Session 2566

ABET EC 2000: Developing Assessment Tools for Continuous Improvement

Francine Battaglia, Robert C. Brown, Donald R. Flugrad
Mechanical Engineering, Iowa State University

Abstract

Mechanical Engineering Department faculty and staff at Iowa State University have introduced significant curriculum changes over the past few years. In addition, they have introduced a comprehensive program for the assessment of program outcomes. Desired program outcomes were defined, course objectives were outlined and aligned with specific outcomes, assessment tools were developed, and a process for continuous quality improvement was implemented. This paper focuses on our development of assessment tools, which includes fives components: design panels to judge reports from design-oriented courses; targeted assessments in all core and technical elective courses; student assessments to receive feedback from students in our courses; graduating senior surveys to allow students completing our curriculum to provide an overall program assessment; and alumni surveys of former students who are three years into their professional careers.

I. Introduction

The faculty and staff of the Mechanical Engineering (ME) Department at Iowa State University have recently devised a new curriculum that includes assessment of program outcomes. The steps in devising an assessment process included: defining desired program outcomes; outlining course objectives; matching program outcomes with specific courses; developing assessment tools; and establishing a methodology for continuous quality improvement of the curriculum.

The ME Curriculum Committee (MECC) began preparations for ABET EC 2000[1] by developing a series of processes that would critically and comprehensively evaluate the entire curriculum. The overall goal was to review the curriculum and develop the best possible educational experience for our mechanical engineering students, providing them with a sound foundation for a successful career. With this in mind, assessment tools were developed that would provide information that could be directly used to evaluate, improve and redesign the state of the curriculum. These steps are detailed in this paper.

II. Desired Program Outcomes

Program outcomes are the specific skills we hope to instill in our undergraduate students by the time they complete the curriculum in Mechanical Engineering. Ideally, they prepare our students for entry level engineering positions in a variety of industries, qualify them for advanced study in science and engineering graduate programs or professional degree programs, and position them for future careers as managers and entrepreneurs. Our department adapted student outcomes appearing in ABET EC 2000 criteria[1] to our own needs. These fifteen program outcomes are listed in Table 1.

III. Course Objectives

During the Fall 1998 semester, two or three-person teams of faculty known as course development committees (CDC) were assigned responsibility for developing objectives for individual core courses and design courses in our new curriculum. The objectives of a course include specific knowledge (such as the Second Law of Thermodynamics) as well as general skills (such as an ability to work on teams) that will be learned by students taking the course. Each CDC prepared an "outcomes accountability" checklist for their course that showed the

Table 1. Desired Program Outcomes for the Mechanical Engineering Curriculum

Program Outcome	Description
PO 1	Apply knowledge of math and science
PO 2	Design, conduct, analyze experiments
PO 3	Design a system, component, or process
PO 4	Function on multi-disciplinary teams
PO 5	Identify, formulate, solve engineering problem
PO 6	Understand profession and ethical responsibility
PO 7	Communicate effectively
PO 8	Understand global/societal impact of engineering
PO 9	Engage in life-long learning
PO 10	Knowledge of contemporary issues
PO 11	Use techniques, skills, and tools of engineering
PO 12	Apply advanced math through multivariate calculus and differential equations
PO 13	Apply statistics and linear algebra
PO 14	Demonstrate knowledge of chemistry and physics with depth in at least one
PO 15	Ability to work professionally in both thermal and mechanical systems areas

correspondence between specific course objectives and the program outcomes for the mechanical engineering curriculum. In this way, course instructors were assigned specific responsibilities toward helping our curriculum achieve its program outcomes.

The curriculum committee was responsible for providing advice to faculty on how to formulate course objectives and relate them to program outcomes. Because few among the faculty had experience in formally defining course objectives, several iterations were required before complete coverage of program objectives was achieved. Table 2 is a matrix showing how the objectives for each course in our curriculum help meet program outcomes. The curriculum committee prepared a report in Fall 1998 that compiled course objectives and outcome accountability for each course. Faculty had an opportunity to review and revise this report before the department moved forward with a plan for program outcome assessment.

IV. General Plan for Program Outcome Assessment

The MECC developed a general framework for the assessment plan to evaluate the performance of students within the ME curriculum. The assessment plan includes several components: program outcomes, educational objectives, course objectives, student and alumni assessments and continuous improvement of the curriculum to achieve desired program outcomes. Our intention in assessment is to target the overall program rather than evaluate performance of individual students, faculty or courses. For each program outcome (Table 1), two independent assessments (from the list below) will be performed. Furthermore, the assessment participants will include constituents internal and external to the university: students, faculty, alumni and industry representatives. The assessment plan includes five major components:

1. *Design Panel Assessments* to judge final design reports (portfolios) from design-oriented courses.
2. *Targeted Assessments* in all core and technical elective courses and some extracurricular activities.
3. *Student Assessments* of how well courses contribute to student outcomes.
4. *Graduating Senior Surveys* to allow students as they complete the degree program to assess how well they have achieved program outcomes.
5. *Alumni Surveys* of former students three years into their professional careers to assess their overall undergraduate educational experience.

