Assessing an Industry-Based IE Senior Design Course

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Abstract

This paper presents an example for assessing course performance and ABET outcomes for an industry-based industrial engineering senior design course. To provide context for the assessment process, we first describe our current senior design course and its relationship to departmental ABET objectives and outcomes. The structure and operating parameters of the course are presented because the assessment process is built into how the course is taught. Finally, we discuss the process by which the outcomes data are collected and presented. An example of the assessment is given to assist other industrial engineering departments wishing to assess ABET outcomes related to senior design.

Introduction

One of the two program criteria specified for ABET accreditation of industrial engineering programs by the Institute of Industrial Engineers is:

"The program must demonstrate that graduates have the ability to design, develop, implement and improve integrated systems that include people, materials, information, equipment and energy. The program must include in-depth instruction to accomplish the integration of systems using appropriate analytical, computational and experimental practices."

The criteria for ABET2000 accreditation emphasize continuous quality improvement [3]. Tooley and Hall believe that capstone design courses are one of the most effective ways for engineering departments to meet specific ABET criteria [7]. They have developed such a course for the Civil Engineering Department at the University of Arkansas. Within this course, the civil engineering students "don't really meet the client and their plans and specs are not used for bidding purposes."[7] Deleveaux and Rudd describe an industry-based senior capstone course within the Penn State University's Department of Industrial and Manufacturing Engineering [2]. In this course, students are exposed to uncertainties such as change in problem parameters, insufficient data, lack of clarity about the customer or sponsor's needs, and discovering corrupt data. The students involved in the project must describe their qualifications and justify being awarded their first choice of the projects. The students provide industry sponsors deliverables such as recommendations, models, designs, hardware, and/or software. Grading of the projects is based on team accomplishment, peer evaluation, written reports, and an industry sponsor evaluation of team performance. This paper discusses the structure, operation, and assessment of the senior level Industrial Engineering Design Course within the Department of Industrial Engineering at the University of Arkansas. We present our process for executing the course including

information for project sponsors, the specification of the project deliverables for the course, a procedure for selecting projects and clients, and a procedure for assessing student outcomes.

Overview of the Course

Industrial Engineering Design (INEG 4904) is a single-semester course generally taken during the last semester of study. The course draws on all prior required industrial engineering courses by exposing the student to an integrated, capstone design experience. Thus, the course represents an opportunity for our students to utilize the breadth and depth of knowledge gained during their time in our program. Obviously, this course is a critical component of our curriculum as it permits students to demonstrate that they have the ability to design, develop, implement and improve integrated systems that include people, materials, information, equipment and energy. The primary objectives of this course are:

- An ability to identify the industrial engineering problems faced by a real organization
- An ability to apply a broad range of industrial engineering skills to solve these problems
- An ability to communicate the scope of and solution to these problems through both written reports and oral presentations

During the initial class period, Project Information Sheets are distributed to the students. The Project Information Sheets are constructed by the Sponsoring Organizations (i.e., the industry sponsors) and include basic information about the sponsor, a point of contact for students who wanted to learn more about the project, and a brief description of the project. The point of contact becomes the primary point of contact for the Design Team if the project is selected.

The first deliverable associated with the course is a Design Team Selection Report. Each team consists of 4-5 student members with one person serving as Project Manager. The purpose of assigning the Design Team Selection Report is two-fold. First, it requires each Design Team to formally discuss their ability to complete any Design Project and their selection of Project Manager. Second, it presents an opportunity for the students to familiarize themselves with the expectations for writing (content and formatting). Each Design Team Selection Report is evaluated and if the report is deemed to be unsatisfactory, the Design Team is required to resubmit the report. This is done to emphasize quality of writing, fulfillment of report requirements, and adherence to formatting requirements. The submitted reports, along with the corresponding evaluation forms, are kept in a team portfolio folder. Future reports and evaluation forms are also maintained in the team portfolio.

After justifying their team's ability to complete the projects, the teams are then allowed to select their projects and begin working on the Project Proposal. Each Design Team and each Sponsoring Organization receives an information packet regarding the Project Proposal. The sponsor's packet contains information regarding the Project Proposal Presentations and evaluation forms for both the Project Proposal and the Project Proposal Presentation. Each Design Team is required to submit a Draft and Final Project Proposal to both their sponsor and the instructor. Sponsor approval is required before submitting the Final Project Proposal for course evaluation. This approval is documented by a letter from their point of contact on the sponsor's letterhead. Each Design Team makes a formal presentation of their Project Proposal.

