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Assessment and Evaluation of Objectives and Outcomes for Continuous Improvement of an Industrial Engineering Program*

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In recent years, ABET accreditation has placed a heavy emphasis not only on the assessment of objectives and outcomes, but also on the evaluation of them and subsequent efforts for continuous improvement based on such an evaluation. Currently, a plethora of assessment tools and conceptual frameworks notwithstanding, there exists a relative paucity of documented efforts on the actual evaluation and subsequent continuous improvement. In this paper, we first concretely (1) show how such assessment and evaluation can be deliberately and systematically conducted in the context of an Industrial Engineering program. We then (2) show how the results of the objectives evaluation lead to the efforts towards continuous improvement through the student outcomes. Through (1) and (2), we enable others to specifically identify and prepare for the critical stages necessary to advance beyond a display of assessment tools and conceptual frameworks and to actually close the loop for a continuous improvement cycle.

Keywords: assessment; evaluation; objectives; outcomes; continuous improvement

1. Introduction

In engineering programs throughout the USA as well as increasingly in non-US programs, ABET accreditation has often become a mandatory minimum standard that must be maintained [1]. At the same time, ABET accreditation has focused not only on the assessment of objectives and outcomes of engineering programs, but also on the evaluation of them and the subsequent efforts towards continuous improvement based on such evaluations [2].

In practice, however, there exists a plethora of assessment tools and conceptual frameworks (see e.g., [3], [4]) and a relative paucity of documented efforts on the actual evaluation and subsequent continuous improvement (see e.g., [5]).

In particular, under these circumstances, it is highly desirable to document step by step how the ABET expectations can be met so that various accreditation stakeholders may be able to specifically identify and prepare for the critical stages necessary to advance beyond assessment tools and conceptual frameworks and to close the loop for a continuous improvement cycle.

ABET specifically asks stakeholders to [6]:

1. document your processes for regularly assessing and evaluating the extent to which the program's educational objectives and student outcomes are being attained;
2. document the extent to which the program's educational objectives and student outcomes are being attained; and
3. describe how the results of these processes are being used to effect continuous improvement in the program.

In this paper, in view of these expectations, we aim to contribute by actually demonstrating how each of these expectations can be met step by step in the context of an Industrial Engineering program (see e.g., [7] in the context of environmental sustainability education and [8] in the context of international supply chain education).

In so doing, we hope to bridge the gap between the plethora of abstract frameworks and the paucity of documented practices—a little bit at a time. By documenting this practice, we also hope to stimulate discussion in this important area of the outcome and objective assessments and evaluations, as well as the subsequent continuous efforts for improvement. Ultimately, we hope all such activities will positively contribute toward better learning experiences by students in engineering programs.

Methodology-wise, our responses to these expectations heavily depend on a series of gap analyses (see e.g., [9]) and exploit triangulations for robustness of our findings (see e.g., [10]). In so doing, for example, it will be clear that the identification of the areas for improvement will be systematic and deliberate. It will also be clear that the pieces of evidence supporting our findings will come from different assessment methods and from different stakeholders.

Hence, it is also hoped that others will be able to understand and rely on such gap analyses and

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triangulations for results that are not haphazardly obtained/attained, and further facilitate discussion and exchange of ideas on the methodology side.

The rest of the paper is organized as follows. In Section 2, we present the IE (Industrial Engineering) program background, program's educational objectives (PEOs), and student outcomes, and show how they are related. Next, in Section 3, we present how the assessment and evaluation of the objectives can be systematically conducted. In Section 4, for student outcomes, we show how the assessment and evaluation are conducted. This is followed by Section 5, presenting how the results of the PEO's evaluation lead to the improvement efforts through the student outcomes. In Section 6, we further comment on our experiences thus far and discuss future endeavors. Finally, in Section 7, we give our conclusions.

2. Program's educational objectives and student outcomes

Iowa State University (ISU) is a land-grant institution with obligations to teach practical classes that will provide students with the knowledge to make a difference in the world. This ISU mission presents a clear vision for an educational philosophy that matches closely the goals of the undergraduate college of engineering: to provide students with the kind of training that will allow them to make a difference in our state, nation and around the world. To achieve this mission, the Industrial Engineering (IE) program for the Bachelor of Science (BS) degree must be responsive to the needs of relevant industries, such as manufacturing and services. Hence, the feedback from the relevant industries, alumni, and current students who often have co-op and internship experiences provide information that should be used to improve our programs through efforts towards continuous improvement.

As one can subsequently observe, this ISU mission-based philosophy greatly influences the assessment and evaluation processes of the IE educational program objectives (PEOs) and student outcomes, as well as the IE program continuous improvement process. In what follows, we describe the PEOs, student outcomes, and their relationships.

2.1 Program's educational objectives

The IE Program educates its future graduates to accomplish its educational objectives in their early careers. Specifically, the IE curriculum prepares its majors so that, within a few years of graduation, the graduate has

1. made industrial engineering decisions that result in well-reasoned, value-added solutions;
2. had communications with stakeholders that are informative, persuasive and constructive;
3. made contributions to team goals through effective team interactions and leadership; and
4. attained new skills and knowledge that advance their professional practice and enable career advancement.

These objectives deliberately and systematically support the ISU mission as they not only emphasize the technical achievements, but also professional practice-related achievements in communications, teamwork, and continual learning by our alumni.

The primary constituencies of the program and how they relate to it are: 1. Faculty, 2. Students, 3. Alumni and 4. Industries. We do note that there are other stakeholders (but not the primary constituencies), such as university administrators, as well as professional societies and other relevant organizations such as the Institute of Industrial Engineers (IIE) and ABET.

2.2 Student outcomes

The IE Program has the following student outcomes.