The selection of assessment tools to evaluate the program outcomes was based on items 1–5. The two basic assessment tools are rubrics (used for items 1 and 2) and surveys (for items 3–5). Standard assessment rubrics are developed for use by all of the constituents with the intent to focus on a single aspect of a program outcome for a given assessment. The first two assessment components (design panel and targeted assessments) will be the focus of the remainder of this paper. In particular, the structure and development of the rubrics, the selection of design panel members and the overall implementation of the assessment plan will be discussed in detail.

Table 2. Program Outcomes for the Mechanical Engineering Curriculum

		ME CORE COURSES								ME DESIGN COURSES					
PROGRAM OUTCOMES: General Criteria		ME 231	ME 332	ME 335	ME 436	ME 324	ME 325	ME 421	ME 370	ME 270	ME 415	ME 442	ME 446	ME 449	ME 466
PO 1		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
PO 2				✓	✓			✓	✓	✓					✓
PO 3		✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
PO 4				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PO 5		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PO 6										✓	✓	✓	✓	✓	✓
PO 7		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
PO 8			✓			✓				✓	✓	✓	✓	✓	✓
PO 9										✓	✓	✓	✓	✓	✓
PO 10			✓										✓	✓	
PO 11		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PROGRAM OUTCOMES: ME Discipline-Specific Criteria															
PO 12		✓		✓	✓			✓		✓		✓			✓
PO 13				✓	✓		✓	✓							✓
PO 14				✓	✓	✓				✓					✓
PO 15			✓		✓			✓		✓		✓	✓	✓	✓

ME 231: Engineering Thermodynamics I
ME 332: Engineering Thermodynamics II
ME 270: Introduction to Mechanical Engineering Design
ME 324: Manufacturing Engineering
ME 325: Mechanism and Machine Design
ME 335: Fluid Flow
ME 370: Engineering Measurements and Instrumentation
ME 421: Mechanical Systems and Control
ME 436: Heat Transfer

ME 270: Introduction to Mechanical Engineering Design
ME 415: Mechanical Systems Design
ME 442: Heating and Air Conditioning Design
ME 446: Elements and Performance of Power Plants
ME 449: Internal Combustion Engine Design
ME 466: Multidisciplinary Engineering Design

V. Rubrics

Rubrics are designed to assess student outcomes at the end of a course and are an essential tool used in the assessment process. The intent is to focus on a single aspect of a program outcome for a given assessment so that the reviewer can easily rank an example of student work. Recognizing the time constraints of our constituents, the MECC wanted to develop rubrics that would be easy to use and tabulate using a spreadsheet rating form.

Using the identified program outcomes (Table 1) in relation to each course, the MECC began by developing an assessment matrix. The matrix provides specific outcomes that should be easily observable by a reviewer after examination of an appropriate sample of student work. As part of the rubric development, the curriculum committee provides the reviewer with a ranked list of levels of student competence for each program outcome. An example of the assessment tool is shown in Table 3 for the ME program outcome PO 1.

Each rubric is divided into a number of categories (typically three to five), each of which identifies a "dimension" for a student outcome. Typical dimensions are engineering knowledge, continuous learning and initiative, to name a few. For each dimension, a description (the rubric) is provided that qualifies the dimension. For example, program outcome PO 1 is assessed in ME 231, Engineering Thermodynamics 1. The assessment rubric for this outcome has four categories (the dimension is underlined for emphasis):

- Demonstrates specific <u>engineering knowledge</u> of subject area
- Demonstrates interest in <u>continuous learning</u>
- Demonstrates <u>initiative</u>
- Demonstrates <u>analysis and judgment</u>

Conventional rubrics were first used during the Spring 2000 semester. A four-point rating system was incorporated; a score of zero was used to designate an unscorable dimension; that is, there was no evidence that the student outcome was reached. A score of 4, the highest rating, indicated a successful student outcome. Table 3a is a sample of the rubric for one of four categories used to assess program outcome PO 1.

