

## **AC 2007-899: EFFECTING IMPROVEMENT IN AN INDUSTRIAL ENGINEERING PROGRAM BY APPLYING OUTCOME ASSESSMENT RESULTS**

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# Effecting Improvement in an Industrial Engineering Program by Applying Outcome Assessment Results

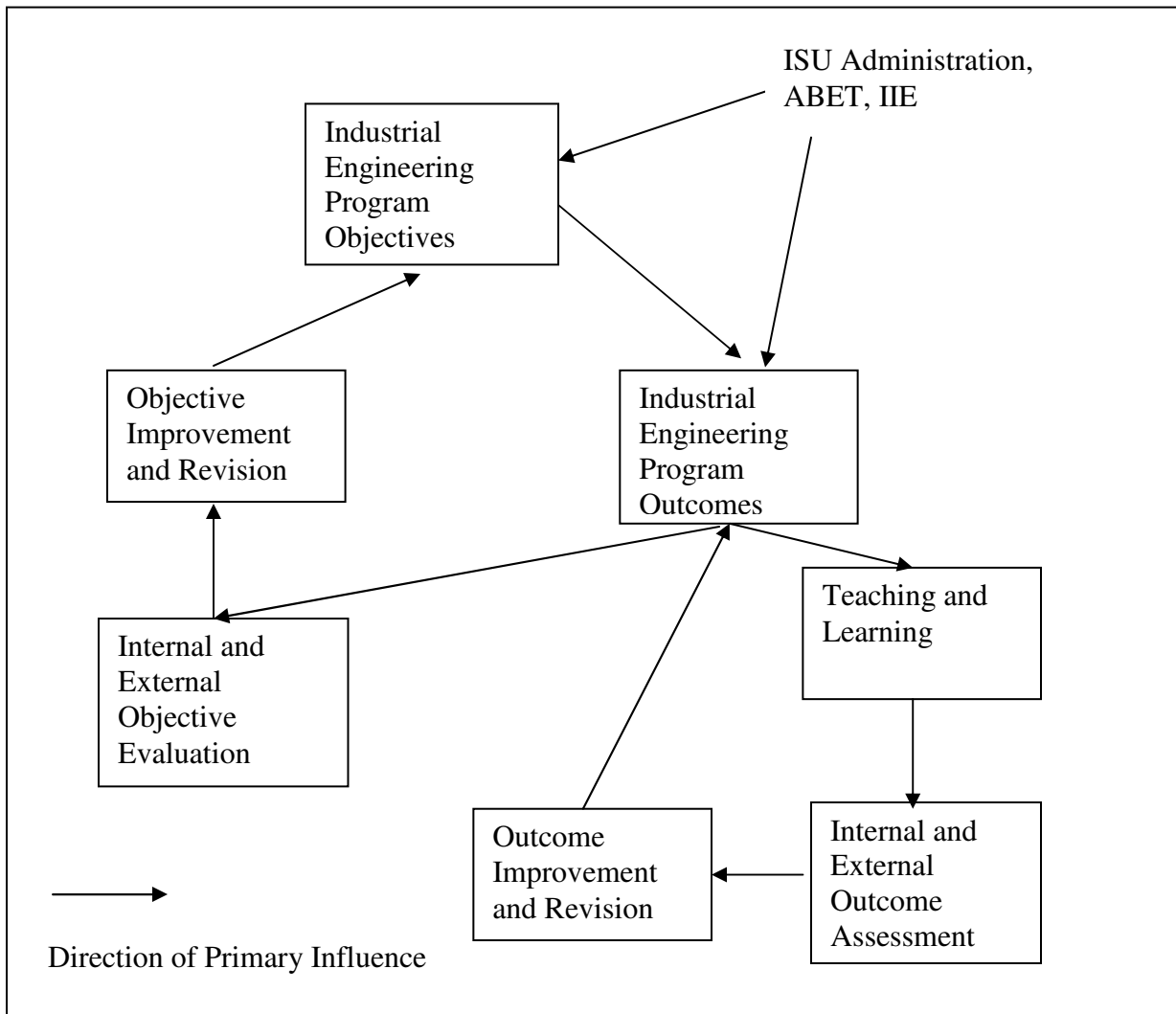
## Abstract

Soft skills and abilities such as ABET-specified outcome item (h) [the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context], which is mandated for all engineering programs, are difficult to assess, and difficult to improve. In this paper, in the context of Industrial Engineering, we show how such outcome items can be assessed and improved. We achieve this through a continuous improvement process via changes to the capstone design course and the creation of a Kaizen course, both of which emphasize qualities important to all vested interests, including students, industrial partners, advisory board members, and faculty. Improvement in the achievement of outcome item (h) is demonstrated first. This is followed by improvement in the achievement of various other outcome items. Results of outcome item measurement are compared between both students and industrial partners. Finally, insights obtained from the experimental Kaizen course are described, and future course changes are detailed, including methods of outcome assessment.

## Background

Since 2000, all accredited engineering programs have been required to document assessment of outcome items a-k as defined by ABET.<sup>1</sup> Some of these outcome items can be classified as ‘hard’ skills, such as (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]. The evaluation and assessment of ‘hard’ skills is generally considered to be significantly easier than that of ‘soft’ skills and abilities, such as (h) [The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context]. Without good assessment methods, determining if improvements have been made becomes even more difficult. If a program can successfully assess the softer skills as required by ABET, then its ability to improve is significantly increased. Moreover, measuring the impact of these improvements can then also be accomplished through the cycle of assessment.