(a) An ability to apply knowledge of mathematics, science and engineering
(b) An ability to design and conduct experiments, as well as to analyze and interpret data
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability
(d) An ability to function on multidisciplinary teams
(e) An ability to identify, formulate and solve engineering problems
(f) An understanding of professional and ethical responsibility
(g) An ability to communicate effectively
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context
(i) A recognition of the need for, and an ability to, engage in life-long learning
(j) A knowledge of contemporary issues
(k) An ability to use the techniques, skills and modern engineering tools necessary for engineering practice
(l) An ability to design, develop, implement, and improve integrated systems that include people, materials, information, equipment and energy
(m) An ability to provide leadership in multi-functional teams.

Outcomes (a) through (k) are the ABET specified

Table 1. Mapping of objectives to outcomes

Objective/Outcome	a	b	c	d	e	f	g	h	i	j	k	l	m
1	×	×	×		×			×		×	×	×	
2				×			×	×					×
3				×		×	×						×
4						×			×	×			

outcomes. We also note that there are two additional outcomes articulated by our program: Outcome (l) and Outcome (m). Both of these are determined by the department faculty, but Outcome (l) is in part inspired by the Industrial Engineering Program Criteria, while Outcome (m) is in part inspired by the IE Industry Advisory Council (IAC).

2.3 Relationship of student outcomes to program's educational objectives

We first show how the student outcomes specifically prepare graduates to attain the program's educational objectives, and summarize their relationships in Table 1 as follows.

2.3.1 Objective 1: Industrial engineering decisions that result in well-reasoned, value-added solutions.

In order to prepare our graduates to attain this objective, it is necessary that our students obtain the technical skills and knowledge specified in Outcomes (a), (b), (c), (e), (k) and (l). Also, obtaining Outcomes (h) and (j) will facilitate reaching well-reasoned, valued-added solutions. The remaining outcomes not mentioned here will also contribute positively toward this objective, but with less direct relationships and perhaps less impact. This note is applicable equally to all other objectives.

2.3.2 Objective 2: Communications with stakeholders that are informative, persuasive, and constructive

In order to prepare our graduates to attain this objective, it is necessary that our students obtain the skills and knowledge specified in Outcome (g). Also, Outcomes (d) and (m) provide some of the best preparations for achieving this objective—context and industry practice-wise. We believe Outcome (h) will strongly support the achievement of this objective.

2.3.3 Objective 3: Contributions to team goals through effective team interactions and leadership

In order to prepare our graduates to attain this objective, it is necessary that our students obtain the abilities specified in Outcomes (d) and (m). Also, Outcome (g) provides some of the best preparation to achieve this objective—skill and knowledge-wise. Furthermore, we believe Outcome (f) is essential for the sustainable attainment of this objective.

2.3.4 Objective 4: New skills and knowledge that advance professional practice and enable career advancement

In order to prepare our graduates to attain this objective, it is necessary that our students obtain the recognition and ability specified in Outcome (i). Also, Outcome (j) will facilitate the achievement of this objective by supplying appropriate and relevant information on contemporary (not stale or obsolete) issues. Furthermore, we believe that, in the long run, Outcome (f) is essential for the advancement of professional practices as well as careers.

2.3.5 Mapping of objectives to outcomes

Table 1 summarizes the mapping of the four program educational objectives to the 13 student outcomes.

So far, we have presented the IE program background, PEOs, and student outcomes, and showed how they are related. Next, we show how the evaluation of the objectives is systematically conducted.

3. Assessment and evaluation of program's educational objectives

The assessment and evaluation process is as follows. With the primary constituencies of the faculty, alumni, and industries in mind, we first design a survey that asks, for each program's educational objective,

- To what extent have BSIE graduates attained the following program educational objectives?
- How necessary are the following program educational objectives for the BSIE graduates?
- How well has the BSIE Program at ISU prepared its graduates to attain the program's educational objectives within a few years of graduation?

The constituents are asked to provide a numerical score for each objective between 1 (not at all) to 5 (very much/well).

With the primary constituency of the students, on the other hand, we designed a similar survey that excludes the first type of question on attainments, as these attainments are years away.

For the faculty, each faculty member is given the survey form. At the same time, Year 1 alumni (those who graduated last year) and Year 3 alumni (those who graduated 3 fiscal years ago), representing the alumni, are given the survey forms. Also, each member of the industry advisory council, representing the industries, is given the survey form. As for the students, each member of the student focus group is given the survey form. The student focus group consists of more mature students with leadership experiences such as peer mentors, student ambassadors for recruiting, and learning community assistants for retention. We do recognize that the students' input should be a valuable component in the objective assessment and evaluation process. At the same time, some students (e.g., often 18 years old) may not be in a best position to answer questions regarding the program graduates' achievements 3 to 5 years after graduation. Hence, we are attempting to strike a balance here by treating the student focus group as a proxy for the students.

The surveys are conducted almost simultaneously to enhance the validity of the cross-checking across the primary constituencies later (cf. one constituency was asked 2 years ago, while another was asked this year). We further note that there are additional entry points for input and feedback, namely faculty meetings as well as industrial advisory council meetings where bi-directional questions and answers are possible. We also note that we are mindful of the students' input revealed in various feedback mechanisms ranging from written comments in graduating senior surveys to oral comments during student focus group meetings.

We note that the current evaluation process, as conducted in Spring 2011, starts every three years with the revised program's educational objectives (if a revision is needed) within six months or so. Also, we note that the old evaluation process, as conducted during Fall 2008–Spring 2009, started every four years with the revised program's educational objectives within twelve months or so (hence, the preceding evaluation was conducted during Fall 2004–Spring 2005, which was before the last general review). With these changes, we aim to coincide better with the university-wide changes in its catalog (e.g., from 2-year catalogs to 1-year catalogs, with submission deadlines less in advance, towards the elimination of paper copies, etc.).