Based on feedback from our constituents, the original rubrics were judged too cumbersome to use, primarily because rubrics explicitly define criteria; this translates into excessive reading during the evaluation. The assessment tool shown in Table 3b is the simplified version of the original rubric forms. The new rating scale is based on a five-point system, ranging from 1–strongly disagree to 5–strongly agree. The revised assessment tools were used during the Fall 2000 semester and proved easier to use and were preferred by the constituents.

Table 3. Example of rubrics to assess program outcomes

(a) First dimension of original rubric for program outcome PO 1

PO 1 – Apply knowledge of math, science and engineering

Demonstrates specific engineering knowledge of subject area	
4 points	Understands and applies mathematical and scientific principles toward solving engineering problems. Skilled at evaluating and analyzing process(es) and/or data. Has a thorough understanding and can successfully use contemporary engineering software programs.
3 points	Adequately understands and applies mathematical and scientific principles toward solving engineering problems. Adequately evaluates and analyzes process(es) and/or data. Understands and shows reasonable use of contemporary engineering software programs.
2 points	Minimally understands and tries to apply mathematical and scientific principles toward solving engineering problems. Shows effort to evaluate and analyze process(es) and/or data. Tries to understand and attempts to use contemporary engineering software programs.
1 points	Does not understand and fails to apply mathematical and scientific principles toward solving engineering problems. Struggles to evaluate and analyze process(es) and/or data. Does not understand how to use contemporary engineering software programs.
0 points	Unscorable

(b) First dimension of simplified (revised) rubric for program outcome PO 1

PO 1 – Apply knowledge of math, science and engineering

Demonstrates specific engineering knowledge of subject area				
Understands and applies mathematical and scientific principles toward solving engineering problems. Skilled at evaluating and analyzing processes and/or data. Has a thorough understanding and can successfully use contemporary engineering software programs.				
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

VI. Design Panel Assessment

One of the most important and innovative activities developed for assessment was establishment of a design panel to evaluate student design projects. The design panel consists of constituents selected from among ME faculty, students, alumni, and industry. Their responsibilities are to jury student portfolios assembled from a sequence of design courses (to be discussed) and capstone design courses. Each semester, instructors in these design-oriented courses require students to turn in two copies of a report on a major design project. The course instructor grades one report as part of the student evaluation. Then, the constituency panel evaluates a random sample of student reports.

A design panel is assembled every semester from among the ME program constituencies. Students in their senior year are asked to help in the assessment process. Faculty members are asked to participate on a voluntary basis. In addition, the ME Department employed the expertise of the Mechanical Engineering Advisory Council (MEAC) in its efforts to ensure independent evaluation. The MEAC is an advisory board of engineers who are familiar with engineering management and practice. This advisory council includes representative constituents from industry, many of whom are alumni.

The design panel is convened at a time to coincide with the MEAC board meetings. Typically, the MEAC convene at the end of a semester. Thus, MEAC board members can conveniently participate in the workshop and board meeting. Six members of the advisory council participate in the workshop along with four students and four faculty members. These numbers serve to provide the viewpoint of the particular constituency, but do not overly weigh the membership toward a specific constituency viewpoint.

The curriculum committee is charged with collecting the student works prior to the workshop. The student portfolios are assembled from the design course sequence of: Engr 170, Engineering Graphics and Introductory Design; ME 270, Introduction to Mechanical Engineering Design; and ME 415, Mechanical Systems Design (all courses are three credit hours). The curriculum committee determined that program outcomes PO 3, 4, 6, 12 and 13 would be used in the design panel assessments. A selection of student team projects is sent to the panel members at least two weeks prior to the workshop meeting at Iowa State University.

Each panel member is asked to review five (5) selected examples of student work and to evaluate these works using rubrics. The portfolios are in the form of comprehensive design (final) reports. Panel members review and evaluate the materials independently prior to the meeting and return the evaluation forms at least two days before the workshop. The panel members convene to review and discuss their conclusions and identify any problems, shortcomings, and/or achievements that are indicated by the data. The curriculum committee is responsible for collecting, tabulating and evaluating the responses from the panel members as well as for facilitating the meeting. Presentation of the results of the Design Panel and recommendations for actions and changes that will improve the courses and curriculum will be made at each MEAC meeting.

VII. Targeted Assessments

Targeted assessments are limited to assessing a single program outcome. These assessments are apportioned among ME courses as well as selected extracurricular activities. It was determined that the remaining program outcomes not used in the design assessments would be the subject of targeted assessments. Technical elective courses were assessed using PO 5 and 11, and ME core courses were assessed using PO 1, 2, 12–14. Although extracurricular activities have not been incorporated into the assessment process yet, in the future these activities will be assessed using PO 12 and 15. Each course will have only one or two program outcomes assessed.

