2006-1882: ABET OUTCOME ASSESSMENT AND IMPROVEMENT THROUGH THE CAPSTONE DESIGN COURSE IN AN INDUSTRIAL ENGINEERING CURRICULUM

Shantha Daniel, Iowa State University

SHANTHA DANIEL is pursuing her doctoral degree in Industrial Engineering at Iowa State University. She has served as a graduate assistant in teaching as well as research including objective evaluation and outcome assessment.

Devna Popejoy-Sheriff, Iowa State University

DEVNA POPEJOY-SHERIFF is pursuing her master degree in Educational Leadership and Policy Studies with an emphasis in Student Affairs. She currently serves as the Academic Advisor for IE undergraduate students in IMSE Department.

K. Jo Min, Iowa State University

K. JO MIN is Associate Professor and Associate Chair for Undergraduate Studies in IMSE Department at ISU. He teaches courses in sustainable production systems. His education research interests include teaching and learning of global enterprise perspectives and international student team operations. He is a member of ASEE and IIE.

Leslie Potter, Iowa State University

ABET Outcome Assessment and Improvement through the Capstone Design Course in an Industrial Engineering Curriculum

Leslie Potter, Shantha Daniel, Devna Popejoy-Sheriff, and K. Jo Min

Industrial and Manufacturing Systems Engineering Department, Iowa State University

Abstract

In this paper, for the capstone design course, we first show how we demonstrate that our IE majors attain the ABET outcome items (c) and (h) where (c) is 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 and (h) is the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. To achieve this, we utilize rubrics that are primarily filled out by the instructors and surveys that are filled out by graduating seniors, Year 1 alumni, and Year 3 alumni. Each rubric is for the assessment of one outcome item, and consists of three subcriteria. Each of these assessment efforts is independent of the other efforts, and the results from each effort are crosschecked with the results from the other efforts. Based on the outcome assessment, we show how we improve the outcome items in the capstone design course by guiding students to consider diverse sets of perspectives and consequences without teaching additional discipline or technique. Finally, we will discuss the lessons learned and challenges experienced, and comment on future endeavors.

1. Background

In recent years, the Industrial Engineering (IE) Program in the Department of Industrial and Manufacturing Systems Engineering (IMSE) at Iowa State University (ISU) has been actively involved in objective evaluation and outcome assessment of its IE majors. The evaluation and assessment activities are highly important for its accreditation as the Accreditation Board for Engineering and Technology (ABET) requires that the graduates of accredited engineering programs attain certain outcome items to foster achievement of the programs' long-term educational objectives (see e.g., [1]).

Specifically, in response to this requirement, IMSE Department has developed and implemented the continuous improvement process for its objectives and outcomes that is depicted in Figure 1.

The Industrial Engineering Program Outcomes shown in on the top of the lower loop in Figure 1 consists of sixteen items, eleven of which are mandated by ABET [1] and five of which are additionally required by the department [2]. Employing the process outlined in Figure 1, various continuous improvement efforts are being made for the outcome items. For example, to improve outcome item (o) [the ability to have a global enterprise perspective], students in IE 341, a required Production Systems course, collaborate with students from foreign universities in a global supply chain team project via Internet [3].