In the following two subsections we will discuss our expectation and results.

3.1 The expected level of attainment of the program's educational objectives

Even though we do not have a single number from a single constituency that will assure the attainment of each program's educational objective, we expect that, for each program's educational objective, a satisfactory level of attainment is achieved if the average numerical scores from the faculty, alumni, and industries are all higher than 3 (5 best/1 worst) concurrently. By cross-checking the independent returns of the three primary constituencies of the faculty, alumni and industries, we believe that our conclusion is robust and entirely plausible as the possibility of all three constituencies coincidently being wrong is remote. The actual (cf. expected) levels of attainment will be discussed in the next subsection.

3.2 Results of program's educational objectives assessment and evaluation

The results from the returned survey forms are summarized in Table 2.

The categories A, B and C represent attainment, necessity and preparation, respectively. We also note that there are four aforementioned objectives

Table 2. Average scores of each objective for each constituency

Average score 5 = Best	Faculty	Alumni Year 1	Alumni Year 3	Industry (Advisory Council)	Student (Focus Group)
Attainment					
A.1	4.31	4.09	4.28	4.20	NA
A.2	3.54	3.82	4.56	3.80	NA
A.3	4.15	4.45	4.67	4.40	NA
A.4	4.15	4.18	4.22	3.60	NA
Necessity					
B.1	5.00	4.82	4.28	4.57	4.36
B.2	4.69	4.82	4.67	4.86	4.30
B.3	4.69	4.91	4.78	4.57	4.73
B.4	4.85	4.91	4.44	4.29	4.73
Preparation					
C.1	4.46	3.91	4.50	4.20	3.91
C.2	3.46	3.82	4.17	3.60	3.60
C.3	3.69	4.09	4.50	4.40	4.36
C.4	4.15	4.00	4.17	3.80	4.18

for each category of questions. We further note that the number of respondents for the faculty, Year 1 alumni, Year 3 alumni, industry advisory council and student focus group are 13, 11, 18, 7 and 11, respectively. Finally, the standard deviations range from 0 (the necessity of Objective 1 according to the faculty) to 1.22 (the preparation for Objective 1 according to the Year 1 alumni).

From Table 2, we easily observe that the average numerical scores from the faculty, alumni and industries are all higher than 3 concurrently. In fact, the absolute majority of the average numerical scores are 4 or even higher. Hence, we conclude that each objective is satisfactorily attained at this point in time. Furthermore, collectively, the rows of A.1, A.2, A.3 and A.4 indicate the actual extent of the attainment for the program's educational objectives 1, 2, 3 and 4, respectively.

As we have concurrently conducted the survey across the four primary constituencies, a gap analysis is visually conducted as follows. Figure 1 plots the average numerical scores from the faculty, Year 1 alumni, Year 3 alumni and the industry advisory council for each objective (the objective number follows the constituency symbol) vs. attainment, necessity and preparation.

For example, if there were a point for an objective near the origin, then there may an objective that is unnecessary, unprepared for in our program, and unattained in the careers of our graduates. Since we can visually verify that all the average numerical scores are far from the origin, along with the numerical values in Table 2, we conclude that our objectives are necessary, prepared for in our program, and attained in the careers of our graduates. We also note that the written comments in the survey forms, our interaction in the faculty and industrial advisory meetings, and other input and feedback by and large confirm the results of our analyses.

Furthermore, we note that similar analyses have been conducted according to the identical process for the objective evaluation during Fall 2008–Spring 2009. Finally, we note that we will use the gap analysis further in our continuous improvement process, which will be elaborated in Section 5. We now proceed to Section 4, and present how the assessment and evaluation are conducted for student outcomes, which are the drivers of our efforts towards continuous improvement in Section 5.

4. Student outcomes assessment and evaluation

In this section, we explain the assessment and evaluation processes for the student outcomes as well as the results of such processes in details. For

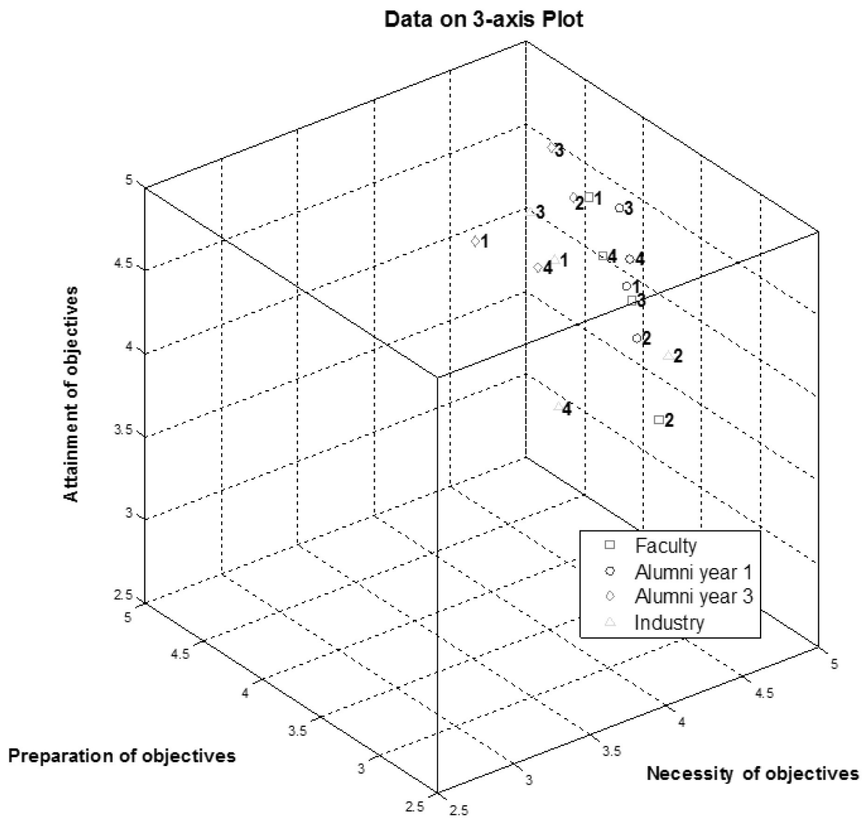

Fig. 1. Plot of the average numerical scores vs. Attainment, Necessity and Preparation

the assessment of the student outcomes, we employ a combination of direct and indirect approaches consisting of instructor-driven rubrics and student- and alumni-driven surveys.