The points of contact from the Sponsoring Organizations are invited to attend. Videotapes of the presentations are included in the team portfolio.

In the time between the beginning of the semester and the submission of the Project Proposal, four guest lectures are presented to the students. These lectures are designed to provide the students with additional knowledge relevant to completing an industry-based project. The lecture topics are Project Management, Technical Writing, Oral Presentation Skills, and Consulting Skills. Upon approval of the Final Project Proposal, each Design Team undertakes the activities required to meet the project objectives. During this phase of the course, each team is required to submit two Project Progress Reports. The Sponsoring Organizations are given information packets, including evaluation forms, regarding these reports. Upon completion of project, each Design Team is required to submit a Draft Project Final Report and the official Project Final Report. The Project Final Report consists of three parts: an Executive Summary (1 page), a Project Overview (10 pages), and the Project Details (no page limit). The purpose of the Project Overview section is to require the students to summarize their efforts into a 10-page, stand-alone document. Additional details are included in the Project Details section. Both versions are evaluated and each Design Team received feedback from the instructor after submitting the Draft Project Final Report. Each Design Team makes a formal presentation of their Project Final Report. The points of contact from the Sponsoring Organizations attend these presentations, and videotapes of the presentations are included in the team portfolio. To complete the course, each Design Team is required to obtain a letter of completion from their point of contact on their sponsor's letterhead.

Relationship to Program Objectives and Outcomes

Industrial Engineering Design directly supports all five of the Department of Industrial Engineering's program objectives. Within the senior design course, students must (1) use the mathematics, science, methodologies, computational skills, and analysis techniques of industrial engineering, (2) present their team's work in both written and oral form, (3) design, improve, and manage an integrated system, (4) formulate and solve unstructured problems, and (5) be faced with just-in-time learning and interact with professional engineers. In addition, the course supports our program outcomes:

a) An ability to apply knowledge of mathematics, science, and engineering
b) An ability to design and conduct experiments, as well as to model, analyze, and interpret data within Industrial Engineering practice
c) An ability to design a system, component, or process to meet desired needs
d) An ability to function on multi-disciplinary teams
e) An ability to identify, formulate, and solve unstructured Industrial Engineering problems
f) An understanding of professional and ethical responsibility
g) An ability to communicate effectively through written reports and oral presentations to stakeholders within Industrial Engineering problem domains
h) The broad education necessary to understand the impact of engineering solutions in a global 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.
l) An ability to improve, and manage integrated systems of people, technologies, material, information, and equipment.
m) An ability to utilize the methodologies, computational skills, and analysis techniques of Industrial Engineering practice including such core Industrial Engineering topics as probability, statistics, engineering economics, human factors, engineering management, computing, and operations research applied to manufacturing, logistics, or service systems.

In Industrial Engineering Design, the students have the opportunity to demonstrate most (if not all) outcomes within the context of a real-life industrial engineering project setting. First, each project is required to include significant economic analysis, statistical analysis and operations research modeling (outcomes a, b, k, m). Second, each project deals with a current problem faced by a local industry (outcome j). The domain of the Spring 2001 projects included manufacturing, distribution, health care and retail. Third, each design team is required to create their own project proposal (outcome e) and develop their own solution approach (outcome l, c). Fourth, each design team is required to submit multiple written reports and deliver multiple oral presentations (outcome g). Finally, successful completion of the courses requires a satisfied industrial sponsor (outcome f).

To ensure that engineering students will be well prepared for a rapidly changing job market, it is important for institutions to assess the quality of its engineering programs. Newcomer considers assessing desired student learning outcomes the key to maintaining accreditation and providing students with a high quality education [5]. In his paper, Newcomer describes the difficulty involved in assessing a Machine Design course in the Engineering Technology Department of Western Washington University. Several opportunities for change are presented including recording student presentations and collecting written feedback from the faculty members and industry sponsors. Additionally, the course evaluation form provided to the students did not provide specific information as to the skills that students believed they had developed as a result of the course. Bakos presents a set of measurement tools to assist programs in assessing how well students have met criteria [1]. Among others, these tools include accreditation, standard testing measures, capstone design courses, and teacher evaluations. Kishline et al presents an outcome assessment plan that is used to evaluate the effectiveness of design curricula against their specified goals [4]. Safoutin et al presents an attribute framework by which the 11 ABET learning outcomes are broken down into finer detail, which can be more easily matched to specific course content [6]. In this paper, develop a framework by which the attainment of our programmatic objectives and outcomes can be evaluated and assessed based on senior design materials.