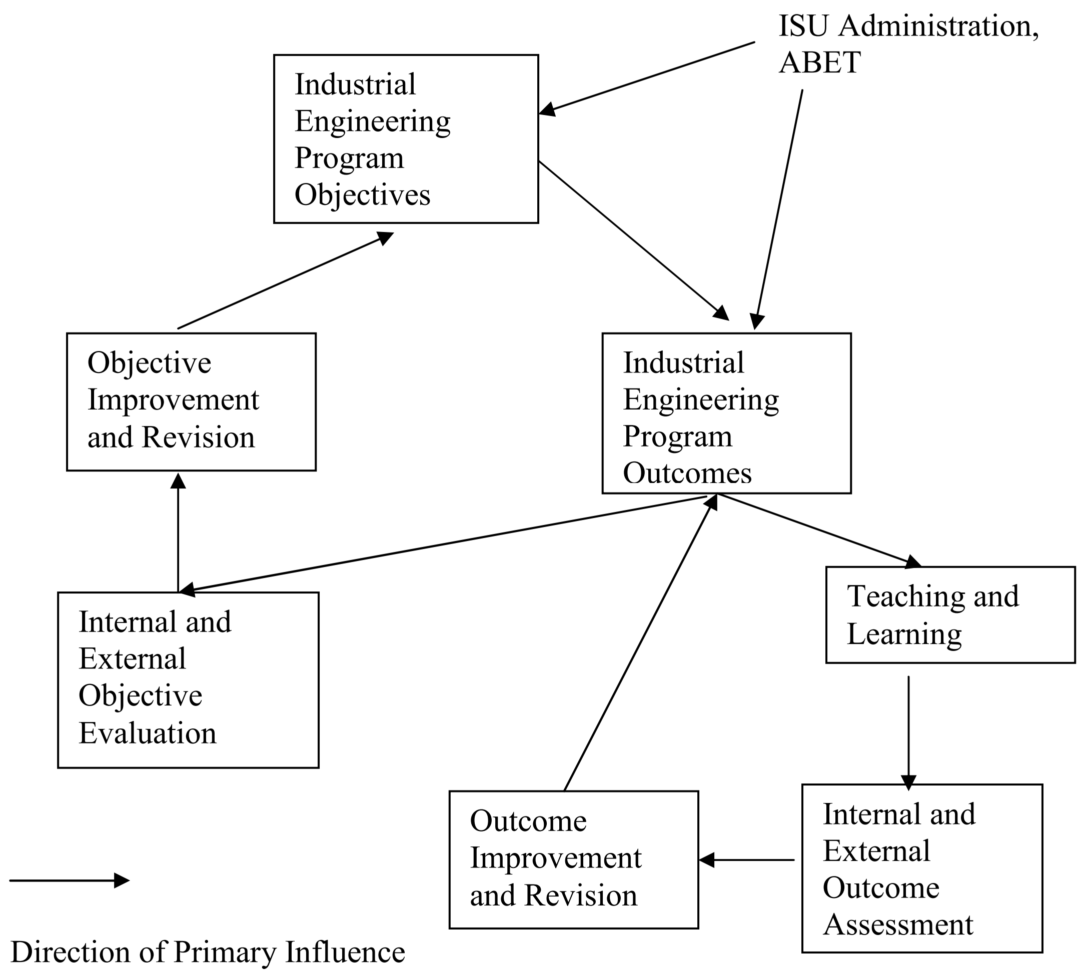

Figure 1. Continuous improvement process for the program objectives and outcomes

Under these circumstances, IE 441, the Industrial Engineering Capstone Design course, has been developed and revised to address a multiple number of outcome items. That is, the objectives, format, and content of IE 441 all work to extensively support both the ABET mandated outcome items, and those specific to the IMSE department. The reason is that the capstone design course serves as a fundamental platform to practice engineering design and to facilitate the integration of what IE majors have learned throughout their curriculum. As such, the capstone design course provides perhaps one of the best opportunity to assess and improve ABET outcomes.

In this paper, through the capstone design course, we will show how we demonstrate that our IE majors attain the ABET outcome items (c) and (h) where (c) is 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 and (h) is the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. The outcome item (c) represents a "hard" skill while (h) represents a "soft" skill, both of which are essential for a successful practicing engineer.

The rest of the paper is organized as follows. In Section 2, we will explain how the course is conducted with the outcome items (c) and (h) in mind. Next, we will describe the outcome assessment process for these two outcome items. This is followed by a review of the outcome assessment results and improvement efforts. Finally, we make concluding remarks and comment on future endeavors.

2. IE 441: the Capstone Design Course

The Capstone Design course is typically taken by students in their last year (i.e., within a semester or two before graduation). The course specifically focuses on the "practice" of four components: engineering, communications, professionalism, and the application of realistic constraints to tangible solution sets.