An ongoing cycle of assessment and improvement activities that effectively improve the soft skill requirements of an engineering program can most likely successfully impact all skills and abilities—both hard and soft. In addition to curriculum improvements, the assessment cycle can and should also include the periodic evaluation of departmental educational objectives. These relationships and the cyclical process are currently used in the Industrial Engineering (IE) program at Iowa State University (ISU) (see e.g., Ball et al. (2007) for the departmental improvement efforts on global enterprise perspectives)<sup>2</sup> as shown in Figure 1.<sup>3</sup> A continuous improvement process can also be applied to individual courses. Over multiple semesters, the changes made within a course can be tracked through the assessment process, and by tracking assessment scores, changes for improvement can be identified.



The capstone design course in every engineering curriculum is the culmination of a student's academic career, and provides a logical and appropriate opportunity for students to demonstrate their mastery of many of the outcome items identified by ABET as well as department-specific outcome items. The capstone design course in the Iowa State IE Program is no exception. The course has been specifically designed to serve as a transition class for students moving from academia to industry while at the same time, like all other courses in the curriculum, supporting many of the ABET outcome items a-k and departmental outcome items l-p.<sup>4</sup>

Objectives for the capstone course, as stated in the syllabus, include: "... 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.”<sup>5</sup>

The capstone course format is designed to require extensive teamwork. Typically, teams of four students (though occasionally three or five) have fourteen weeks to move through all the steps of problem definition and solution generation at an industrial partner facility. Teams write and present a formal proposal during the third and fourth weeks of the semester. After instructor acceptance, they spend ten weeks researching, designing, and justifying solutions, which they must then formally write and present to the industrial partner during the last week of the semester. The only individual evaluations throughout the entire process are the professionalism assessment of each student made by the instructor and the peer evaluations which students provide for each team member. Otherwise, all work is group work and all grades are group grades.

Student teams accomplish most of their work during two three-hour labs each week. They are also required to attend an 80-minute lecture each week. The lecture content is not necessarily directly applicable to each individual project, but addresses things such as how to work with difficult people and how to handle strategic vs. economic project justification. It also emphasizes the criticality of realistic constraint consideration throughout the solution generation process. Projects are design-based, and typically include, but are not limited to, setup reduction, ergonomics analyses, machine specification, process improvements, layout, information flow, quality analyses and mistake-proofing. Small weekly assignments are made which generally support the overall final project results.

The capstone design course is typically assigned three to five outcome items for assessment each semester. These assignments are made by the IE Department’s Curriculum, Assessment, and Standard Committee (CASCOM) and are announced mid-semester. Assignments are largely based on the need at the time and the available data at the time. For example, if the assessment of a particular outcome item is ambiguous at the time of assignment decisions, that outcome item could be assigned to more courses for clarity and resolution. Assessment itself is made through the use of rubrics<sup>6</sup> (see e.g., Huba and Freed, 2000) which were created by faculty members and approved for general use by CASCOM. Rubrics serve as the objective evaluation component of the program. Assessments are made at the conclusion of each semester.

Each rubric consists of three major criteria with three levels of achievement. Examples of the rubrics for outcome (c), outcome (h), and outcome (j) [a knowledge of contemporary issues] are shown in Figures 2-4.

c) An ability to design a system, component or process to meet desired needs

Performance Criteria					
Item	Exemplary 5-6	Acceptable 3-4	Poor 1-2	Score	Comments
Ability to state the problem and determine design requirements	Problem statement is clearly defined, measurable objectives developed, and deliverables are clearly defined and relate to objectives	Problem statement is generally understandable, most objectives are measurable but may not be completely specific or quantifiable, and deliverables generally relate to the objectives	Problem 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		
<b>Total</b>					

Figure 2. Rubric for assessment of learning outcome (c) [An ability to design a system, component or process to meet desired needs].

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	Score	Comments
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		
<b>Total</b>					

Figure 3. Rubric for assessment of learning outcome (h) [The broad education necessary to understand the impact of engineering solutions in a global societal context].

j) a knowledge of contemporary issues

<b>Performance Criteria</b>					
<b>Item</b>	<b>Exemplary 5-6</b>	<b>Acceptable 3-4</b>	<b>Poor 1-2</b>	<b>Score</b>	<b>Comments</b>
Understanding of Contemporary Industrial Engineering Issues	Understands the contemporary industrial engineering challenges, solution tools and methods, and future trends	Some understanding of challenges and future trends	Little understanding of challenges or trends		
Understanding of Contemporary Economic and Business Issues	Understands the contemporary economic and business challenges, solution tools and methods, and future trends	Some understanding of challenges and future trends	Little understanding of challenges or trends		
Understanding of Contemporary Environment and Energy Issues	Understands the contemporary environmental and energy challenges, solution tools and methods, and future trends	Some understanding of challenges and future trends	Little understanding of challenges or trends		
<b>Total</b>					

Figure 4. Rubric for assessment of learning outcome (j) [a knowledge of contemporary issues].