4.1 Direct assessment by the instructors-driven rubrics

Let us first explain the instructor-driven rubrics approach as follows (see e.g., Table 4 for Outcome (a)). Even though the student outcomes can be achieved by IE majors via diverse optional educational experiences at Iowa State University, which may include internships and student organization activities, the primary way of achieving such outcomes is through the courses specified in the IE curriculum course requirements.

These requirements consist of IE and non-IE courses, some of which are required, while others are from various lists of electives. We believe that all these courses contribute significantly towards the achievement of the outcomes by our students. To ensure that the achievement of all the outcomes is fostered and facilitated for all IE majors within a standard IE curriculum, however, the IE program places great emphasis on 12 courses (consisting of fundamental manufacturing, human factors, and operations research courses) that are mandatory for IE majors. This is consistent with the guidelines provided by the ABET Program Evaluator (PEV) Refresher Training Program in Module 4 [11], which specifies that the evidence of the student outcomes "should be the product of faculty reviewing and/or observing student work related to the program requirements."

In particular, these required IE courses serve as a primary vehicle through which the student outcomes can be assessed. The mapping of the 12 required IE courses to the 13 outcomes, which specifically shows how these courses are related to the outcomes, is shown in Table 3.

Table 3 shows the relevance and appropriateness of each course to various outcomes (marked by ×), which can be assessed as needed. This table does not necessarily show all the possible or remotely related outcomes that can be assessed for each course.

When an outcome is assessed in a required IE course, the instructor is asked to use the pre-specified rubric for the outcome. The rubric for the outcome, in turn, consists of three rows of subcriteria that collectively explain the outcome and three columns of the degree of achievement for each subcriterion. For example, the rubric for outcome item (a) is as shown in Table 4. As one can observe, the maximum score for a rubric is 18, while the minimum is 3.

In the early part of each semester, the director of undergraduate studies, often based on the practice of past years, invites all the instructors of the required courses in the semester to assess a few relevant and appropriate outcomes, shown in Table 3. In a typical course, the number of outcomes to be assessed is one or two, but an exception can be made. For example, due to the summative nature and value of the outcome assessment conducted in the capstone design course, more than two outcomes are directly measured in IE 441. On the other hand, to strike a balance and to cross-check the validity, many outcomes are directly measured across the curriculum outside the capstone design course. The goal of this assignment is that all 13 outcomes are assessed via the rubrics at least once in an academic year. Empirically, this goal has always been met or exceeded.

In implementing the direct measurement of outcomes via the rubrics, we closely follow the guidelines provided by the ABET Program Evaluator (PEV) Refresher Training Program in Module 4 [11]. For example, "appropriate sampling methods may be used as part of an assessment process."

In view of such guidelines, our approach is substantially different from an approach to assess each student with respect to each outcome in each course in every semester (i.e., a significantly inordinate faculty load).

Table 3. Mapping of the required IE courses to the student outcomes

Required courses	**Outcome items**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**
IE 101							×				×			
IE 148		×				×						×	×	
IE 248		×	×					×			×	×		
IE 271			×	×								×	×	
IE 305		×			×	×			×			×	×	×
IE 312		×				×		×				×	×	
IE 341					×	×				×	×		×	×
IE 348		×	×				×			×		×		
IE 361	×	×	×		×		×							
IE 413						×						×	×	
IE 441		×		×	×	×	×	×	×	×	×	×	×	×
IE 448				×							×	×	×	

Table 4. Rubric for outcome (a)

(a) An ability to apply knowledge of mathematics, science and engineering

Performance Criteria Item	Exemplary 5-6	Acceptable 3-4	Poor 1-2	Score
Ability to apply general mathematical principles	Correct mathematical principles are chosen and applied without error	In general correct mathematical principles are chosen with minor errors in their application	Incorrect principles are chosen for the given engineering problem and/or there are major errors in their application	
Ability to apply general scientific knowledge	Demonstrates good general knowledge of scientific principles and the ability to correctly apply them to engineering problems	Basic scientific knowledge is demonstrated with only minor errors in application to engineering problems	A general lack of scientific knowledge is demonstrated and/or the inability to apply this knowledge to engineering problems	
Ability to apply general engineering knowledge	Demonstrates good general knowledge of engineering principles and their application to engineering problems	Basic engineering knowledge is demonstrated with only minor errors in application to basic engineering problems	A general lack of general engineering knowledge is demonstrated and/or the inability to apply this knowledge to basic problems	
Total				

Once the assignments are made, the instructors complete and report the direct measurement of the outcomes before the beginning of the next semester. Some instructors, for example, use some specific parts in a course project report, an exam, a homework set, etc. When there are more than 20 data points for the direct measurement, the instructors have the option of randomly sampling 20 data points for the direct measurement. This policy was instituted in order to avoid any inordinate faculty program assessment load for the instructors, who have an enrollment level of perhaps 70 to 80 IE majors.