Evaluation Process

Student work from senior design plays a dual role in our department's program objective evaluation and outcome assessment processes. For program objective evaluation, senior design materials are an indicator of what might be expected from the student shortly after graduation. For outcome assessment, senior design materials are a reflection of how well the curriculum has

prepared the students to demonstrate our program outcomes. Because of the dual role that senior design materials play, a single evaluation method was established; however, the results of the method are interpreted according to how each result helps in objectives evaluation and outcome assessment. The evaluation process for the course involved three main aspects: (1) sponsor evaluations, (2) student evaluations, and (3) faculty evaluations. The Sponsoring Organization provides valuable feedback about our students and their achievement of departmental outcomes from an outside perspective. The students provide information about themselves, the projects, and the sponsors. Faculty members provide information concerning how well the outcomes have been achieved. In this section, we illustrate the process by presented data from the 2001 Spring Semester. As such the data is only 1 observation from what will eventually be observations from each semester that the course is offerred. By tracking the data over time, trends that may need to be addressed can be identified.

During the course, the Sponsoring Organizations are asked to provide information on the Project Proposal (and presentation), Project Progress Reports, the Project Final Report (and presentation), and the Design Team's ability to perform departmental outcomes. After reviewing both the Final Project Proposal, the sponsor is asked to rate on a scale of 1 to 5 (1-Strongly disagree, 2-Disagree, 3-Neither agree or disagree, 4-Agree, and 5-Strongly agree) the following aspects of their team's work:

1. Proposed objectives meet needs and expectations
2. Proposed activities and tasks meet expectations
3. Proposed deliverables meet expectations
4. The proposal meets expectations in terms of quality of writing
5. Design team demonstrated technical skill
6. Design team showed enthusiasm
7. Design team demonstrated professionalism

One of our key outcomes is "An ability to identify, formulate, and solve unstructured Industrial Engineering problems". In order for students to achieve this outcome, they must be able to develop the appropriate objectives and activities necessary for solving the problem. With this evaluation we are attempting to better understand how capable our students are relative to this outcome from an outside perspective. In addition, we are looking for students to demonstrate appropriate IE technical skills and show professionalism during the process. For the 2001 Spring Semester, the evaluation was positive with the averages above 3 for each team on each of the criteria. The only potential areas of concern were found during the Project Proposal Presentations: problem definition and technical content.

For the Final Project Report, the sponsor is asked to rate the Design Team in a similar manner the following:

1. Summary of activities and tasks met expectations
2. Conclusions made by team were appropriate
3. Recommendations by team were appropriate
4. Areas for further study were appropriate
5. The report met expectations in terms of quality of writing
6. The team demonstrated technical skill
7. The team showed enthusiasm pursuing the project
8. The team demonstrated professionalism

This assessment is evaluating whether or not the Design Team actually solved the sponsor's problem. In addition, we are looking for feedback on outcome (g) "An ability to communicate effectively through written reports and oral presentations to stakeholders within Industrial Engineering problem domains". The sponsor also evaluates the content, delivery, and visuals associated with the Project Proposal Presentation and the Project Final Report Presentation. Finally, each sponsor is asked to evaluate their Design Team in terms of the team's ability to perform on the departmental outcomes (a)-(l). Each outcome was rated on a scale from 1 to 5 (1-Poor, 2-Below average, 3-Average, 4-Above average, and 5-Excellent). Many departments utilize an employer survey to provide such feedback, but we feel that performing this assessment within senior design provides immediate feedback from persons directly involved with our students. For the 2001 Spring Semester, the teams were all rated very highly by the sponsors at 4 or above. We feel that more guidance as to the meaning of the scale and criteria for the sponsors will make this evaluation more useful in the future.

Students are also asked to become involved in the evaluation process by:

1. Evaluating the applicability of the required courses within our curriculum to their projects both prior to and after completing the project
2. Evaluating themselves and their teammates with respect to their ability to perform departmental outcomes
3. Evaluating the course's impact on achieving departmental outcomes.

Because the senior design course is an important aspect of meeting the IE program criteria, we are interested in maintaining the applicability of the material learned in prior courses to the projects. During the proposal preparation process, the students rate the applicability of required courses to their particular project on a scale (3-Significantly applicable, 2-Applicable, 1-Somewhat applicable, and 0-Not applicable). At the end of the project, the students are again asked to rate the required courses.