Faculty members teaching core and/or technical elective mechanical engineering courses are designated to perform targeted assessments in their classes. Not only is each course assessed, but each section of multiple-section courses (e.g., core courses may have two to four sections with different faculty teaching each section). In addition, assessments are carried out for every student in each course section.

The assessment materials used for each program outcome will vary from one instructor to the next. The curriculum committee has provided general guidelines and suggestions for assessment materials. For example, types of student works used as assessment materials may include homework, exams, projects, reports, etc. It is not necessary that all assessment materials be tangible. For example, faculty interaction with students in labs or group meetings may be sufficient for an evaluation as to whether students have met an outcome. Regardless of the assessment medium, it is imperative that the same type of assessment material used in the evaluation of a dimension be consistent for all students in that class. Furthermore, different types of assessment materials may be used for each dimension, or the same material can be used for all dimensions. Referring to the rubric in Table 3, for example, possible types of assessment materials for the four dimensions may include:

- Engineering knowledge: final exam
- Continuous learning: homework
- Initiative: personal student interactions (e.g., office meeting)
- Analysis and judgment: final exam

Clearly, for targeted assessments to provide meaningful data, the faculty must carefully evaluate and assess the program outcomes designated for their course. The MECC recommends that faculty receive the assessment rubrics within the first two weeks of a semester to provide ample time for faculty to determine what course work materials they will use in the assessment process.

VIII. Continuous Quality Improvement

The MECC developed a plan to use the assessment data in a continuous process of improvement for the Mechanical Engineering curriculum. The MECC will gather all raw results in tabular or graphical form. These data will be presented to the ME faculty at the annual faculty retreat, traditionally held during the week before classes start in the fall semester of each year. The retreat provides an opportunity for the faculty to discuss and evaluate the raw data found in the assessment results. Indications of problems and successes related to the overall curriculum can be highlighted and discussed.

During the retreat, assessment data associated with specific courses will be passed on to the course development committee associated with the specific course. Each CDC will be charged with detailed evaluation of the results from the course assessment, and will prepare a report for the MECC describing these results and noting any problems or deficiencies. In addition, the CDC will develop a plan, if needed, to improve achievement of the curriculum program outcomes. The MECC will be responsible for reviewing the information provided by each CDC. The MECC will coordinate curriculum changes among the courses and CDCs to assure improvement of the curriculum. In addition, a report of this process and the changes to the curriculum will be presented to the MEAC and to the ME Student Advisory Board.

IX. Experiences to Date

Design Panel Assessment Workshop Results

On April 28, 2000, the ME Department hosted the first Design Panel workshop to begin the process for continuous curriculum improvement. Results obtained from the design panel assessments are in the preliminary phases of analysis. Following is a summary of the experience as recorded by a MEAC participant.

What Worked?

1. MEAC members felt more deeply involved this year with department objectives and issues, particularly those who participated in the ABET assessment.
2. The subject and projects chosen for the assessment seemed to work well.
3. Sending out the pre-work was time efficient.
4. The assessment data was easy to quantify.
5. Efforts to learn and apply several skills needed to be successful in industry were evident in the student's work.
6. Most (probably all) felt the time doing the pre-work and attending the Assessment Panel was time well spent.
7. Several expressed they enjoyed working on this task.

What could have worked better?

1. Prior to the meeting it was not clear what the objective of the assessment exercise was or specifically how the information would be used.
2. Individuals made different assumptions on the basis for the grading scale - some used an absolute scale and some "curved" the scores based on the class year and assumed experience of the students.
3. Items 1 and 2 above degraded the value of the numerical data
4. The assessment form can be refined or tailored to better guide our work to insure the data is relevant to the purpose.

Targeted Assessment Faculty Results

At this time, the collected data can only provide qualitative results. Data were collected for two semesters (Spring and Fall 2000), but as mentioned in Sec. V, the rubric was modified for the Fall 2000 targeted assessment. This produced incompatible statistical analyses between the two sets of rubrics. While the details of the data will not be discussed here, a number of issues surfaced during the targeted assessment process that deserve mention. The issues can be divided into three categories: faculty participation, data, and improvements.

The first issue, faculty participation, is a crucial aspect of the assessment process. It was apparent after collecting the data that many of the faculty did not contribute. Only about 50% of the faculty provided targeted assessment data for their courses taught in Spring 2000, while this number approached 80% for Fall 2000 after strong encouragement by the Department Chair. This is a serious issue: if the department as a whole is to find ways to improve the curriculum then all faculty must perform targeted assessments in their courses. Our experience suggests that faculty do not yet appreciate the importance of the assessment process. This perception must change before conducting future assessments. In addition, faculty must change the way they think about teaching a course. That is, every course has a set of course objectives the students should achieve. Thus, faculty need to consider how their teaching can help students achieve course objectives, which are related to program outcomes. This will be an evolutionary process as faculty become aware of how department goals and program outcomes relate to their teaching.