The class objectives for IE 441, as stated in the syllabus, are to "obtain practice in comprehensive engineering and communication skills, while simultaneously honing personal effectiveness skills, through the development and completion of an industrial design project supplied by a "real world" company. Engineering expectations include applying both previously learned and newly acquired knowledge and skills to identifying, formulating, and solving a complex engineering problem, which results in tangible deliverables and a financial incentive for the company. Engineered solutions will consider extensive ramifications, including political, ethical, environmental, social and economic issues, as well as sustainability and manufacturability of solutions. Project developments will be communicated formally and informally, through written and verbal means, to all levels of personnel. Personal effectiveness skills will be developed through an understanding of the concepts of professionalism, business and cultural etiquette, and other related topics [4]."

The capstone class is a critical step in the professional career of the students. It is during this particular semester that they are given the opportunity to make the transition from academia to industry, and they are asked to demonstrate their ability to tackle open-ended design problems. The course is treated like a job, the students are treated as engineers, and the instructor is their supervisor. During the first day of the semester, teams of three or four students are self-selected, taken through team-building activities, and then asked to rank-order their top six projects from the list(s) provided by Iowa-based business partners. Project assignments are made that maximize the highest options chosen by each group for the entire class.

Projects span the spectrum of what is considered to be industrial engineering, ranging from productivity improvements associated with workstation and facility design, process analyses, and value/non-value add identification to safety and ergonomics to quality analyses and mistake proofing. Projects also include machine specification, philosophy implementation (such as lean manufacturing), and modeling/simulation. All projects are design-based, and project scopes are tailored to meet the semester timeframe. Business partners include both manufacturing and service industries. For example, during Spring semester 2006, IE 441 twelve project groups are split between working with a foundry and a hospital.

Specific dates for formal reports and presentations (proposal and final) as well as periodic update meetings and reports throughout the semester are clearly specified to the students on the first day of class. Students take an all-day plant trip to the business partner the second week of class, and from that point in time, they are submerged in the process of project definition and solution generation. Much of their work throughout the semester is accomplished during the six hours of laboratory time that they have scheduled each week An hour lecture period held most weeks provides the students with relevant project information, as well as various other topics pertinent to their future roles as engineers. The intent of the lecture is mainly to reiterate the importance of the economic feasibility of solutions, to raise awareness about how the "people component" of projects is critical but also unpredictable, and to make the point how challenging yet essential it is to constantly consider realistic constraints throughout the design process. Global, economic, environmental, and societal constraints are some of those emphasized throughout IE 441.

The students' first task is to write a project proposal that clearly defines the problems they are trying to solve. Their initial proposals include identifying measurable objectives, relevant assumptions and constraints, their intended statements of work, tangible deliverables, project schedules, and an expected project costs. Formal written proposals are submitted during the third week of class, and then presented formally a week later. Once the students' proposals have been accepted, the teams are essentially independent throughout the completion of their projects. The instructor and teaching assistants TA's are available whenever needed but they allow the students as much autonomy as is desired. During the semester, progress is monitored at two update meetings held by the instructor and TA with the students.

Weekly assignments include requirements by the project teams to write "Impact Statements" regarding realistic constraints and how they affect project definition and results. These constraints include, but are not limited to, economic, environmental, social (including global context), political, ethical, health and safety, manufacturability, and sustainability [5]. Other smaller assignments are made occasionally during the semester, but they do not relate directly to the final projects.

During week fourteen of the semester, teams submit final written reports. The following week (and last week of the semester), they then make formal presentations to the instructor, TA's and business partners. The business partners identify first and second place teams. The instructor and TA's determine student grades, which consist of 95% group grades, and 5% individual grades. Each student's final grade can be impacted significantly by peer evaluations within the groups, and by the instructor's professionalism evaluation of each individual student.

3. Outcome Assessment Process

The relevant outcome assessment tools for outcome items (c) and (h) consists of the rubric-based assessment of the capstone design course as well as the surveys of graduating seniors, Year 1 alumni, and Year 3 alumni.