Students are assessed by the instructor for each specific course. Assessments are generally (but not always) made based on work submitted. For example, for outcome item (c) in the capstone design course, the three performance criteria are easily evaluated using student papers and presentations (proposal, milestones 1 and 2, final). Scores for team members tend to be the same, but are tempered based on instructor and teaching assistant (TA) interactions with individual students as well as peer evaluations. For outcome item (h) in the capstone design course, performance criteria “Broad Education” and “Impact” are garnered out of specific material discussed in the team’s final papers. Specifically, these scores are made based on the final report sections titled, “Discussion of Realistic Constraint Considerations and Solution Ramifications” and “Summary,” while the assessment of the “Global” criterion is made by the department’s academic advisor who has access to student resumes, transcripts, and files. Each faculty member determines and documents their assessment methods for their assigned rubrics each semester.

We note that the rubrics themselves have been subjected to the process of continuous improvement (CI). Application of the rubrics began in 2003, but because of the CI process, several of the assessment rubrics have been modified since their initial application. After the Fall ’04 semester, the rubric for outcome (h) was determined to need adjustment to increase its effectiveness. Two of the evaluation criteria were further defined. In addition, senior student resumes were collected to provide additional information about student activities.<sup>3</sup> Likewise, the rubric for outcome item (j) has required some revising. After the Fall ’05 semester, for example, IIE introduced an energy component in ABET Criterion 8. The current rubric for (j) reflects that. In addition to the objective measures obtained through the use of rubrics, surveys of different populations are conducted annually for cross-checking purposes. In this way, rubric results are

validated and their representativeness verified. The content of these surveys was generated and is periodically updated by CASCUM, as appropriate. The surveys, which are independent of the rubrics, include Spring and Fall graduating seniors (administered near graduation each semester), and Year 1 and Year 3 alumni (administered in the Fall semester). Graduating senior surveys are currently administered while students are still on campus, though this is another recent CI change made in the F'05 semester. Alumni surveys are sent and returned to the department by mail. After survey results are returned and tallied, they are compared to rubric results.

While much of the CI assessment data is collected through formal rubrics and surveys, data is also collected as part of the CI process through various other means as is appropriate. Some of these types of data include collecting course data from students, discussions with industrial advisory board members, and conversations/data collection from industrial partners. One specific example of data collection from students is a pre/post test that has been administered to capstone design students for several semesters regarding sustainability, global impact, and design. The purpose of this data collection is to determine what students are bringing to and taking away from the course in terms of their level of understanding and confidence in considering sustainability and global perspectives when designing solutions. Another example of data collection occurs each year when the industrial advisory board meets on campus with faculty members to hear about program changes and results as well as to provide feedback. As part of the CI process for external outcome and objective assessment during the April 2005 meeting, advisory board members recognized the existing Lean Manufacturing topics in the curriculum but expressed a need for a more concentrated course with industrial experience. As a result of that discussion and as part of the CI conversations for the senior design course, the possibility of a Kaizen course was considered and is described in detail later in this paper.

Finally, a last example of data collection comes from industrial partners. During the execution of an experimental Kaizen course during the Spring 2006 semester, industrial partners were queried on their assessment of the value of the course with respect to program outcome items and objectives; these results are detailed later in this paper.

### **Changes to Capstone Design**

Based on these multiple feedback cycles, changes are made to the Industrial Engineering program and to specific courses as is deemed necessary and appropriate with the intent of achieving program objectives and increasing outcome achievement. Many changes have been made to the capstone design course over the past ten semesters. These changes are based on the continuous improvement process that is established within the department. Some changes have been made by the instructor based on observation of student interaction and achievement, such as videotaping proposal presentations and reviewing the videos later in the semester; adding a professionalism component to the grading process; and adding lecture material on business and cultural etiquette and contemporary industry 'buzzwords.' Other changes have been made through the tighter feedback loop of student evaluations to instructor, such as adding student roundtable presentations, business partner philosophy information, and lectures on working with unions and also working with difficult people. The final category of changes made within the capstone design course is based on outcome assessment results and focused on international perspective. Enhancements include making *The Economist* and *The Financial Times* available in

lab; posting a global map showing the international impact of industrial projects within the course; inviting outside faculty members to read students' papers addressing sustainability and global impact with respect to their projects; providing a realistic constraint checklist to students; and requiring a series of small papers to be written each semester regarding realistic constraints. In addition, more emphasis has been placed on written communications and more specifically, on punctuation. Finally, a brief pre- and post-test has been administered to capstone design students at the beginning and ending of each semester so that the instructor can easily determine if students are understanding the relationships between sustainability, global impact, and design.

## **Creation of the Kaizen Course**

A second example of CI process results is the creation of a Kaizen course. CI process feedback from the IMSE advisory board and CI conversations surrounding the capstone design course led several IE faculty to envision the possibility of incorporating an on-site Kaizen experience for students within the capstone design course. Kaizen is a Lean Manufacturing tool used to quickly address and eliminate waste from a process.<sup>7</sup> Because of the inherent nature and short duration of the 'Kaizen Blitz' as it is sometimes called, participating students would have the opportunity to achieve multiple outcomes—they would design and implement a solution for a specific problem and be able to experience the impact of their solutions while on-site. The possibility of partnering with a global facility existed. The idea that students would be fully valued team members was very significant since many Kaizen events purposely pull in 'outsiders' to act as a fresh set of eyes when trying to solve problems. Kaizen events are typically very focused, hands-on, and results oriented, and all of these things would be beneficial to students.<sup>8</sup> During Spring '05 senior exit interviews, the concept was offered up for opinion, and student interest was very strong.

