Using Industry to Drive Continuous Improvement in Capstone Design

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Iowa State University's Industrial and Manufacturing Systems Engineering (IMSE) Department has been teaching and practicing continuous improvement for many years. Since 2003, a formal process for curriculum assessment related to ABET outcome items [a-k] and departmental outcome items [l-p] has been in place. This process has provided structure for obtaining, documenting, and using feedback from stakeholders, including students, alumni, faculty, and industry. Quantitative feedback is received through stakeholder surveys and outcome item assessment. Qualitative feedback is received from capstone design industry partners, alumni working in industry, and the IMSE Industrial Advisory Board. The IMSE capstone design course (IE441) has served as a principle linkage within the department for this process, and this paper describes how Industry and outcome item assessment are used to improve the capstone curriculum. Quantitative data are provided that indicate positive improvements resulting from interactions with Industry. Examples of qualitative feedback are also included. Outcome items [g] (An ability to communicate effectively) and [h] (The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context) are specifically addressed for the period of 2003-2011, with positive results seen in both areas.

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Background

Department Overview

Iowa State University's Industrial and Manufacturing Systems Engineering (IMSE) department includes undergraduate and graduate programs, with eighteen faculty, approximately 280 undergraduates, and approximately 60 graduate students. The department has an 8-member Industrial Advisory Board (IAB) which meets yearly to support the program. The department has had formal and consistent assessments in place since 2003, which provide feedback to the faculty about the usefulness and accomplishment of the curriculum.[1, 2] To meet graduation requirements, undergraduate students take a one-semester 3-credit capstone design course.

Capstone Course Overview

The IMSE capstone course (IE441) has many similarities to other capstone design courses. It is a semester-long 3-credit course, which undergraduate students take their senior year. The average team size is four students. A typical semester has eight project teams, all of which work within a single industry partner's facilities on different projects. This provides multiple advantages for the students, company, and course. Student teams work on various projects that appeal to their different interests, yet still collaborate on measurable objectives, methods, and tangible deliverables so that the industry partner receives integrated and efficient solutions. The course instructor (an industry professional who spent eight years working in manufacturing as an engineer and supervisor prior to joining the IMSE faculty) establishes a close working relationship with the industry partner through a single point of contact, enhancing communication and allowing for better feedback to students.

The capstone course has four main emphases:

- Open-ended problem definition and engineered design solution development,
- Realistic constraint and ramification consideration,
- Effective and efficient communication, and
- Professional skill effectiveness.[4]

Realistic constraints and ramifications are reflected by outcome item [h], and global issues have been identified as significant and relevant by many sources, including Downy, et al.[5] Effective communications are specifically called out by outcome item [g] and have also been identified as significant and relevant by many sources, including Shuman, et al.[6]

As students progress through the course, they communicate about their projects with all levels of industry and academic personnel (managers, engineers,

line workers, suppliers, faculty, students), in different types of settings (formal, informal, large and small groups, one-on-one), and through different mediums (written reports, emails, presentation slides, work instructions, face-to-face conversations, phone calls, round-table presentations, formal presentations, etc.).

Lecture/discussion topics include, but are not limited to, decision analysis, project justification, working with unions, service industries, business and cultural etiquette, industry buzzwords, writing, presenting, professionalism, constructive feedback, and patent law.[4] Realistic constraints and ramifications (sustainability, environment, energy, health and safety, economic and strategic, manufacturability and serviceability, politics, ethics, social, and global) are also discussed and evaluated throughout the semester.[4]

As part of the assessment process, students are graded on their methods and solutions, as well as their communication of accomplishments. Assessments for both grades and outcome item achievement (as assigned each semester by the department curriculum committee) are made at semester's end by the course instructor and teaching assistant (with the exception of outcome item [h-2], which is evaluated by the department undergraduate advisor).[2]

Industry is directly involved in the capstone design course in three ways. In addition to the course being taught by a professional from industry, course projects are "real world" and come directly from industry partners. These partners provide direct feedback to the students and faculty about the course and projects. The IMSE IAB is also regularly updated on capstone design course developments and provides direct feedback to the course instructor and department.