The second issue pertains to the data, including its collection, management and evaluation. Clearly, the use of computers is valuable for the data storage and evaluation. Computers can also be used to expedite collection of data. After collecting a hard copy form from faculty for the first targeted assessment (Spring 2000), we opted to use an electronic spreadsheet for the Fall 2000 assessments. In this way, all the data could be easily collected and stored. The spreadsheet then provides a useable medium for which statistical analyses can be conducted and eventually cross-correlated. The database is also a concern. What sort of database should or could be used to effectively store and process the data is still being decided.

Finally, once data are statistically analyzed, what do the results mean and how should the results be used? There is no obvious or easy answer. Not only must the curriculum committee consider the results, but faculty should also provide input as how to best use the results. Once the MECC has a set of results pertaining to a course, that information is passed on to the appropriate CDC. If the results indicate that program outcomes are not being met for a course, it is necessary to determine the source of the deficiency. Program outcomes for a specific course do not necessarily mean that the course is responsible for providing the basis for the outcome. For example, PO 1 requires that students demonstrate knowledge of math, science and engineering in a thermodynamics course. If students do not show evidence of meeting this program outcome, then perhaps other departments should be consulted for corrective action. For example, perhaps the Mathematics or Physics Department needs to work with the Mechanical Engineering Department to ensure that certain fundamental concepts are being adequately covered in a general mathematics or physics course.

These issues are by no means insignificant. They are however issues that a department must consider is the goal if to demonstrate that students are meeting the program outcomes, and in turn, the educational outcomes of ABET.

X. Summary Remarks

Much has been learned to date, and several improvements have already been instituted. Most of the improvements thus far, however, have related to changes in the assessment process rather than in modifications to the curriculum. After both Design Assessment Panel workshops, valuable feedback was gathered to streamline and improve the next meeting of the design panel. The Mechanical Engineering Advisory Council is still enthusiastic about the opportunity to participate in this important activity, and with faculty and students also involved, this approach is likely to remain a unique and significant element in the overall outcomes assessment plan.

The targeted assessments conducted by faculty teaching each required core and elective courses will also evolve with time and experience. The rubrics have been modified to increase efficiency, and steps have been taken to develop computer-based tools to collect, store and analyze the data. Once all faculty realize that continuous improvement of the program depends on reliable assessment of student outcomes, the opportunity to introduce significant changes in the curriculum will be evident.

Perhaps the most important lesson learned thus far is that processes do not have to be perfect from the start. It is more important to establish what seem to be reasonable methods for assessment and begin using them without too much concern that the methods might be flawed. Once the assessment begins and some data are collected, then problems can be identified and corrected. This approach will surely result in an improved educational experience for the students, and that, after all, is the ultimate goal of the program.

Acknowledgements

The authors would like to acknowledge the help and support of the Mechanical Engineering faculty at Iowa State University. In particular, the assessment development and process would not have been possible without the dedication of the members of the Mechanical Engineering Curriculum Committee.

Bibliography

1. Criteria for Accrediting Engineering Programs: Effective for Evaluation During the 2000–2001 Accreditation Cycle, Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, Baltimore, MD (1999).

FRANCINE BATTAGLIA
Francine Battaglia is an Assistant Professor of Mechanical Engineering at Iowa State University. She is currently active in teaching and research, serves as faculty advisor for the student section of ASME, and is a member of MECC. She received a Ph.D. in Mechanical Engineering from the Pennsylvania State University. Prior to joining Iowa State in 1999, she worked two years at the National Institute for Standards and Technology.

ROBERT C. BROWN
Robert Brown is Professor in the Departments of Mechanical Engineering and Chemical Engineering at Iowa State University. He also serves as Director of the Center for Sustainable Environmental Technologies where he performs research on biomass energy and fossil fuels. Dr. Brown received his Ph.D. from Michigan State University in 1980. He joined ISU in 1983 after working three years at General Dynamics Corporation.

DONALD R. FLUGRAD
Don Flugrad is an Associate Professor and Associate Chair of the Mechanical Engineering Department at Iowa State University. He attended the University of Missouri-Rolla, where he received his Ph.D. in 1981. Before returning to graduate school he worked five years in product engineering at International Business Machines, Inc. Since joining the faculty at Iowa State he has spent several summers designing mechanisms at the John Deere Des Moines Works.