While it was determined that a Kaizen event would be too large of an undertaking for the current capstone design course, the potential positives associated with an industry-sponsored Kaizen were many. After further consideration, an experimental independent study format was specified, and an Industry Partner was identified. John Deere Waterloo Works, Waterloo, Iowa, agreed to plan a Kaizen event within one of their component assembly departments that would coincide with the timing of the experimental course. While the location was a 'local' one, the fact that John Deere's customers and suppliers are global was not insignificant. Four students would participate in the Kaizen event as full-fledged members. In addition, the John Deere Foundation agreed to sponsor the housing and travel costs of the students during the Kaizen event week. Objectives for students, industrial partners, and faculty were all identified. They were:

### **For Students**

- To learn and understand how the concepts of Kaizen and continuous improvement fit into a Lean Manufacturing environment
- To obtain practical experience using Lean Manufacturing techniques in a company setting
- To obtain practice in teamwork, communications, and problem solving skills



#### For Industrial Partners

- To have students contribute to the productivity of the Kaizen process
- To provide meaningful exposure of the company to potential recruits

#### For Faculty

- To meet Student and Industry objectives
- To evaluate the success of the pilot and determine if extension is merited

In January, 2006, an invitation for application to the class was announced, and eleven students submitted the required information. Prerequisites for the course included majoring in IE and having completed IE248 (Engineering System Design, Manufacturing Processes and Specifications). Four students were chosen based on previous achievement, seriousness of purpose, communication ability, and year in school, including one female and three male students. These four students were also diverse by year in the program with two sophomores and two seniors participating. The class met formally three times prior to the Kaizen event, including an all day trip to John Deere Waterloo Works prior to meet the industry team members, observe the area to be analyzed, and to understand the product. The students then traveled to John Deere for their spring break week (March 13-17, 2006) for a full Kaizen event. Other Kaizen team members included John Deere assemblers, material handlers, a scheduler, a supervisor, a quality engineer, and a manager. It is noted that the wage team participants were members of the United Auto Workers (UAW) union. The Kaizen team started with a charter on Monday AM and by Friday had successfully implemented their recommendations and presented the results to John Deere's management team. Faculty members were on-site each day to monitor progress and make sure the process moved along smoothly.

Prior to the event and again at the conclusion, students were surveyed (anonymous responses) regarding department outcome and objective assessment. On the pre-survey, students were asked, "Indicate your personal satisfaction with how your undergraduate education in industrial engineering helped you to (1=not satisfied at all; 5=very satisfied)" for outcomes items a through p. On the post survey, students were asked this same question as well as, "How helpful has this project been for increasing your ability described in outcome items a-p (1=not satisfied at all; 5=very satisfied)?" where, for example,

c=design a system, component, or process to meet desired needs

h=know social, economic, and international implications of engineering solutions  
and understand their impact on people and communities

j=know international and diversity perspectives, and understand contemporary issues  
of industrial engineering

Industry partner participants were similarly surveyed at the conclusion of the event. Students were also pre- and post-tested regarding their understanding of Lean Manufacturing and Kaizen, and queried about their confidence in applying this philosophy and tool on the job. Students and faculty were both asked "what worked?" and "what could be improved?" All post assessments and testing occurred at the conclusion of the course. The course was completed with the students writing summary papers about their experience.

## Measured Improvements within the Capstone Design Course

As part of the cycle of continuous improvement, rubric and survey results have been measured on an on-going basis, capturing the impact of changes to the capstone design course specifically and to the industrial engineering program more generally. In addition, outcome assessment survey results were captured from the experimental Kaizen course. From these two sources, comparisons over time for specific outcome items can be made. Comparisons in opinion between different populations (namely students and industrial partner participants) are also identified. In this paper, we highlight the impact of improvement efforts on outcome items (h) and (c), and begin discussions about results for outcome item (j).

Over the past seven semesters, the assessment schedule within the capstone design course has purposely repeated several outcomes. This schedule is seen in Table 1.

Semester	Outcome Items Assessed
F'03	c, e, f, g
S'04	c, e, f, g
F'04	d, g, h, p
S'05	h, i, j
F'05	c, h, i, j
S'06	f, i, j, n
F'06	c, g, h, i, j

Table 1. Outcome assessment schedule in capstone design course.

Rubric data is gathered each semester for the assigned outcomes within a particular course. For outcome items (c), (h), and (j), the number of students evaluated, the average scores, and standard deviations are detailed in Table 2.

Semester	Criteria	Number of students evaluated in IE441	Average Score (Max=18)	St Dev.
F'03	c	18	12.83	1.86
S'04	c	37	13.76	3.11
F'05	c	29	13.55	3.50
F'06	c	29	17.86	0.35
F'04	h*	14	6.43	0.85
S'05	h	19**	11.74	2.13
F'05	h	29	11.86	3.09
F'06	h	29	14.31	1.63
S'05	j	19**	13.79	2.37
F'05	j	29	12.97	3.01
S'06	j	42	12.57	2.61
F'06	j	29	15.17	2.80
*h not assessed by department advisor using resumes or transcripts ** graduating seniors only				

Table 2. Rubric results for (c), (h), and (j) in IE441 Capstone Design Course.

