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Engineering Economics as a Benchmark Course in the Context of a Sustainable Continuous Improvement Process

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Dr. Yamayee's current professional interests include outcomes assessment in engineering education; design in engineering education; engineering design methodologies; and application of design methods to electric power distribution, transmission, and generation. Dr. Yamayee's work to date has included projects in power system planning, maintenance scheduling, hydro-thermal simulations, unit commitment, operational and financial impacts of integrating new technologies with power systems, probabilistic production simulations, and integrated resource planning. In recent years, he has authored a number of articles and has given numerous presentations on outcomes-based engineering curriculum development and the implementation of the ABET Criteria for Accrediting Engineering Programs. He has authored and/or co-authored over 45 articles, a textbook which has been translated into Chinese, 22 technical reports, 12 summary papers, and 15 discussions and reviews.

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Abstract

Programs seeking ABET accreditation must demonstrate that they satisfy eight general accreditation criteria, plus any program specific criteria. The two most important and widely debated ABET accreditation criteria are Student Outcomes (SOs), and Continuous Improvement (CI).

While ABET has always encouraged program improvement as part of the accreditation process, Continuous Improvement (CI) has emerged as the most important criterion for accreditation. The primary inputs to this criterion are the results of assessment and evaluation of SOs. And, course-embedded assessment plays a major role in the assessment of Student Outcomes. The outcomes of the CI process are the changes that improve an engineering program.

Since 2006, we have been periodically reviewing our assessment and evaluation processes with a goal to reduce the amount of time faculty spend in gathering and analyzing data. The outcome of this effort is a more sustainable CI process; a process in which not all courses are involved in course-embedded assessment and not all student outcomes are assessed and evaluated every year.

The choice of courses for course-embedded assessment is guided by two principles: (1) each Student Outcome is assessed with student work in a benchmark course, and (2) only required courses, not elective courses, in the curriculum are selected as benchmark courses.

Assessment of a benchmark course is conducted with the following in mind: (1) assessment of student work measures the extent to which SOs are being attained, (2) it is not necessary to use all of the student work to assess an outcome, and (3) outcomes assessment is based upon student work and is guided by the grading of that work.

The implementation of our course-embedded assessment method to a benchmark course, namely Engineering Economics, is presented in this paper. A description of the process, data collection efforts, and analysis of the results in applying course-embedded assessment method to the benchmark course are

presented in this article.

Introduction

In 1992, ABET invited academic, industry, and professional society leaders to participate in a review of the accreditation process, and the Accreditation Process Review Committee was formed. In 1996, after thousands of hours of hard work by hundreds of engineering professionals, the ABET Board of Directors approved a new set of criteria for engineering education, the Engineering Criteria 2000[1].

The new criteria provided more flexibility to individual programs, allowing engineering schools to be more responsive to the needs of their students, as well as the mission of their institutions and programs[2,3,4,5]. Over the years, these criteria have evolved and improved to the current Criteria for Accrediting Engineering Programs[6].

Programs seeking accreditation from one of the four ABET Commissions must satisfy eight general accreditation criteria, plus any program-specific criteria[6]. Since the early days, the three most challenging and widely debated criteria have included:

- Criterion 2. Program Educational Objectives. PEOs describe what graduates are expected to achieve (attain) within a few years of graduation. A few years is generally interpreted to be 2-5 years after graduation.
- Criterion 3. Student Outcomes. SOs describes what students are expected to know and be able to do by the time of graduation.
- Criterion 4. Continuous Improvement. CI requires that program improvements should be based on assessment and evaluation of student outcomes, as well as other information gathered by the program.

The focus of this paper is the assessment and evaluation of Student Outcomes. Results of evaluations of student outcomes are used to identify improvements to courses and curricula. To make the assessment and evaluation process sustainable and less cumbersome, at our institution we assess half of the SOs each year. Every two years we assess all 11 of the EAC of ABET's SOs.

This paper is organized as follows. First, an overview of the outcomes assessment process is presented followed by a description of direct and indirect assessment methods. Then, course-embedded assessment is described, followed by the assessment of Engineering Economics as an example. Finally, the paper is closed with a summary of assessment and evaluation of student outcomes and annual documentations of improvements based on assessment and evaluation.

Overview of the Outcomes Assessment Process

The purpose of assessment is to gather data that can be used to: (1) document the success of an educational program in assisting students to achieve desired outcomes, and (2) identify aspects of the program that may need improvement.