Industry is involved indirectly as well, through casual feedback to faculty members and other university staff, alumni surveys (solicited) and email (unsolicited), and corporate interaction through other courses and programs. In addition to this, feedback about the IMSE capstone program occasionally appears in non-university media.

Outcome Item Assessment

In 2003, the IMSE department developed rubrics for each of the ABET outcome items [a-k] and departmental outcome items [l-p][1,2]. Each semester, the curriculum committee determines which outcome items will be assessed within each course, and these vary as necessary to generate a complete picture of how well the department is accomplishing what it intends.[2] Each rubric consists of three criteria with three different levels of achievement. Faculty assess student achievement of outcome items and provide evidence from coursework to support these findings. Total scores range from 3 to 18, with 3 being the lowest possible score and 18 being the highest. Because capstone design is, by nature, the most inclusive course in the curriculum, it is used significantly for assessment of outcome items (see Table 1). When sufficient evidence is collected for individuals, assessments are made at this level. Otherwise, assessments reflect team assessments.

TABLE 1 – By semester, outcome items assessed in IE441 (capstone design)

Semester	Outcome Items Assessed in IE441	Semester	Outcome Items Assessed in IE441
Fall 2003	c, e, f, **g**	Fall 2007	c, **g**, **h**, i, j
Spring 2004	c, e, f, **g**	Spring 2008	c, **g**, **h**, i, j
Fall 2004	d, **g**, **h**, p	Fall 2008	i, j, k, l, m, n
Spring 2005	**h**, i, j	Spring 2009	a, c, e f, **g**, **h**
Fall 2005	c, **h**, i, j,	Fall 2009	c, f, **g**, **h**, i
Spring 2006	f, i, j, n	Spring 2010	c, d, **g**, **h**, i
Fall 2006	c, **g**, **h**, i, j	Fall 2010	c, f, **g**, **h**, i
Spring 2007	c, **g** i, j	Spring 2011	c, d, **g**, **h**, i

Outcome item [g] (An ability to communicate effectively) has been assessed within the capstone design course twelve times since 2003. The rubric for outcome item [g] is seen in Figure 1.

Item	Exemplary 6-5	Acceptable 4-3	Poor 2-1
Written	Good organization, concise, level appropriate for audience, well-reasoned, facts are substantiated, no grammar or spelling problems	Some minor problems with organization, substantiation, grammar or spelling	Poorly organized, many grammar and/or spelling problems, poorly substantiated
Presentation	Good organization, media appropriate, delivery is smooth, speech is understandable, proper grammar, good use of time, prepared for questions	Some minor problems with organization, media, delivery, grammar, use of time, and questions	Little or no organization, poor use of media, speech is not clear, poor time usage, not prepared for questions
Team	Well prepared for meetings, participates in discussions, keeps team members informed	Some minor problems with preparation, participation, and keeping team members informed	Often misses meetings, poorly prepared, adds little to discussions, rarely informs team members
Total			

FIGURE 1 – Outcome item [g] rubric for IMSE

Outcome item [h] (The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context) items 1 and 3 have been assessed within the capstone design course eleven times since 2003, though the initial assessment in Fall 2004 produced outlier information and isn't included in trend analysis because it skews the

trend too positively. This happened because the initial assessment rubric was not as effective as desired, and as part of the continuous improvement process, the rubric was modified by the Spring 2005 semester.[1] The current rubric for outcome item [h] is seen in Figure 2.