When this data is plotted by semester as shown in Figure 5, positive trends appear to be established for outcome items (h) and (c), soft and hard skills respectively. We note that as published in an earlier paper, the data for the F'04 semester for outcome item (h) is suspect because of the original rubric format and definitions.<sup>3</sup> Changes were made after the F'04 semester, and so while still positive, the slope is most likely not as steep as the chart in Figure 5 appears. We also note that changes were made to the assessment rubric for outcome (j) after the F'05 semester, and so while the most recent two semesters evaluated indicate a positive improvement, there is not enough data to definitively state this. Future semesters will provide more conclusive data with respect to the soft skills and abilities of outcome item (j).

Regardless of the rubric adjustments, it appears that there is a positive trend for outcome items (h) and (c). Four semesters of data over the course of 3.5 school years indicates that the changes being made within the department and the capstone design course with respect to outcome item improvement are working. The average outcome item (h) score has increased by over 20% since its second semester of assessment. The average outcome item (c) score has increased by over 35% since its first semester of assessment.

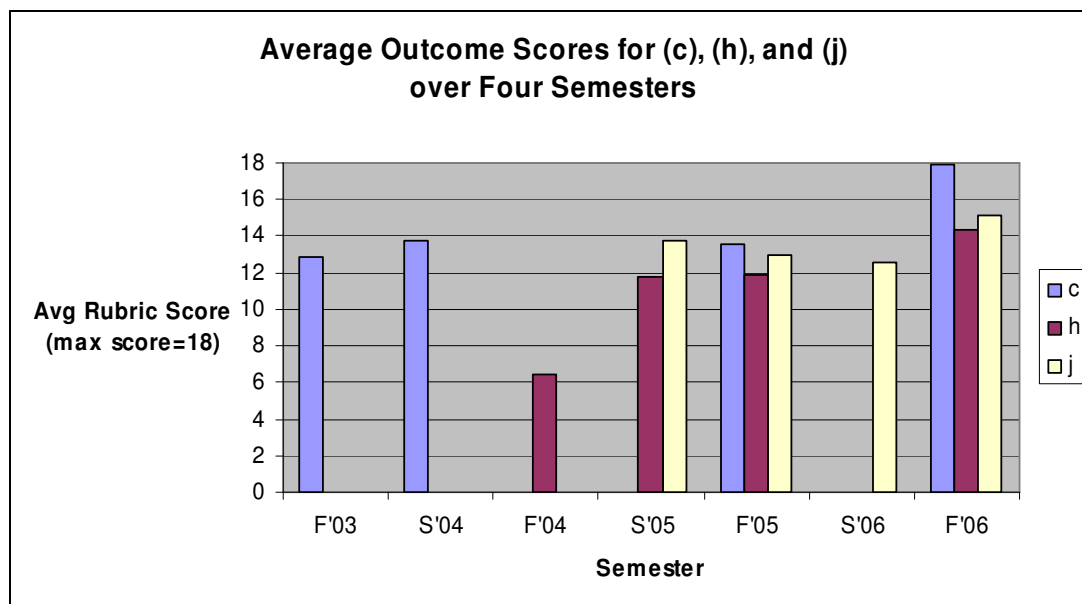


Figure 5. Average rubric scores for outcome items (c), (h), and (j) shown by semester.

These improvements have been crosschecked with survey results over the same periods for the robustness of the findings. For example, graduating senior survey results for outcome items (h), (c), and (j) tallied from the Spring '04 through the Spring '06 semesters (shown in Table 3 and plotted in Figure 6) have all converged around a score of 4.0 (Max=5, Min=1), indicating that objective rubric evaluations of high “Acceptable” scores to low “Exemplary” scores are in fact perceived at the same success levels by the students.

Semester	Criteria	Number of graduating senior respondents	Average Score (Max=5, Min=1)
S'04	c	21	3.71
F'04	c	6	4.33
S'05	c	11	4.09
F'05	c	11	4.09
S'06	c	10	4.00
S'04	h	21	4.00
F'04	h	6	3.58
S'05	h	11	4.55
F'05	h	11	4.00
S'06	h	10	3.90
S'04	j	21	4.00
F'04	j	6	3.67
S'05	j	11	4.09
F'05	j	11	3.91
S'06	j	10	4.00

Table 3. Graduating senior respondent results for (c), (h), and (j) in IE program.