Table 1 presents the 2001 Spring Semester averages across Design Team Members for each of the four Design Projects (P1, P2, P3, P4) both before (B) and after (A) the course. From the table, we see that core IE topics (Engineering Economics, Methods and Standards) got relatively higher ratings while manufacturing courses (Manufacturing Processes and Automated Production) had lower ratings. Only projects 1 and 4 had a manufacturing orientation; but the manufacturing issues were more at the systems level, as noted by the application of systems simulation. In addition, we can see that Introduction to Operations Research had very low applicability ratings before the projects, but had much higher ratings after the projects.

Table 1: Applicability of Courses

	P1		P2		P3		P4	
Course	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
Industrial Cost Analysis	2	2.25	1	2	0	0.75	3	2.5
Engineering Economic Analysis	2	3	3	2.75	3	1.5	3	3
Manufacturing Processes	0	1.25	0	0.25	0	0.25	1	2
Engineering Statistics	2	2	3	2.5	2	1.75	2	2.75
Methods and Standards	3	2	3	2	3	2.5	3	3
Industrial Statistics	1	1.75	2	2.75	3	2.25	2	2.75
Intro. to Operations Research	0	2.75	2	2.5	0	0.75	2	1.75
Automated Production	0	1.25	0	0.25	0	0	2	2.25
Administrative Analysis	1	0.75	3	2.25	0	0.67	2	0.75
Material Handling	2	3	3	1.25	3	1.25	3	2
Introduction to Simulation	3	3	3	3	3	1.75	2	3
Ergonomics	2	1.75	3	3	2	0.25	2	1.5
Production Planning/Control	3	2.75	2	1.25	1	0.5	0	1

The course is also an important part of meeting departmental outcomes. As such, students are asked to assess themselves and their fellow Design Team Members in terms of departmental outcomes on a scale (5-Excellent, 4-Above average, 3-Average, 2-Below average, 1-Poor). An example assessment for one of the 2001 Spring Semester projects is given in Table 2.

Table 2: Example Self/Team Evaluation of Outcomes

Program Outcome	**S1**	**S2**	**S3**	**S4**
Apply mathematics, science and engineering	4.75	4	4.33	4.5
Design and conduct experiments, as well as analyze and interpret data	4.75	4	4.33	4.75
Design a system, component or process to meet desired needs	4.75	4.25	4.25	4.75
Function on multi-disciplinary teams	3.33	3.67	4	3.67
Identify, formulate and solve industrial engineering problems	4.75	4.5	4.25	4.75
Understand professional and ethical responsibilities	4.75	5	5	5
Communicate through written reports and oral presentations	3.75	3.25	4.75	4
Understand the impact of engineering solutions in a global and societal context	4	4	4	4.33
Recognize the need to engage in life-long learning	4.75	5	4.67	5
Increase knowledge of contemporary issues	4.25	4.25	4.25	4.25
Use the techniques, skills, and modern engineering tools necessary for engineering practice	4.75	4.25	4	4.75
Improve and manage integrated systems of people, technologies, material, information, and equipment	4	4	4	4
Use the methods, computational skills, and analysis techniques of industrial engineering	4.75	4.5	4.25	4.75

Generally, we felt that the students rated each other higher than expected. In other words, average for them can probably be translated as below average. Two areas of note from this evaluation; there appears to be some concern about their ability to work on multi-disciplinary teams and also about communicating through written and oral reports.

Finally, the students are asked to assess the impact of the course on their education with respect to departmental outcomes. With this assessment, we are interested in understanding how senior design helps to achieve our outcomes. For each outcome, the students rated the impact (1-Very

negative impact, 2-Negative impact, 3-No impact, 4-Positive impact, and 5-Very positive impact). Table 3 presents the frequency of the responses for the 2001 Spring Semester. No responses of 1-Very negative impact or 2-Negative impact were given and so these columns have been left out of the table.