At our school, the relationship between the assessment instruments/methods and the student outcomes are determined by the faculty of each program. Many of the assessment instruments are used to assess and evaluate more than one student outcome.

A matrix, mapping the student outcomes against assessment methods used to assess each of the 11 ABET EAC Student Outcomes, is prepared by each program faculty. One common assessment method used by all programs is course-embedded assessment. Each program ensures that the courses in their curriculum address all of the 11 SOs. Assessment methods for student outcomes include both direct and indirect assessment methods.

Direct and Indirect Assessment Methods for Student Outcomes[7,8,9]

Student Outcomes are closely tied to the PEOs. In a general sense, students who achieve the abilities in the 11 ABET Engineering outcomes should be prepared to attain the PEOs a few years after graduation.

Several assessment methods, both direct and indirect, are used for measuring the degree to which Student Outcomes are being achieved and for continuously improving the program. Direct assessment methods require students to demonstrate their knowledge and skills, and provide data that directly measure achievement of expected outcomes. Indirect assessment methods, such as surveys and interviews, gather reflection about learning. These methods are likely to suffer from validity and reliability problems as individual perception of their actual performance may be difficult to candidly or accurately report. Therefore, it is important to use a mix of both direct and indirect assessment methods in the assessment and evaluation of student outcomes.

The three direct assessment methods we use are Course-Embedded Assessment, Senior Design Course Assessment, and Nationally Standardized Examinations (Fundamentals of Engineering Examination or Major Field Test) or a Faculty Administered Comprehensive Examination. The indirect assessment tool we use in the assessment of student outcomes is a graduating senior exit survey. Below are brief descriptions of these assessment methods:

- Course-embedded (course-based) assessments. These include projects, assignments, reflective essays, or exam questions that directly link to student outcomes and are scored using established criteria.

- Exams. Locally developed comprehensive exams or nationally standardized exams (FE Exam or Major Field Test).

- Capstone or senior-level projects provide evidence of how well students integrate and apply principles, concepts, and abilities into a culminating project. They are evaluated by faculty and/or external review teams. This is an effective assessment tool when the student work is evaluated in a standard manner that focuses on student achievement of the outcomes.

- Graduating senior exit surveys.

Course-Embedded Assessment: Purpose **and Structure**

We use course-embedded assessment as a direct assessment method for measuring the extent to which Student Outcomes have been attained. We also use other direct and indirect methods for assessing Student Outcomes. Here, we focus on the course-embedded assessment.

Course-embedded assessment has two primary roles:

- Using student work to assess the extent to which each Student Outcome has been attained, and
- Providing data for developing and improving the programs.

The course-embedded assessment process also provides a means of documenting the assessment results and the effects of any course and program changes that follow from the process. We assess

Student Outcomes on a two-year rotating schedule. Although some assessment activities are conducted every year, each group of outcomes receives primary attention during alternating years.

Not all courses in the curriculum are involved in course-embedded assessment. The choice of courses is guided by the following principles:

- Each Student Outcome will be assessed with student work in a course(s) termed "benchmark course(s)."
- Only required (not elective) courses in the program curriculum will be selected as benchmark courses.
- Although a benchmark course will likely address multiple Student Outcomes, typically one or two of its learning outcomes will be designated for course-embedded assessment.
- Because Student Outcomes are assessed in two groups on a rotating schedule, the benchmark courses are organized and assessed in two alternating groups.

Course-embedded assessment is administered with the following factors in mind:

- Assessment of student work will measure the extent to which Student Outcomes are being attained and will provide useful information for making program improvements.
- Within a benchmark course, it is not necessary to use all student work to assess an outcome that has been designated for the course. Some student work will be more appropriate than others for assessing a particular outcome.
- Outcome assessment instruments (i.e. student work) will be designed so that they are focused and easy to administer and evaluate.
- Outcomes assessment will be based upon student work and will be guided by the grading of that work.

Course-Embedded Assessment: The Process

The process outlined below is used for selecting benchmark courses, assessing the benchmark courses, and making recommendation for course and program improvement.

- The program faculty periodically articulate the Performance Criteria (Indicators) associated with each Student Outcome[8,9].
- The program faculty identifies the benchmark courses that will be used for assessing each Student Outcome.