Item	Exemplary 6-5	Acceptable 4-3	Poor 2-1
Broad education	Acquired knowledge in the domains of social sciences and humanities in a global, economic, environmental, and societal context	Some knowledge domains are not comprehensive or in-depth	Many knowledge domains missing, concentration in only one area
Engineering solutions in a broader context	Participated in a coop/internship program or a study abroad program	Participated in a relevant on/off campus extracurricular activity such as an IIE paper competition or a solar car competition	Little participation in such a program or an activity
Impact	Correctly identifies potential impacts on workers, other companies, community, and other major constituencies	Some constituencies are missing, but describes some major impacts	Little consideration of constituencies or impacts
Total			

FIGURE 2 – Outcome item [h] rubric for IMSE

Engaging Industry Directly in Capstone Design

The most direct use of Industry in capstone design is through the projects that industry partners provide to students. The capstone instructor works directly with industry partners to identify projects that are relevant, timely, and significant to their businesses, as well as appropriate and well-scoped for students. Industry partners are asked to assess student projects mid-semester during report-out presentations using a rubric provided by IMSE, based on engineering, communications, and professionalism. Industry partners also attend a final presentation day and make four assessments of the projects and course, including

- choosing a first and second place team (these teams receive small monetary awards),
- assessing the "value-add" of each project which is part of the students' final project grades,
- providing qualitative feedback to students, and
- providing qualitative feedback to the instructor.

Using Industry to Drive Change in Capstone Design

The IMSE department responds to assessments and feedback as part of continuous improvement. Some capstone design course changes have resulted directly from Industry feedback. These changes have been communicated directly to the IAB. Many of these changes include direct partnering with Industry for course execution, and have been called out specifically by industry partners as positive and useful. The most significant changes have been achieved through multi-year experimental course development, delivery, assessment, and then integration back into capstone design, including a Professional Industrial Engineering (IE) Interactions course and a Lean/Kaizen course that have directly contributed to content changes in capstone design for outcome items [g] and [h].

Professional IE Interactions Course

In the summer of 2007, Dr. John Jackman and Leslie Potter (capstone design instructor) developed a Professional Industrial Engineering Interactions course. The impetus for this course included communication skill deficiencies observed in capstone design students (which were reflected in outcome item [g] assessments), casual feedback from capstone industry partners and the IAB, and surveys of alumni and faculty. It was approved as a 3-credit substitution for the required speech course within the curriculum.[3]

Potter and a teaching assistant from the English department taught the course Fall 2007 and Spring 2008 semesters.[3] Much of the content developed, including teaching an effective engineering communication process, has since been incorporated back into capstone design. The increase in student understanding of effective and efficient communications is reflected in outcome item [g] data from IE441 ABET assessment.

Lean/Kaizen Course

In the Spring 2005 semester, the IAB asked IMSE faculty if they could provide more concentrated and hands-on Lean Manufacturing as part of the curriculum. Data from assessments of outcome item [h] also indicated that concentrated effort was needed to increase the accomplishment of that particular outcome item within the curriculum. Dr. Jo Min, Dr. Frank Peters, and Leslie Potter combined the two needs with the concept of a "kaizen" (Japanese for continuous improvement) course.[7] Kaizen requires understanding culture and its impact on the people within an organization, as well as impact in a more global context. A series of experimental kaizen courses from Spring 2006-Spring 2008 were developed and taught by Min, Peters, and Potter, and included international travel to England to do kaizen events at Caterpillar production facilities. The dual emphases of Lean and global exposure were met effectively, with positive feedback from students, industry partners, and the IAB.[7]

Lessons learned about global culture, corporate culture, and Lean methods have been incorporated into both capstone design and a new elective (IE222X). The increase in understanding of global impact combined with an increase in study abroad experiences is reflected in outcome item [h] data.

Other Changes

Other changes have been made to capstone design as part of the continuous improvement process, which include direct suggestions from industry feedback. Two examples include requiring report-out presentations by student teams at industry partners mid-semester (affecting outcome items [g] & [h]), and adding business value assessment of projects by both industry and the course instructor (affecting outcome item [h]).