For the capstone design course, the assessment for outcome items (c) and (h) was made at the end of each semester assigned by the ABET coordinator. Assessments were made by the either the IE 441 instructor or the instructor and TA combined, and consist of applying the rubric criteria to each individual student and evaluating their achievement levels as defined by the rubric. In addition to the rubric-based assessment of the outcome items (c) and (h) in the capstone design course, separate assessments are performed via Graduating Senior Surveys as well as Year 1 and Year 3 Alumni Surveys. These independent surveys can be used to crosscheck the rubric-based assessment of outcome items (c) and (h). The Graduating Senior Surveys are administered twice a year in Spring and Fall semesters while the Year 1 and Year 3 Alumni Surveys are administered once in Fall semesters. All surveys are sent by mail to the relevant students and alumni. The relevant students and alumni are asked to rate all 16 (11 ABET and 5 IMSE additional) outcome items by answering how the IE Program at ISU helped them attain the abilities described in the outcome items (Likert scale of 1 to 5; 1=not at all and 5=extremely well).

In what follows, we describe how the rubric is utilized in details in the past several years (the entire rubrics for (c) and (h) are attached at the end of this section). Assessment of outcome item (c) was very straight-forward. The rubric was well-written, and the assessment of the students' abilities to design a solution within realistic constraints was relatively easy to measure. Evidence of their achievement level was clearly demonstrated in their final project reports and presentations in IE 441, as well as all of the written and oral assignments throughout the semester. For all three performance subcriteria on the rubric, students were assessed based on the quality and of their work. In addition, the number of realistic constraints that the students discussed was considered for the "Impact" criteria. While students in IE 441 work in teams, and as a result essentially receive a "group" grade for the class, their ABET evaluation was tempered by personal knowledge of each individual as garnered by the TA's and instructor through personal interaction and conversation with the students. Peer evaluations of individuals made by group members were also considered if appropriate. Assessment scores were documented for students in IE 441 during semesters Fall 2003, Spring 2004, and Fall 2005.

Assessment of outcome item (h) was more challenging. Assessments were initially made during fall semester 2004, but because of issues identified with the rubric and process used, adjustments were made. Beginning spring semester 2005, the criterion "Broad Education" was further defined as "global understanding". In addition, "Impact" was specifically identified as “local” impact. Group assignments from IE 441 were once again used for assessment. As detailed in [5], “If groups identified two or more points regarding monetary impact, social issues, or global issues in their final projects, ‘exemplary’ scores were assigned for ‘Broad Education’. Likewise, if they discussed two or more social issues on a more local level in their reports and presentations, ‘exemplary’ scores were assigned for ‘Impact.’ The absence of any discussion related to these criteria resulted in ‘poor’ scores for each [5].” For the “Global” criterion, resumes were collected by the Academic Advisor for the IE majors. This information, in addition to her knowledge of the students’ transcripts, internships, and exchange program participation, allowed her to assess this criterion. During Spring 2005, only graduating seniors were evaluated, but during Fall 2005, all seniors were evaluated to allow a larger set of 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

Performance Criteria

Item	Exemplary 5-6	Acceptable 3-4	Poor 1-2
Ability to state the problem and constraints	Problem and constraints statement is clearly defined, measurable objectives developed, and deliverables are clearly defined and relate to objectives	Problem and constraints statement is generally understandable, most objectives are measurable but may not be completely specific or quantifiable, and deliverables generally relate to the objectives	Problem and constraints statement is vague or ambiguous, objectives are not measurable and deliverables are not clear and do not directly relate to the objectives
Ability to determine applicable IE tools or methodologies and utilize them to correctly design a process or evaluate process alternatives	Chooses most applicable tools/methodologies, utilizes the tools correctly and consistently	In general applicable tools are chosen and correctly applied, with some exceptions or inconsistencies	Clearly inappropriate tools are chosen and/or the tools are not applied correctly
Ability to compare and make selection between design alternatives	Multiple alternatives developed, performance of each alternative rigorously evaluated, reasonable methodology for selection of alternative utilized and reasons for final selection are clear and credible	Minimal number of alternatives developed, evaluation of each alternative shows some rigor, and reasons for selection are generally clear but some explanation may be missing	Insufficient number of alternatives developed, method of comparison unclear and reason for final selection missing or unclear
Total			