- The instructor identifies the specific instruments (i.e. student work, such as homework assignments, classroom activities, projects, and exams) that will be used to measure attainment of the designated outcome.
- The instructor assesses the student work in the benchmark course and determines the extent to which the Student Outcome has been attained.
- At the end of the academic year, the instructors prepare Course Assessment Summaries for each of the benchmark courses that are receiving primary attention during that year. The summary should: (1) identify the Student Outcomes that are being assessed in the course, (2) include a list of the Performance Criteria for each Student Outcome that is being assessed in this benchmark course, (3) identify the assessment instruments, and (4) characterize the extent to which a Student Outcome is attained. Grades on student work can be used as a measure of the extent to which an outcome is being attained.
  The summary should also state whether the course will be modified to improve the program and whether program faculty action is recommended to improve the curriculum.
- At the end of the academic year, the program faculty considers the assessments of that year's group of benchmark courses. In combination with other assessment instruments and evaluation measures, the faculty determines the extent to which each of that year's group of Student Outcomes is being attained and whether program changes are desired or required.

Assessment of Engineering Economics as a Benchmark Course

Engineering economics, a required course for all engineering students at our institution, is used as benchmark course for the following two of the EAC of ABET Student Outcomes:

- <u>Student Outcome h.</u> The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
- <u>Student Outcome j.</u> A knowledge of contemporary issues.

The following Performance Criteria (Indicators) were used in assessing Student Outcomes h and j:

- Students use comprehensive concepts of engineering economics to address environmental, political, economic and social impacts of many engineering decisions, in both societal (a particular community) and global contexts.

- Students learn about non-technical contemporary issues such as socio-economic, political, and environmental.

<u>Assessment of Student Outcome "h": "The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"</u>

Performance Criterion h.1: Students can explain or discuss the global, economic, environmental, or societal context of an engineering problem

4 = explains or discusses the global, economic, environmental, or societal context of engineering problems
2 = limited explanation of the context
0 = cannot explain or give examples of global, economic, environmental, or societal context of engineering problems

Performance Criterion h.2: Students can discuss the political and societal settings of an engineering problem

4 = explains or discusses these settings and how they affect the problem. Identifies both benefits and adverse impacts of possible solutions
2 = discusses the political and societal settings, but not how they affect solution choices
0 = no discussion of the political and societal settings or their effects

To assess Criterion h.1 and Criterion h.2, we used the group presentation format. The students, as a group of five, were selected as the economic advisors to the President of the United States. The students made a 10-12 minute presentation and discussed engineering solutions for improving the economy of the United States so that we can compete in the global market. Students were competing against other teams in the class for the best presentation.

Students offered numerous ideas and recommendations for improving the economy of this country. The ideas presented included improving science, technology, engineering, and math education (STEM), being more innovative, investing in research and technology, investing in transportation infrastructure, focusing on the usage of alternative energy and reduction of energy consumption, improving manufacturing, protecting the environment, and competing globally.

Assessment and Analysis of Student Work: Student Outcome "h"

This outcome was assessed by grading the student presentations. The grades for the group presentation (on a scale of 0 to 4) were as follows:

Group 1	3.12 / 4
Group 2	3.26 / 4
Group 3	3.76 / 4
Group 4	3.62 / 4
Group 5	3.68 / 4
Average:	3.49 / 4

The average grade for the student presentations was 3.49 / 4.0 which is a (B+) and indicates that students had a good understanding of the impact of engineering solutions in a global, economic, environmental, political or societal context of engineering solutions.

Assessment of Student Outcome "j": "A knowledge of contemporary issues"

Performance Criterion: Students can discuss contemporary issues and how an engineering problem is affected by current societal, political, or economic issues.

4 = effectively analyzes and discusses a current issue and its effects

2 = demonstrates knowledge of an issue, but cannot effectively describe its effects

0 = is not aware of contemporary issues and does not recognize their effects

In this course, the first 15 to 20 minutes of each lecture was devoted to the discussion of contemporary issues. Students learned about the non-technical contemporary issues such as socio-economics, political, and environmental.

The questions on the midterm examinations were used for the assessment of Student Outcome "j". Twenty (20) % of Midterm #1 and 15% of Midterm #2 were allocated for questions on contemporary issues. The students were tested on contemporary issues, such as recession, role of the Federal Reserve of the United States, unemployment rate, financial markets, personal finance, mortgage rates and types, USA gross domestic product (GDP), identifying engineering solutions for reduction of energy consumption, identifying engineering solutions to save manufacturing jobs in this country, and competing globally.