Thus far, we have explained the direct assessment by the instructors-driven rubrics. Let us now proceed to explain the indirect assessment by the students and alumni-driven surveys.

4.2 Indirect assessment by the students and alumni-driven surveys

In addition to the direct measurement via the rubrics, we also gather the relevant and appropriate indirect measurements via surveys as follows. At the end of both Fall and Spring semesters, graduating seniors are asked about each student outcome in the form of:

> Indicate your personal satisfaction with how your undergraduate education in industrial engineering helped you to: (1 = not satisfied at all; 5 = very satisfied)

Also, around the midpoint of each academic year, Year 1 alumni are asked about each student outcome in the form of :

> How well did your education in IE at ISU help your ability to: (1 = not at all; 5 = extremely well)

We note that perhaps the seniors are the most appropriate students for the survey as their opinions by the time of their graduation is summative. We also note that the Year 1 alumni (who graduated in the previous calendar year) should provide a different, yet valid perspective on their very recent educational experience.

We now explain the assessment and evaluation processes for the student outcomes as well as our expectation and results in the following three subsections.

4.3 Assessment and evaluation processes for student outcomes

For the direct and indirect measurement data of the previous semester, at the beginning of each semester, the director of the undergraduate studies, with the help of the chair, curriculum committee, academic advisor, staff, a graduate assistant, and the relevant faculty, collect, compile and organize the data. In addition to the aforementioned three principal instruments of outcome measurement, we may use additional information (qualitative, anecdotal and/or quantitative) from Faculty and Industry Advisory Council meetings, student focus group meetings, OPAL (Online Performance and Learning; observation frequency based assessment of co-op/internship students; co-op/internship is encouraged, but not required), inputs from internal and external administrative units, etc.

The organized data are primarily in the form of numerical values. Hence, they can be easily evaluated quantitatively and objectively by the director of the undergraduate studies. Depending on the major findings of this evaluation, in conjunction with any other relevant input, further evaluation processes may be necessary; they are elaborated in the subsection 4.6, "Further information on outcome evaluation processes."

The current assessment processes for the instructor-driven rubrics and the graduating student-driven surveys are for both Fall and Spring semesters of each year. The Year 1 alumni-driven surveys are for an approximately midpoint of each academic year. To be more precise, since the program's educational objectives alumni survey of Spring 2011, the alumni survey has been moved to early Spring (cf. before Spring 2011, the alumni survey was conducted late Fall).

4.4 The expected level of attainment for each of the student outcomes

We do not have a single number from a single source (e.g., instructors, graduating seniors, or Year 1 alumni) that will assure the attainment of each student outcome. However, by the design of the survey questions (a numerical score of 1 to 5), an average score of an outcome that is greater than 3 in a survey can be viewed as evidence illustrating that the level of the student outcome achievement is satisfactory. Furthermore, by the design of the rubrics (a numerical score of 3 to 18), an average score of an outcome that is greater than 9 (when averaged over all corresponding courses and instructors during an academic year) can be viewed as evidence illustrating that the level of achievement is satisfactory.

In general, if and when all three metric values that are obtained independently of each other support the fact that the level of the student outcome achievement is satisfactory (triangulation), then a convincing case is made that the level of achievement is indeed satisfactory. In our case, we expect that, for each student outcome in an academic year (basically Fall and Spring semesters), the average numerical scores from the graduating senior and Year 1 alumni surveys are all above 3 AND the average rubric score(s) from the primary rubric-based data set is (are all) above 9 if a satisfactory level of attainment is achieved. The numerical score ranges from 1 (worst) to 5 (best) in a survey while the rubric score ranges from 3 (worst) to 18 (best).

Concurrently, for the primary rubric-based data set, we institute the percentage of students with the rubric score of 9 or higher as an additional performance indicator. We expect that, for each student outcome in an academic year (basically Fall and Spring semesters), this indicator is above 70% if a satisfactory level of attainment is achieved. Combining this performance indicator with the aforementioned scores, for each student outcome, we expect that a satisfactory level of attainment is achieved if the average survey scores are all above 3, the average rubric score(s) is (are all) above 9, AND the performance indicator percentage is above 70%.

By cross-checking the results from the three independent sources of the graduating students, Year 1 alumni, and rubrics, we believe that our conclusion is robust and entirely plausible as the possibility of all results from these sources coincidently being wrong is remote. The actual (cf. expected) levels of attainment will be detailed in the next subsection.

4.5 Results of student outcomes assessment and evaluation

The primary rubric-based data sets for the last five semesters are as shown in Table 5 where, within a class in a semester, the first number is the average rubric score (18 being the best and 3 being the worst) and the number in parenthesis is the aforementioned performance indicator percentage. For the sake of brevity and compactness, we will present only Outcomes (a), (g) and (i) here, and we note that, in an IMSE Working Paper, there is a complete table for all the outcomes, (a)–(m).

As one can easily observe, the actual attainment levels typically far exceed the expected attainment levels. We note that the number of students within a class (or a section in a class) in a semester varies as the numbers of IE majors assessed/enrolled in it

Table 5. Rubric-based data sets

ABET Criterion 3 outcomes	**Fall 2009**	**Spring 2010**	**Fall 2010**	**Spring 2011**	**Fall 2011**
a. An ability to apply knowledge of mathematics, science, and engineering	**IE305A** 16.07 (100%)	**IE305B** 11.00 (50%)		**IE305A** 14.89 (94.4%)	
g. An ability to communicate effectively	**IE441** 15.24 (100%)	**IE441** 13.55 (87.10%)	**IE441** 14.97 (100%)	**IE441** 14.22 (100%)	**IE441** 14.38 (100%)
i. A recognition of the need for, and an ability to engage in life-long learning	**IE441** 15.14 (100%)	**IE348** 12.70 (100%)	**IE441** 15.13 (100%)	**IE348** 14.76 (100%)	**IE441** 16.31 (100%)