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

Performance Criteria

Item	Exemplary 6-5	Acceptable 4-3	Poor 2-1
Broad education	Acquired knowledge in the domains of economy, environment, and society	Some knowledge domains are not comprehensive or in-depth	Many knowledge domains missing, concentration in only one area
Global	Participated in an on-campus international project or event, and participated in an international study program	Participated in an on-campus international project or event	No significant international component
Impact	Correctly identifies potential impacts on workers, other companies, community, and other major constituencies	Some constituencies are missing, describes the major impacts	No consideration of impacts on society
Total			

4. Outcome Assessment Results and Improvement Efforts

In this section, we will first review the rubric results, then the survey results. Accordingly, the rubric results are summarized in Table 1 as follows.

Semester	Criteria	Number of students evaluated in IE 441	Average Score (Max=18)	St Dev.
F03	c	18	12.83	1.86
S04	c	37	13.76	3.11
F05	c	29	13.55	3.50
F04	h	14	6.43	0.85
S05	h*	19**	11.74	2.13
F05	h*	29	11.86	3.09

*h2 assessed by Academic Advisor based on resumes and transcripts.
**Graduating seniors only.

Table 1. Rubric results for (c) and (h) in IE 441 Capstone Design Course

With respect to Table 1 results, we make the following observations and comments: The average score per student is significantly higher for outcome item (c) vs. (h), perhaps indicating that senior students are more competent in the design process than in their understanding of the impact of engineering solutions in a global context. Also, while scores for outcome item (c) decreased from Spring to Fall semester 2004, the standard deviation was much higher, the result of one team during Fall 2004 that did a very poor job with their project. Considering that team to be an anomaly throwing it out, the average score for 25 students that semester would be 14.76 with a standard deviation of 1.81.

Furthermore, we note the difference in scores between Fall 2004 and Spring 2005 semesters for outcome item (h) as follows: we believe that a substantial portion of this difference is not attributed to a change in student understanding of the impact of engineering solutions in a global societal context, but to the change in how this particular rubric was defined and applied during assessment. Specifically, the previous rubric contained subcriteria components that may be less than well defined. e.g., the strong participation in international activities is rated exemplary while acquiring international perspectives is rated acceptable. Finally, while the average scores for students (ignoring the data for outcome item (h) during Fall 2004) are all above "Poor" levels, they are also all below "Exemplary" levels, indicating that room for improvement is available in both areas.

We now proceed to review the survey results. They consist of the graduating senior surveys (Table 2) and the alumni Year 1 and Year 3 surveys (Table 3).

Graduating Senior Surveys

Semester	Criteria	Number of Graduating Seniors	Average Score of Outcome item	St Dev of Outcome item
Spring 04	c	21	3.71	0.78
Fall 04	c	6	4.33	0.52
Spring 05	c	11	4.09	0.7
Fall 05	c	10	4.00	0.94
Spring 04	h	21	4	1
Fall 04	h	6	3.58	0.49
Spring 05	h	11	4.55	0.52
Fall 05	h	10	3.9	0.99

Table 2. Graduating Senior Surveys (Max = 5)

Year 1 and Year 3 Alumni Surveys

Year	Survey	Criteria	Number of Respondents	Average Score of Outcome item	St Dev of Outcome item
2004	Year 1	c	14	4	0.78
	Year 3		13	4.19	0.8
2005	Year 1	c	16	3.81	0.83
	Year 3		19	3.53	0.9
2004	Year 1	h	14	3.86	0.66
	Year 3		12	3.25	0.62
2005	Year 1	h	16	3.88	1.02
	Year 3		18	3.28	1.23

Table 3. Year 1 and Year 3 Alumni Surveys (Max = 5)