Results

Positive trends have been seen in outcome items [g] and [h] in capstone design since 2003, as seen in Figure 3. While one-sided p-values are not yet significant (0.15 for [g] and 0.13 for [h]), it is important to note that they are affected by the small sample size. Collecting ABET assessment data is an inherently slow process, but after eight years of assessment and continuous improvement, scores for both outcome items are now in a range that is considered "achieved" (12-15 points: high acceptable to low exemplary). While there are too many external variables (other courses, work experience, etc.) to attribute full cause and effect to the industry feedback/ continuous improvement in capstone design, it appears that what IMSE is doing is having a positive effect.

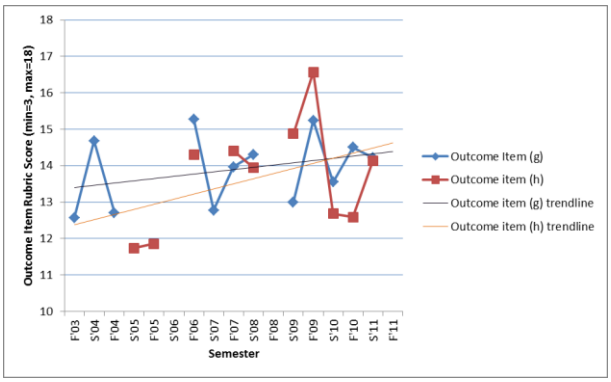

FIGURE 3 – Outcome item [g] and [h] trends in IE441

Qualitative feedback is received from industry partners every semester. Comments address observations and results of student teams and projects. Consistent positive feedback indicates that students are meeting industry needs and communicating project results effectively. Examples of this feedback include

- "We have heard nothing but positive feedback from the staff who worked with the students. They thought it was (a) great experience and expect to see great outcomes as a result of the work." Val Boelman, Process Improvement Coordinator, Iowa Health Systems, Des Moines, Iowa
- "The team spent a lot of time on the floor trying different assembly techniques and capturing the data…the impact to customer satisfaction is immeasurable." Garrett Goins, Manufacturing Engineering Manager, John Deere Des Moines Works, Des Moines, Iowa

Relationships with industry partners are very strong; companies request to work with IMSE capstone design. Repeat partners are numerous. Both quantitative and qualitative assessments indicate that IMSE should continue industry involvement as part of capstone design.

Conclusions

Iowa State University's IMSE department is achieving continuous improvement in its senior capstone design course through engagement with Industry as a driver. Assessment of these efforts includes both quantitative data (including ABET outcome item assessment) and qualitative information (including direct feedback from industry partners). While data are not yet statistically significant, all indications over the past eight years are positive, and efforts to engage Industry and use their expertise to improve both content and delivery of capstone design will continue.

References

1. Potter, L. and Min, J. "ABET Outcome Assessment in an Industrial Engineering Capstone Course," *Proceedings of ASEE North Midwest Conference*, October, 2005.
2. Potter, L., Peters, F., and Min, J. "Effecting Improvement in an Industrial Engineering Program by Applying Outcome Assessment Results," *Proceedings of ASEE National Conference*, June 2007.
3. Potter, L., Jackman, J., Min, J., and Search, M. "Integrating Communication and Engineering Skills in an Industrial Engineering Curriculum Based on Outcome Assessment Results," *Industrial Engineering Research Conference*, May, 2008.
4. Potter, L. "IE441 Syllabus," Fall 2011.
5. Downey, G. et al. "The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently," *Journal of Engineering Education*, April, 2006.
6. Shuman, L., et al. "The ABET 'Professional Skills' – Can They Be Taught? Can They Be Assessed?" *Journal of Engineering Education*, January, 2005.
7. Peters, F., Potter, L., and Min, J. "Developing Students' Understanding of Global Issues through Lean Manufacturing," *ASEE/IEEE Frontiers in Education Conference*, October, 2008.