Assessment and Analysis of Student Work: Student Outcome "j"

Outcome "j" was assessed on two midterm examinations. These exams included short answer questions that tested their knowledge of contemporary issues and understanding the impact of engineering solutions in a global, economic, environmental, and societal context.

The average score of the two exams was 3.34/4.0. This score, which is equivalent to a B+, indicates that the students had a good understanding of contemporary issues, and their performance exceeds the expected minimum performance of 2.0/4.0 for Student Outcome "j".

From an analysis of the examinations and frequent feedback during classroom discussions, it can be concluded that by the completion of this course, students are conversant with the importance of non-technical contemporary issues, such as socio-economic, political and environmental impacts of many engineering decisions in both societal and global context.

Summary Remarks

Programs seeking accreditation from one of the four ABET Commissions must demonstrate that they satisfy eight general accreditation criteria, plus any program specific criteria. Two of the most challenging and debated criteria are: Criterion 3. Student Outcomes; and Criterion 4. Continuous Improvement. At our institution, to prepare a program for a successful accreditation review, we divided the six-year ABET accreditation cycle into three distinct phases; the years before the Self-Study year (phase one), the Self-Study year, and the visit year.

During phase one of the accreditation cycle, which is the primary focus of this paper, a number of direct and indirect assessment methods were used to assess and evaluate Student Outcomes. The results were used for measuring the degree to which the Student Outcomes are being achieved and to identify program improvements. The program faculty documented the results in annual assessment and evaluation reports for use in preparation for the ABET visit.

This paper described the course-embedded assessment and its use in determining the achievement of SOs in the context of a sustainable continuous improvement process.

Continuous Improvement (CI) has emerged as one of the most important ABET criteria for accreditation. The primary inputs to this criterion are the results of assessment and evaluation of Student Outcomes (SOs).

The purpose of assessment and evaluation of SOs is to gather data that can be used to: (1) document the success of an educational program in assisting students to achieve desired outcomes, and (2) identify aspects of the program that might need improvement.

Course-embedded assessment plays a major role in the assessment of Student Outcomes. In a sustainable CI process, not all courses are involved in course-embedded assessment. The choice of courses is guided by two criteria: (1) each Student Outcome is assessed with student work in a benchmark course, and (2) required courses are selected as benchmark courses.

Assessment of a benchmark course is conducted with the following in mind: (1) assessment of student work measures the extent to which SOs are being attained, (2) it is not necessary to use all of the student work to assess an outcome, and (3) outcomes assessment is based upon student work and is guided by the grading of that work.

As an example of course-embedded assessment in a Sustainable Continuous Improvement Process, EGR 351- Engineering Economics was selected a Benchmark Course for assessing two Student Outcomes. The process and the results of the assessment and evaluation were presented in this paper.

Bibliography

1. Engineering Criteria 2000, ABET, Baltimore, Maryland, 1996.
2. G. M. Rogers and J. K. Sando, "Stepping Ahead: An Assessment Development Guide," Rose-Hulman Institute of Technology, Terre-Haute, Indiana, 1996.
3. 2001 ABET International Yearbook, ABET, Baltimore, Maryland, 2001.
4. American Society for Engineering Education, *How do you measure success?: Designing Effective Processes for Assessing Engineering Education, ASEE Professional Books, (1998) pp 5-12.*
5. J. W. Prados, G. D. Peterson, and L. R. Latuca, "Quality Assurance of

Engineering Education Through Accreditation: The Impact of Engineering Criteria 2000 and its Global Influence," Journal of Engineering Education, 2005, pp 165-180.

6. "Criteria for Accrediting Engineering Programs," Engineering Accreditation Commission of ABET, November 1, 2014, ABET, Baltimore, Maryland.
7. P. Mack, "Using multiple Assessment Methods to Explore Student Learning and Development Inside and Outside of the Classroom," Director of Assessment, American Association of Higher Education, January 15, 2002.
8. Z. A. Yamayee and R. J. Albright, "Direct and Indirect Assessment Methods: Key Ingredients for Continuous Quality Improvement and ABET Accreditation," International Journal of Engineering Education, Volume 24, Number 5, 2008, pp 877-883.
9. Z. A. Yamayee, "The Most Debated Sections of an ABET Self-Study Report: Objectives, Outcomes, and Improvements," Best Assessment Processes Symposium XI, Indianapolis, Indiana, April 3-4, 2009.