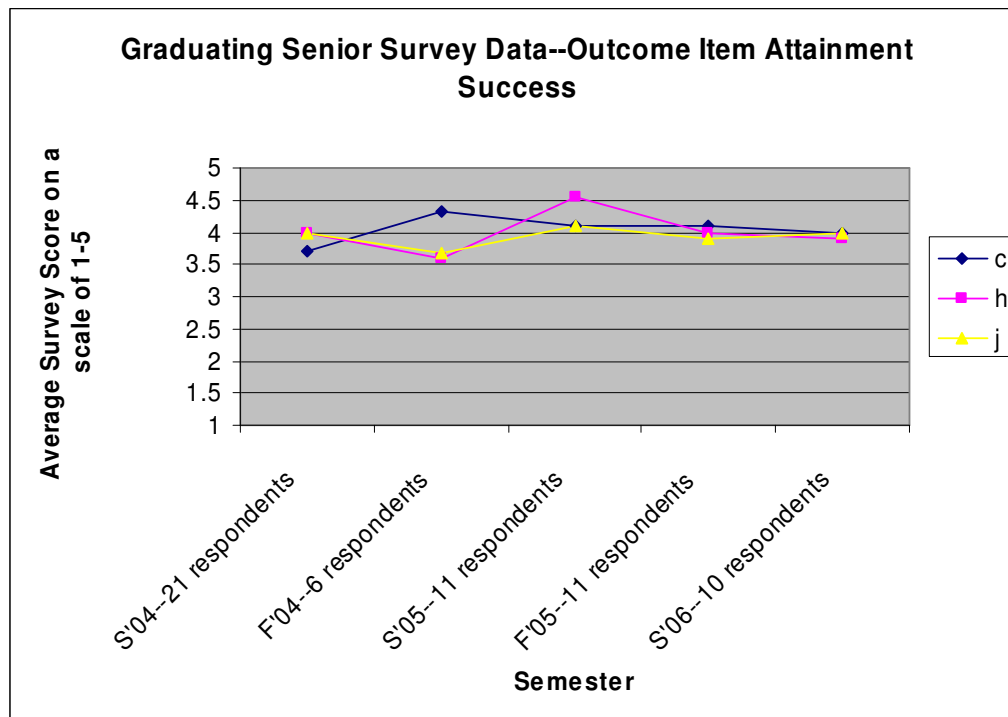


Figure 6. Graduating senior survey results for outcome items (c), (h), and (j) shown by semester.

## Measured Improvements within the Experimental Kaizen Course

The Kaizen course was constructed as a direct result of the IMSE CI process with the intent of providing students the type of knowledge and experience valued by faculty, students, industrial partners, and advisory board members. The process was treated as an experiment and data collection and analysis were completed at the end of the course. The impact of the Kaizen course was measurable on multiple outcome items, including (c), (h), and (j).

Figure 7 shows the increase in student scores from pre-survey to post-survey regarding how their education has helped them with individual outcome items. ABET specified outcome items a-k and departmental outcome items l-p all show an increase or no change from pre- to post-survey, indicating that students felt very positive about the IE program as a result of their Kaizen experience. Figure 8 shows the change from pre- to post-survey for all outcome items. Among those showing an increase of more than 0.5 points on a 1-5 point scale were outcome items (c) and (j).

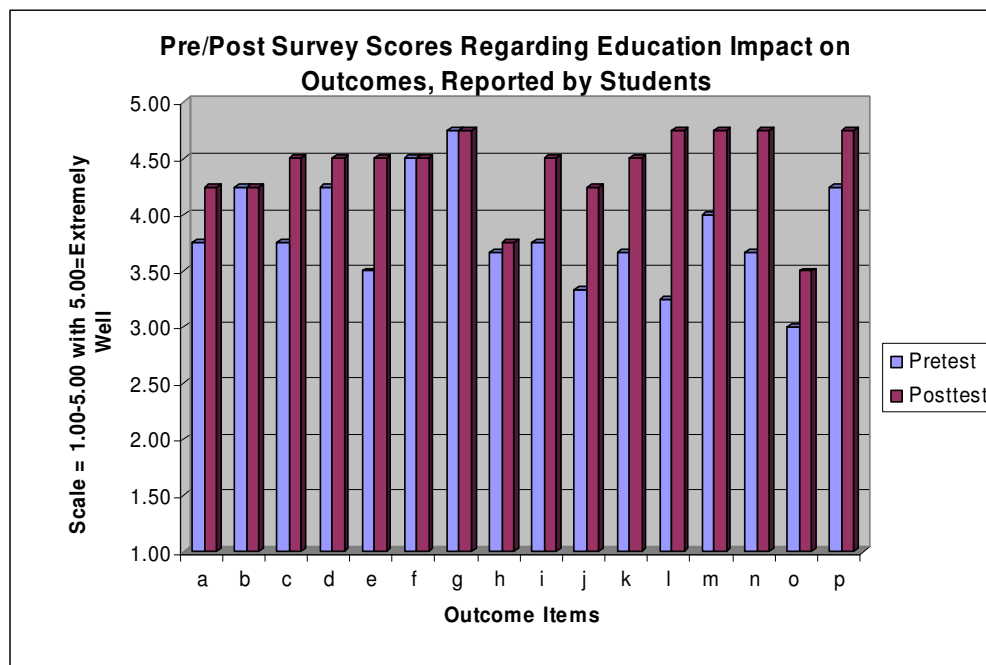


Figure 7. Pre- and post-survey scores by students (n=4) regarding how well education has helped with individual outcome items on a numerical scale of 1-5.