Table 6. Graduating students' survey results

ABET Criterion 3 outcomes	Fall 2009	Spring 2010	Fall 2010	Spring 2011	Fall 2011
No. of respondents	21	30	31	23	16
a. An ability to apply knowledge of mathematics, science, and engineering	4.43	4.38	4.55	4.57	4.25
g. An ability to communicate effectively	4.57	4.18	4.65	4.48	4.56
i. A recognition of the need for, and an ability to engage in life-long learning	4.71	4.37	4.74	4.57	4.69

vary. Even in cases where the actual attainment does not appear to far exceed the expectation at a first glance, a little further investigation confirms that it actually is the case. For example, for Outcome (a), the academic year performance indicator percentage for Fall 2009–Spring 2010 is actually 94.12%. We also note that the older data sets of the prior years exhibit similar characteristics.

As for the graduating students in the same period, the survey results are as in Table 6 where, within a semester, the average score for each outcome is shown (5 being the best and 1 being the worst). As in Table 5, we will present only Outcomes (a), (g) and (i) here.

As one can easily observe, the actual attainment levels far exceed the expected attainment levels for each outcome. We also note that the older data sets of the prior years exhibit the similar characteristics.

As for the Year 1 alumni in the same period, the survey results are as in Table 7 where, within a year, the average score for each outcome is shown (5 being the best and 1 being the worst). As in Tables 5 and 6, we will present only Outcomes (a), (g) and (i) here.

As one can easily observe, the actual attainment levels far exceed the expected attainment levels for each outcome. We also note that the older data sets of the prior years exhibit the similar characteristics.

We also note that the written comments in the survey and rubric forms, our interaction in the faculty and industrial advisory meetings, and other input and feedback by and large confirm the results of our analyses. Furthermore, we note that, all the data in the prior years since the last general review exhibits the similar characteristics.

All in all, one can observe that all three average values as well as the performance indicator percentage far exceed the expected levels of the satisfactory attainments. Hence, we conclude that the attainment of these outcomes by the IE majors by the time of their graduation has been convincingly demonstrated (average-wise as well as percentage-wise). We do note that the summary of the outcomes in and of itself does not seem to radically change in recent years as the numerical data indicate a high level of attainment that is consistent and stable. We also note that we will use these data further in our continuous improvement process, which will be elaborated in Section 5.

Finally, as mentioned earlier (Subsection 4.3), for some outlying cases, it may be necessary to employ a more elaborate evaluation process. This is described in the following subsection.

4.6 Further information on outcome evaluation processes

As we mentioned in the subsection of 4.3 (Assessment and Evaluation Processes for Student Outcomes), at the beginning of each semester, a straightforward and quantitative review of the numerical values of the available data by the director of undergraduate studies is often sufficient to conclude that the student outcomes are achieved at a satisfactory level. This is consistent with the Evaluator (PEV) Refresher Training Program in Module 4 [11], which states that a program does not have to assess every outcome every year to know how well it is doing toward attaining student outcomes (outcomes not assessed every year necessarily imply that they are not evaluated every year).

In any case of unusual deviations from the high level of attainment that has been consistent and stable in recent years, or for the outcome items of special interests such as being a part of efforts towards continuous improvement for the program's educational objectives (see the subsection of 5.1

Table 7. Year 1 alumni survey results

ABET Criterion 3 outcomes	Year 09–10	Year 10–11	Year 11–12
No. of respondents	14	13	8
a. An ability to apply knowledge of mathematics, science, and engineering	4.36	4.54	4.75
g. An ability to communicate effectively	4.29	4.62	4.13
i. A recognition of the need for, and an ability to engage in life-long learning	4.07	4.58	4.00

Usage of Evaluation Results for Continuous Improvement of the Program), the director of undergraduate studies may call for a more elaborate evaluation process as follows:

We note that all steps are on an as-necessary basis.

1. Around early Fall semester, in the meetings of the curriculum committee/the faculty, based on the available data, formal evaluation and improvement decisions on outcomes are made.
2. During Fall semester, improvement efforts are made.
3. Around early Spring semester, in the meetings of the curriculum committee/the faculty, based on the available data, formal evaluation and improvement decisions on outcomes are made.
4. During Spring semester, improvement efforts are made.
5. During the Industrial Advisory Council meeting, the council's input on outcomes are solicited.

Finally, we note that what has been described in this subsection and the previous subsection of 4.3 is to effect outcome improvement efforts based on the evaluation of PEOs. We now formally present our efforts towards continuous improvement as follows.

5. Continuous improvement

The continuous improvement process for the objectives and outcomes is depicted in Fig. 2 as follows.

The left-hand side cycle is for every 3 years, while the right-hand cycle is for every semester. By following the direction of the primary influence, one can observe how the outcomes support the later attainment of the objectives and how the objectives can effect changes in outcomes if and when necessary.

In what follows, we first describe how the program's educational objective evaluations have led to the efforts towards continuous improvement in the student outcomes.

5.1 Usage of evaluation results for continuous improvement of the program

As one can recall from Section 3, the program's educational objective evaluation led to the conclusion that the current objectives are necessary, prepared for in our program, and attained in the careers of our graduates. For a deeper analysis, we employed Figs 3, 4 and 5: Preparation vs. Attainment, Necessity vs. Attainment, and Necessity vs. Preparation with a value of (2.5, 2.5) as the origin. We also note that, for the figure of Necessity vs. Preparation, we were able to include the students as a primary constituency.