With respect to Table 2 and Table 3 results, we make the following observations and comments: For graduating seniors, the average scores of both items (c) and (h) fall within the 3.5 to 4.5 range (Max = 5; Min = 1). This is consistent with the rubric observation that "while the average scores for students are all above "Poor" levels, they are also all below "Exemplary" levels, indicating that room for improvement is available in both areas." Also, we note that for alumni, the average scores of the Year 1 alumni for both items (c) and (h) tend to be higher than the average scores of the Year 3 alumni for both items (except 2004 (c)). It remains to be seen if this is a pattern. Furthermore, if so, the underlying reasons might be that the degree of attainment of such capabilities is increasing for IE majors and/or that the necessity of such capabilities becomes diluted as alumni may pursue diverse career paths in later years.

We also note that by crosschecking the graduating senior survey and alumni survey results, some highly consistent outcomes can be observed. For example, for outcome item (h), 2005 Year 1 alumni average score (3.88) is between the 2004 Spring graduating senior average score (4) and the 2004 Fall graduating senior average score (3.58).

As a result of the assessment process, several improvements have been made to the IE 441 capstone design course. The changes enhance the learning experience for the students while providing a visible and definable linkage between the concepts of process design and understanding the impact of engineering solutions in a global, economic, environmental, and societal context.

A boilerplate check sheet was created and is distributed to the students for use as the basis for a section of their final project reports subtitled "Constraint Considerations and Ramifications." Along with this, the grading rubric distributed in the syllabus was modified to evaluate how well this is accomplished by each project team. During Fall semester 2005, Dr. Min was invited to read students' impact statements regarding social constraints, and to offer opinion about their ability to synthesize global enterprise concepts with their company-specific projects.

Assessment improvements have been made in several ways in IE 441. A pre- and post-test was designed and administered to IE 441 students the first and last days of the Fall 2005 semester. The test indicates their current knowledge and self-efficacy with respect to understanding sustainability, global perspective, and the process design. The focus on two of the many realistic constraints considered throughout IE 441 was made to compare student knowledge across courses, as well as classes. Data from Fall 2005 was compiled and average score and standard deviation was calculated. Rubric assessment has been adjusted as necessary to provide an accurate reflection of student abilities. Grading rubrics in IE 441 have been modified to help the students know what is expected and to allow the instructor to better evaluate the students' abilities to consider realistic constraints as they impact the design process.

6. Concluding Remarks

In this paper, we showed how the capstone design course is conducted with respect to the outcome items (c) and (h). We also described the outcome assessment process for these two outcome items. This was followed by a review of the outcome assessment results and improvement efforts.

As Figure 1 in the Background section implies, our emphasis is on the continuous improvement process. Therefore, we expect continual efforts for further improvements in the future. For example, a new learning process in the tradition of the capstone design course (i.e., aforementioned orientation toward the practice of industrial engineering) is also under development, and is being offered as an Independent Study course during Spring 2006. Specifically, a Lean Manufacturing and Applied Kaizen pilot course, which includes both design decisions and global considerations, is scheduled for March 13-17, 2006, at the John Deere Waterloo Works (Waterloo, Iowa). Four students will learn about solution design within Lean Manufacturing principles on campus, and will spend one week on-site participating in a Kaizen event. Funding has been obtained to extend this concept to international locations during Spring 2007 for a larger pilot group, with the expectation that if successful, it will be absorbed by the capstone design course as part of the class requirements, possibly by Fall 2007. This process will support the goals of outcome items (c) and (h) by providing a value-added opportunity for the students to generate designed solutions while actively considering the global impact of those solutions.

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Biographies

LESLIE POTTER spent seven years with Deere & Company in various engineering and supervision capacities prior to joining the IMSE department at ISU as Lecturer. She is currently teaching her sixth year of Capstone Design. Her research interests include capstone design course effectiveness, engineering communications, and team homogeneity. She is a member of ASEE.

SHANTHA DANIEL is pursuing her doctoral degree in Industrial Engineering at Iowa State University. She has served as a graduate assistant in teaching as well as research including objective evaluation and outcome assessment.

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