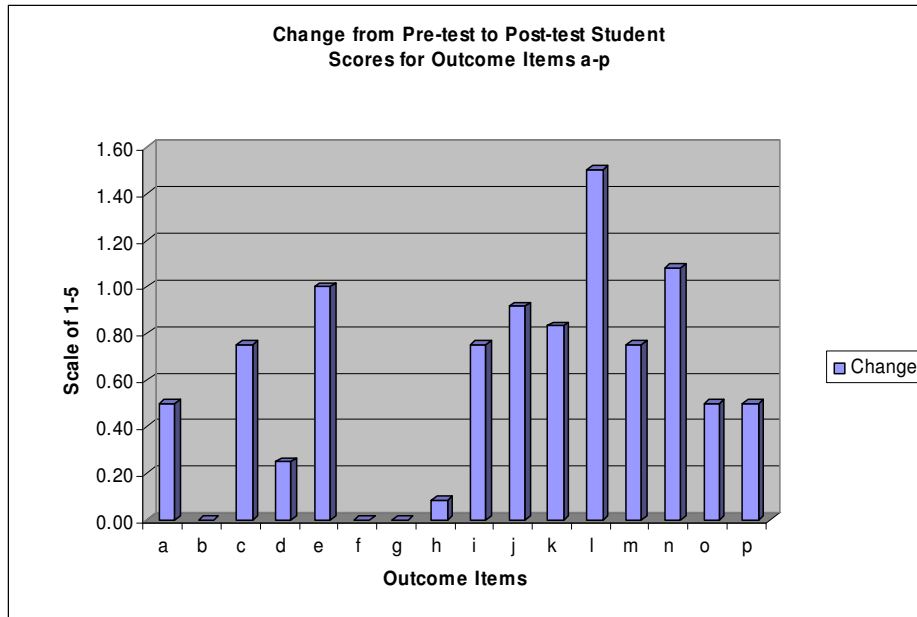


Figure 8. Change in outcome item average score from pre- to post-survey by students before and after Kaizen event week on-site at John Deere Waterloo Works, Waterloo, Iowa.

Post-survey student opinion about the Kaizen course was compared directly to pre-survey data about the IE program in general to determine which outcome items were most dramatically impacted by the experience. Outcome items (c, d, e, k, l, n, and p) all scored higher for the Kaizen experience, indicating the value of the experimental course to the IE program in terms of outcomes. These comparisons are shown in Figure 9.

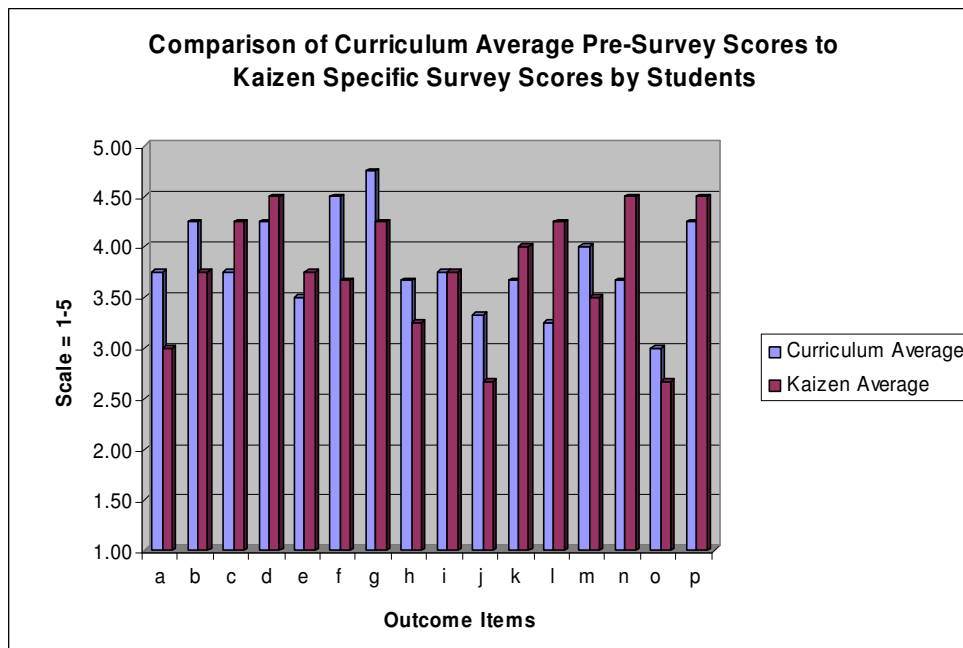


Figure 9. Comparison of student opinions about value of Kaizen course vs. general IE program curriculum as related to outcome item achievement.

Industry partner participants were invited to complete a post-Kaizen event survey. Three respondents did so, and this data was compared to student post-survey opinion about the value of the Kaizen event, as shown in Figure 10. Of interest is how the two independent sets of data showed remarkable tracking, indicating that the students and industrial partner participants were in agreement about the value of the Kaizen experience to the students' education. The highest (and really only) discrepancy is seen in outcome item (j). Industrial partner participants found more value provided by the Kaizen experience with respect to having knowledge of contemporary issues. This might indicate that the relationship between solution generation and knowledge of contemporary issues needs to be more clearly addressed with the students.

With respect to the data shown in Figure 10, it is also noted that the range of scores for the different outcome items points to the validity of the survey data. It would be unrealistic to expect a single course to be able to emphasize all outcome items.

Finally, written feedback from all vested interests in the Kaizen experiment was overwhelmingly positive. Comments from students included the following:

- “The kaizen event at John Deere was a huge benefit to me both as a student and professionally. The trip allowed me to see how many of the concepts learned in class are applied in a work environment.”
- “I feel that the most valuable lesson I learned was to never be afraid to talk and learn from the person who has been doing the job you are about to change.”

Comments from industry included the following:

- “Team came together very efficiently and achieved the pre-determined goals of the project. They were very mature throughout and were not afraid to get engaged! Great results overall!”
- “Dividends already as both the east rack and marked benches are providing input and raising awareness. Thanks for the departmental shot in the arm.”

While the immediate timing of the assessment could impact the results attained, it was imperative to gain rapid feedback so future course offerings could be planned and improved.