By visually inspecting the gaps between the three key aspects of the program's educational objectives of Attainment, Necessity, and Preparation, the curriculum committee concluded that Objective 2 *relatively* seemed to be in need of improvement. The department faculty agreed and recommended additional efforts to foster the achievement of Objective 2. This would be facilitated by efforts to improve Outcome (g), an ability to communicate effectively. For this improvement, IE 248, a required manufacturing course, would be adding a written communication module and IE 441, a required capstone design course, would use its peer feedback process as a communication module in Fall 2011.

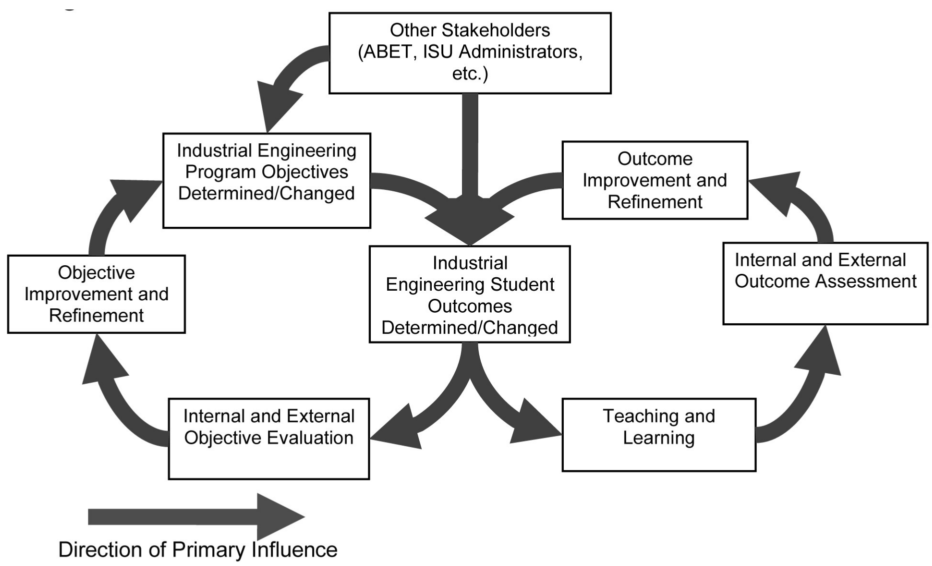

Fig. 2. Continuous improvement process for objectives and outcomes.

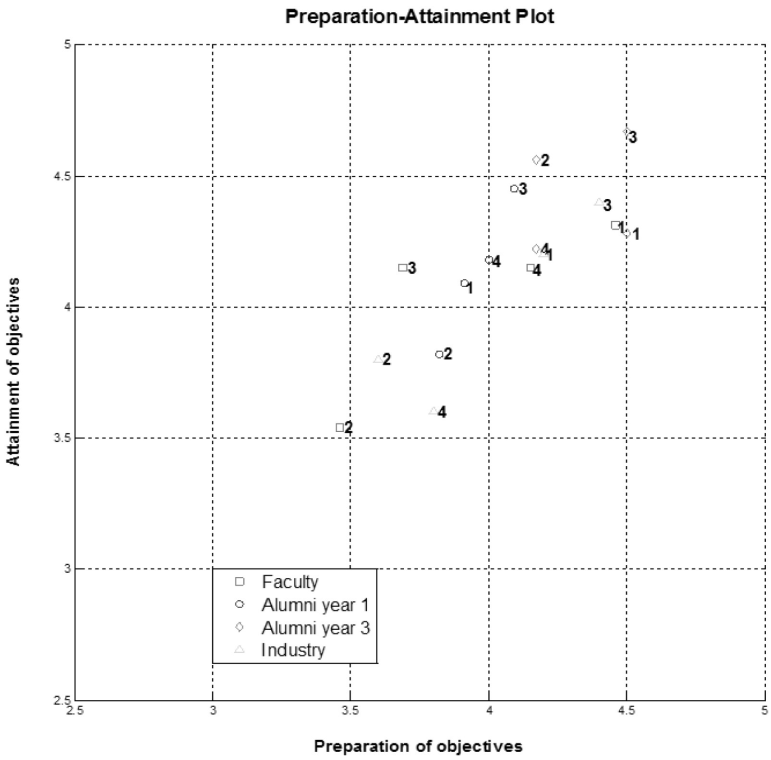

Fig. 3. Preparation vs. Attainment.

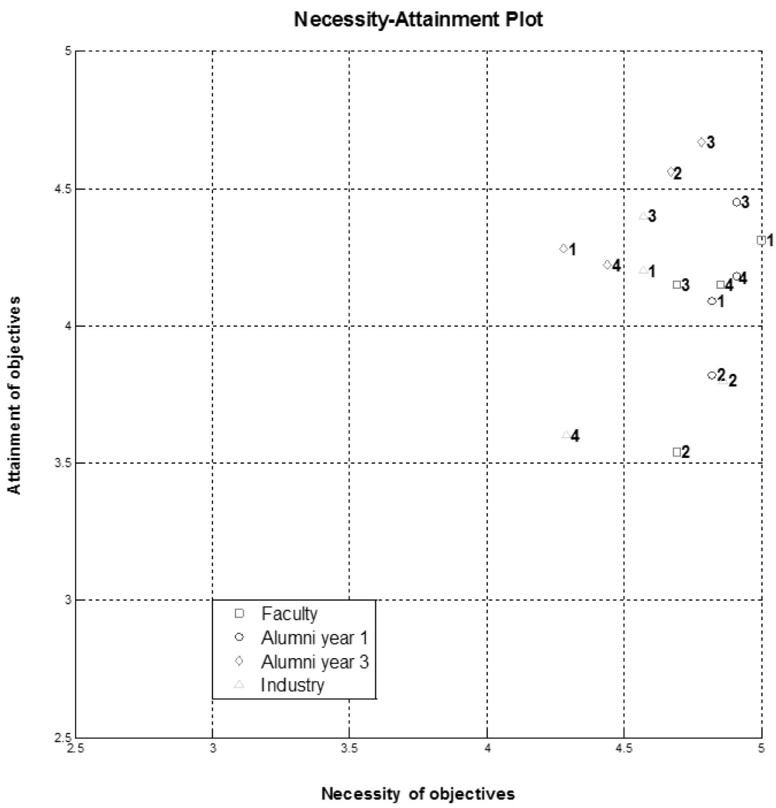

Fig. 4. Necessity vs. Attainment.

