4.19	Not assessed
f) …professional and ethical responsibility.	4.58	4.44

Additionally, the assessment plan requires the capstone course instructor to also assess the student work samples as evidence that assessment outcomes have been or at what level outcomes have been achieved. Instructor assessments have been focused on outcomes i-k heretofore and therefore are not germane to this discussion.

Summary

The vetting process has worked well to identify viable and productive capstone projects and also develop a shared faculty vision on expectations for capstone projects. So far, proposals have exceeded available capstone teams. However, program growth, the impact of non-traditional students, and the inclusion of 2+2 transfer students has necessitated trailing sections of capstone. As a new program with limited faculty resources, this has added the challenge of out-of-sequence capstone projects, i.e., calendar year basis versus academic calendar basis. While the course implementation/project completion effort for trailing sections (i.e. spring- fall compared to fall- spring) requires recognition that a summer break is necessary, the existing vetting process serves well. Proposals that were acceptable but not staffable are considered for the off-sequence capstone design courses. Again, priority is given to previous sponsors and all projects are considered based on overall compiled ratings. In the case of ties, first submitted is selected.

Selecting capstone projects from a diversity of projects for a mixed set of programs has proven manageable using basic selection criteria formulate from ABET outcomes. The process described above is can link assessment outcomes with curricular concentration needs and promote an iterative process of project evaluation and selection.

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Appendix A

2008 Capstone Project Evaluation Sheet ECU- Department of Engineering	
Evaluator: Kauffmann	Date: March 12, 2008
Project Title: LED lighting assessment	
General comments: This project is a very good systems or engineering management design project. It focuses on developing a path forward for migration from HID or incandescent light fixtures to LED technology. Project requires students to apply general engineering skills to a specific engineering area.	
Note: Outcomes represent specific ABET accreditation criteria.	

Assessment Plan Outcome	**Describe potential for assessing the outcome using the provided project scope description**	**Rating: 1= min., 5 = max.**
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.	This project will require students to develop engineering designs for LED lighting and related justification. This includes economic, physical, logistic, and environmental constraints.	4
d) an ability to function on multi-disciplinary teams	The project requires a team of students and a complex, multi faceted approach. In addition, the industrial client will be involved in the project	5
e) an ability to identify, formulate and solve engineering problems	Students will need to understand current lighting technology and the major technological shift in LED technology. This is real engineering problem for our local public utility.	4
f) an understanding of professional and ethical responsibility	Energy reduction and the importance of a critical and major change in technology which is occurring in the lighting industry. These two facets both illustrate the importance of professional development relative to technology changes and the importance of energy issues.	4
g) an ability to communicate effectively	Industry client will develop critical communication skills	4