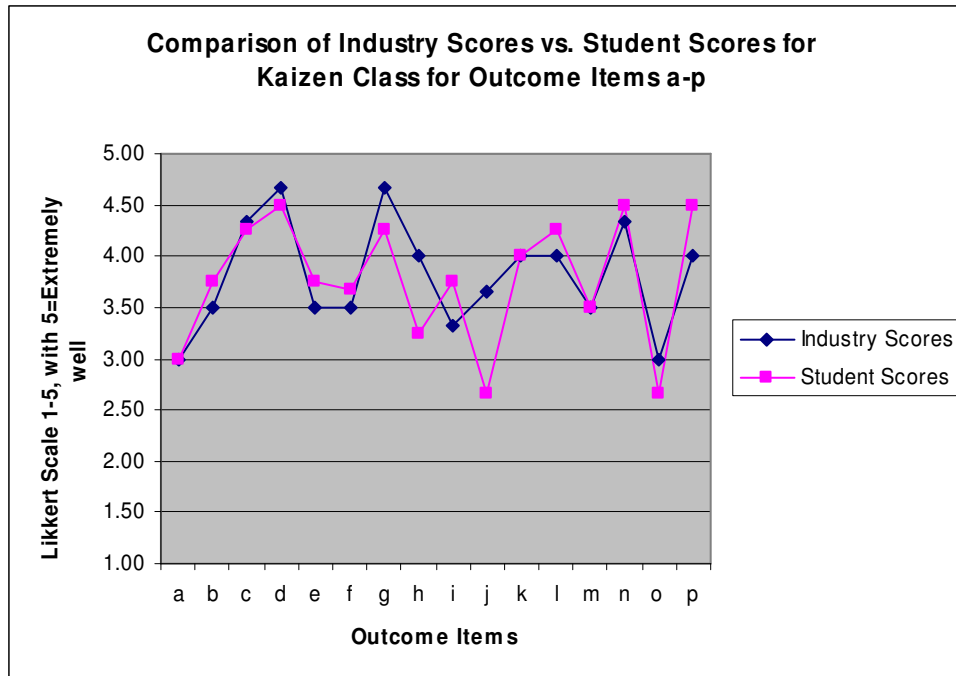


Figure 10. Comparison of student and industry partner participants' opinions about the value of the Kaizen experience as related to individual outcome items.

A significant piece of feedback is the invitation by John Deere to repeat this experience. While sample sizes were too small to make any definitive statements, the sum total of information collected from the Kaizen experiment (pre/post surveys, pre/post tests, interviews, papers, and comments) indicates that the Kaizen event is a very beneficial addition to the industrial partner, to the students, and to the IE program. Faculty members were very pleased with the increase in outcome assessment scores. In addition, the information was reported to department advisory board members during the April, 2006, meeting. Advisory board members expressed strong approval for both the results observed as well as the fact that the CI process was working in that their suggestions from the year prior had been pursued.

### Insights and Future Changes

The continuous improvement process is working. Assessment of outcome items through the use of rubrics and surveys provides two independent measures which support each other. It also provides insight into changes needed for improvement. Changes made in specific courses such as the capstone design course have had a measurably positive impact. These improvements have been observed in both hard and soft skills. Changes to the program such as the experimental Kaizen course show great promise for future improvements.

While this paper focuses only on two of the more difficult-to-measure 'soft skill' outcome items (h and j) and compares them to an easier-to-measure 'hard skill' (c) outcome item, it is noted that positive impact was observed for many of the outcome items being evaluated.

As a result of the observations within the capstone design course, future changes include refining the data collection from pre/post-testing students about sustainability, global impact, and design.

This will better guide the instructor to make changes to the course content for the purposes of achieving outcome items. In addition, the relationship between solution generation and knowledge of contemporary issues will be emphasized.

Another change currently underway and based on the results of assessment is the current offering of two university-approved experimental 3-credit courses titled “International Lean Manufacturing Production Systems (IE 421X)” and “Lean Manufacturing Production Systems (IE 422X).” During the spring semester 2007, three student teams of four members each will travel to England to participate in a week-long Kaizen event at two different facilities, while one student team of three members will travel to John Deere in Waterloo, Iowa, to do the same. The course will delve significantly deeper into the tools and techniques utilized in Lean Manufacturing implementation. Course material will include 5S, setup reduction, inventory management, etc., as well as Kaizen. It will also focus heavily on international business perspectives with a nod toward greater impact on outcome items (h) and (j). The experimental 3-credit courses are not required for graduation, but are approved technical electives and count toward graduation. Future expansion of the courses will be considered as part of the 2007 CI process cycle.

Changes to outcome item assessment are of a refining nature at this point in the process. All of the major concerns have been addressed after four years of use. However, as the feedback loops between students, faculty, industrial partners, and advisory board members continue to function, curriculum changes will continue to be made which will inherently drive assessment changes as well.

### **Concluding Remarks**

In this paper, we showed how challenging ‘soft skill’ outcome items can be assessed and improved within an Industrial Engineering curriculum. We described both how improvements were made and measured within the structure of the existing capstone design course, as well as through the creation of an experimental Kaizen course. We summarized the feedback from all vested populations in the IE program, including students, faculty, industrial partners, and advisory board members.

As we continue down a path of continuous improvement, there is still an expectation that the Kaizen event experience might be incorporated into the capstone design. Survey data will be collected from IE 421X/IE 422X students and industrial partner participants to help determine the feasibility/desirability of this alternative. Whether such a merger occurs or if the Lean Manufacturing Production Systems courses remain stand-alone, the impact on outcome assessments is expected to remain positive. Results from the first three-credit Lean Manufacturing classes will be analyzed and published.

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