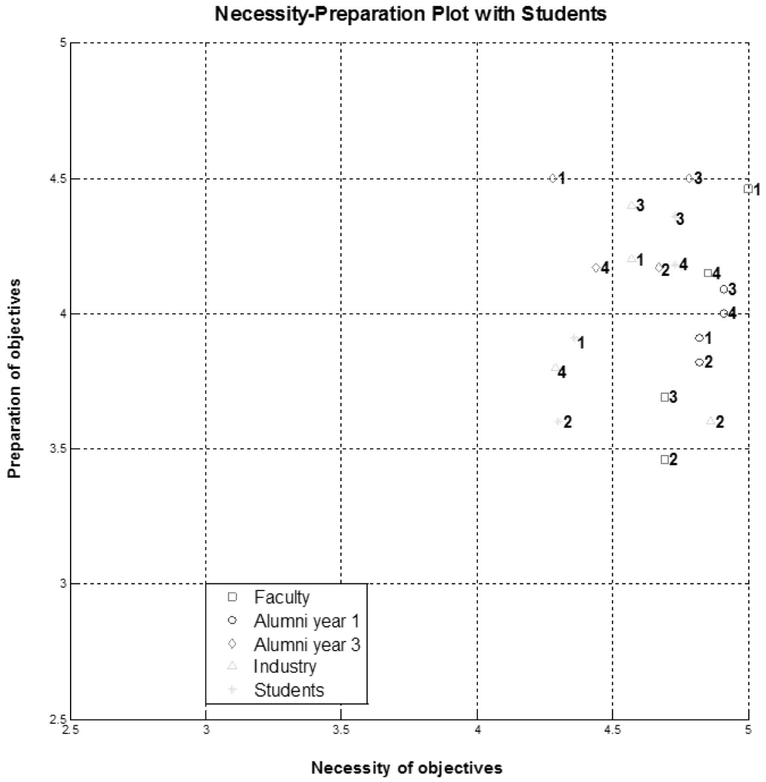

Fig. 5. Necessity vs. Preparation.

As of now, we do have the following baseline on Outcome (g):

- Fall 2011:
  IE 441: 14.38 (100%)
  Graduating students: 4.56
- Year 11–12:
  Year 1 alumni: 4.13

As we track more Outcome (g) data over the next three years or so (the program objectives evaluation cycle length is 3 years), we will be able to learn more about the effectiveness of these improvement initiatives and, if necessary, make further efforts.

Through a similar analysis during the Fall 2008–Spring 2009 program's educational objective evaluation, even though the objectives then were achieved at a satisfactory level, Objective 6 relatively seemed to be in need of improvement. We note that Objective 6 was "new skills and training for life-long learning and professional development." This objective has been re-worded to "new skills and knowledge that advance professional practice and enable career advancement" in our current Objective 4 to better reflect the recent ABET emphasis on "broader" PEOs.

In response, at that time, the department faculty recommended additional efforts to foster the achievement of Objective 6. This was facilitated by efforts to improve Outcome (i), a recognition of the need for, and an ability to engage in life-long learning. For this improvement, IE 348, a required manufacturing course, added how to utilize professional magazines in the class and IE 441, a required capstone design course, added how to learn from peer feedback in the class.

The outcome data that are most relevant to this previous initiative are:

- Fall 2009: IE 441: 15.14 (100%)
  Graduating students: 4.71
  Year 1 alumni (prior to the initiative): 4.07
- Spring 2010: IE 348: 12.70 (100%)
  Graduating students: 4.37
- Fall 2010: IE 441: 15.13 (100%)
  Graduating students: 4.74
  Year 1 alumni (after the initiative): 4.58

We observe that the rubrics and graduating senior survey results seem strong and robust, and the improvement in the Year 1 alumni survey seems encouraging.

6. Discussion

Based on our experience, there exist several critical challenges on the assessment, evaluation, and continuous improvement. For example, how does one strike a balance between the ideal conceptual framework and current practice with substantial resource constraints? Such efforts require personnel time as well as money, and in a period of decreasing budget, it is currently unclear which activities should be adjusted accordingly.

We also note that our systematic way of continuous improvement does not necessarily prevent any individual instructor from initiating one's own improvement endeavors (see e.g., [12] for improvement in leadership, teamwork, and contemporary issues). Rather, we view the systematic way of improvement as a required expectation and the individually initiated endeavors as an elective expectation. Ultimately, they both should be able to significantly contribute to better learning experiences by the students in an accredited engineering program.

From a methodology perspective, as [13] correctly points out, tracing and attributing any actual improvement to a particular set of efforts towards continuous improvement have never been exact in practice. Therefore, more accurate measuring of the degree of such contributions would be highly desirable.

7. Conclusion

In this paper, we have shown how the assessment and evaluation of the PEOs and outcomes can be systematically conducted. We have also shown how the results of the PEO's evaluation, which heavily utilizes gap analysis as well as triangulation, lead to the efforts towards improvement through the student outcomes.

In so doing, we have documented step by step how the ABET expectations can be met so that various accreditation stakeholder might be able to prepare specifically for the critical stages and move forward to close the loop for a continuous improvement cycle.

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