Table 3: Impact of Course On Outcomes

Program Outcome	No Impact	Positive Impact	Very Positive Impact
(a) Apply mathematics, science and engineering	1	7	8
(b) Design and conduct experiments, as well as analyze and interpret data	1	5	10
(c) Design a system, component or process to meet desired needs		4	12
(d) Function on multi-disciplinary teams	1	2	8
(e) Identify, formulate and solve industrial engineering problems		5	11
(f) Understand professional and ethical responsibilities	1	8	7
(g) Communicate through written reports and oral presentations		4	11
(h) Understand the impact of engineering solutions in a global and societal context	4	8	4
(i) Recognize the need to engage in life-long learning	3	6	7
(j) Increase knowledge of contemporary issues	2	10	4
(k) Use the techniques, skills, and modern engineering tools necessary for engineering practice		7	9
(l) Improve and manage integrated systems of people, technologies, material, information, and equipment	2	6	8
(m) Use the methods, computational skills, and analysis techniques of industrial engineering		7	9

The results indicate that a majority of the students recognize the positive impact that senior design has on their ability to perform departmental outcomes. In addition, we see that a substantial portion feel that senior design has a very positive impact on outcomes (c), (e), and (g), all of which are critical outcomes and very pertinent to IE program criteria. We also see that the experience had less of an impact on outcome (h), "understanding the impact of engineering solutions in a global and societal context". This can be attributed in part to the context of the design projects but is an area of further investigation.

The faculty evaluation process involves an evaluation of student deliverables and an evaluation of each Design Team based on departmental outcomes. For the Project Proposal Presentation, a faculty panel evaluates the presentation and the individual students. The presentation is evaluated on a scale (5-Excellent, 4-Above average, 3-Average, 2-Below average, 1-Poor) over the following criteria: (1) clarity of problem motivation and definition, (2) appropriateness of objectives and deliverables, (3) technical content, and (4) quality of visual aides. Each student is rated on their performance during the presentation and the follow up question period. For the 2001 Spring Semester, the results of the evaluation indicated that only one student performed below average on the question period and all students performed at an average level or above. The inability of students to quantify their analysis was identified as a potential area of concern. In addition, it became apparent that particular students (especially international students) could not effectively communicate in oral form. At the end of the semester, the instructor rates each design team relative to each program outcome on a scale from 1 to 5 (1-Poor, 2-Below average,

3-Average, 4-Above average, and 5-Excellent). For this evaluation in the 2001 Spring Semester, all teams rated at above average or higher. Only one area of concern was found: the ability to function on a multidisciplinary team.

Concluding Remarks

This paper discussed the application of assessment techniques to an industry-based senior design course for industrial engineering majors. The assessment process involved three of the major constituents within the ABET process, industrial sponsors, students, and faculty. Each constituent evaluated both the deliverables and the ability of the students on department outcomes. In addition to the above assessment, the students evaluate the sponsoring organization, the format of course, the relevance of deliverables, the instructor, and the teaching assistant. Finally, the Sponsoring Organization provides feedback on the course and potential use of the student work. As a final part of this evaluation process, the evaluations are written up and discussed within a Senior Design Semester Report prepared by the instructor with the assistance of a teaching assistant. The individual student work and the raw evaluations are also organized into team portfolios for review by ABET committee members. This process was designed to be easy to implement and pertinent to our ABET process. Indeed, the evaluation process is relatively "painless" because a teaching assistant associated with the course can perform the tabulations and summaries. This evaluation process not only helps to measure whether ABET outcomes are being achieved but also helps to ensure the quality of the senior design course.

Bibliography

1. Bakos, J.D. (1996) "Direct outcome-based assessment measures." *Professional Issues in Engineering Education and Practice*, Vol 122, No 1, pp. 31-34.

2. Deleveaux, Velma J and Clayton O. Rudd. (1997) "Designing and Teaching a Successful Industry Based Capstone Design Course." *Proceedings of the 1997 ASEE Annual Conference & Exposition*, Session 1263.

3. Enbody, Richard J. (1998) "Our experience developing CQI procedures for ABET2000 accreditation." *Proceedings of the 1998 28th Annual Frontiers in Education Conference*, Vol 2, pp.878-883

4. Kishline, Carl, Francis Wang and El-Hadi Aggoune. (1998) "Competency-based engineering design courses development." *Proceedings of the 1998 Northcon Conference*, pp. 202-207.

5. Newcomer, Jeffrey L. "Reassessing Design Goals: Using Design Projects to Meet Assessment Goals." *Proceedings of the 2000 ASEE Annual Conference & Exposition*, Session 1625.

6. Safoutin, Michael J. et al. (2000) "A Design attribute framework for course planning and learning assessment." *IEEE Transactions on Education*, Vol 43, No 2, pp. 188-199.

7. Tooley, Melissa S. and Kevin D. Hall. (2000) " Using a Capstone Design Course to Facilitate ABET 2000 Program Outcomes." *Proceedings of the 2000 ASEE Annual Conference & Exposition*, Session 1625.

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