ABET Engineering Criteria 2000: Assessment of Classroom Instruction

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Abstract

Although much attention has been given to ABET's new Engineering Criteria (EC) 2000[1], to date there is only a limited amount of information available on assessing student learning associated with classroom instruction. This paper explores strategies for assessing student learning. Two detailed assessment examples are given, both of which employ a tool called a Program Goals Matrix. The examples illustrate how assessment approaches can be unique yet still satisfy the EC 2000 Criteria[1] and promote continuous improvement in classroom instruction.

Introduction

The new Engineering Criteria (EC) 2000[1] that have been adopted by the Accreditation Board for Engineering and Technology (ABET) have evoked a variety of emotions and reactions among engineering professors: dread, skepticism, enthusiasm, and uncertainty, to name a few. Over the last couple of years, numerous workshops and conference sessions have been devoted to explaining the new accreditation process. As more institutions are evaluated under the new guidelines, it is likely that many more workshops and conference papers will be generated to provide direction to institutions facing accreditation visits.

Most of the information that has surfaced to date has dealt with the overall assessment process for institutions or departments. Only a limited amount of information is available to guide an individual professor in bringing assessment of classroom instruction into the process. One purpose of this paper is to explore strategies for incorporating student learning associated with an individual course into the assessment process depicted in EC 2000[1]. Other questions that will be explored in this paper include:

- How can student learning be assessed?
- How can assessment be done in an effective manner so as not to take valuable time from student learning?
- What is the best way to document assessment?
- Is there a specific methodology that must be followed?
- How can assessment be used for continuous improvement?
- How are evaluators going to view efforts at assessment?

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Criteria 2 and 3 – Framework for Continuous Improvement

At first glance, an engineering professor may view the new EC 2000 Criteria[1] as an administrative nightmare that lacks a clear sense of direction. A closer look reveals that the continuous improvement of engineering education is at the heart of the matter[2,3]. The key to understanding how to implement assessment initiatives at the course level is to capture the vision of the overall assessment process described in Criteria 2 and 3 of the "Basic Level Accreditation Criteria." Table 1 provides an overview of the process. It is important to note that while the list of actions is

Table 1. Overview of Criteria 2 and 3 Assessment Process

- Establish *educational objectives* consistent with mission of institution
- Establish *strategies* for achieving objectives
- Identify program *outcomes* that can be measured to assess how effectively objectives are being achieved [outcomes must include: Criterion 3 outcomes and those critical to institution's mission and the program objectives]
- Establish appropriate *means for measuring outcomes*
- *Collect data* and *assess*
- Implement *improvements*
- *Gather evidence* to demonstrate effectiveness of assessment program

displayed in linear fashion, the assessment process is really more of a looping process. At any point, it may be necessary to loop back to a previously accomplished step to make improvements, as indicated by the bullets.

Examples of "evidence" provided in Criterion 3 includes both internally and externally collected data: student portfolios, design projects, national exams, alumni surveys, employer surveys, and placement data. There are 11 outcomes specifically noted in Criterion 3 that engineering programs must demonstrate that their graduates meet (designated in this paper as O.1 – O11). These are shown in Table 2.

Table 2. Criterion 3 Outcomes

Designation	Criterion 3 Outcome
O.1	An ability to apply knowledge of mathematics, science, and engineering
O.2	An ability to design and conduct experiments, as well as to analyze and interpret data
O.3	An ability to design a system, component, or process to meet desired needs
O.4	An ability to function on multi-disciplinary teams
O.5	An ability to identify, formulate, and solve engineering problems
O.6	An understanding of professional and ethical responsibility
O.7	An ability to communicate effectively
O.8	The broad education necessary to understand the impact of engineering solutions in a global and societal context
O.9	A recognition of the need for, and an ability to engage in life-long learning
O.10	A knowledge of contemporary issues
O.11	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Criterion 4 – Professional Component

Criterion 4 addresses a "professional component" that must be incorporated into the overall framework of institutional mission and program objectives. The professional component provides general guidelines for a curriculum in which students ultimately participate in a major design experience, as shown in Figure 1. Issues that must be included in the professional component are also shown in Figure 1 (P.1 – P.9).

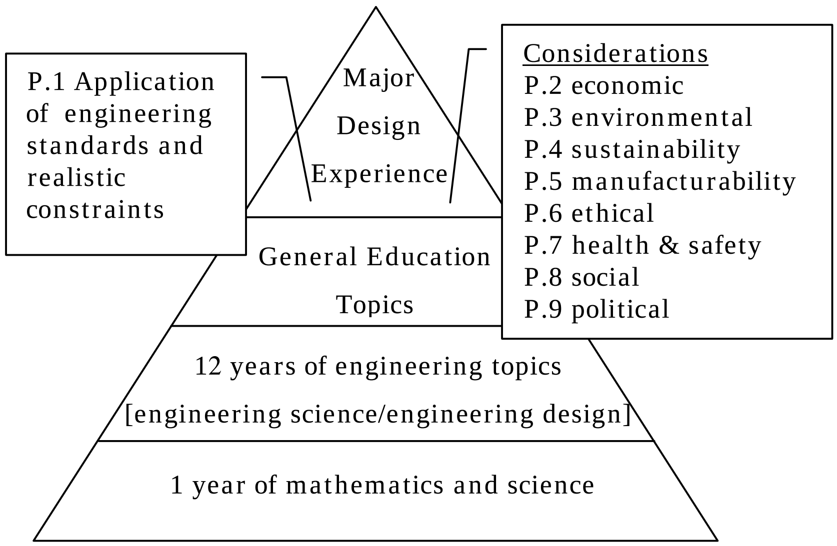

Figure 1. The Professional Component

Creating a Program Goals Matrix

To summarize at this point, each institution must develop a set of measurable outcomes that are consistent with the mission of the institution and that included in EC 2000[1]. In the early stages, a logical step would be to identify the specific outcomes associated with each academic program, including the curriculum. Taken collectively, the entire set of courses in the curriculum should broadly support the outcomes, with an appropriate amount of redundancy. Aldridge and Benefield[3] describe a model assessment system that includes a feedback learning outcomes system. Three levels compose the learning outcomes system: program outcomes level, curriculum level, and course level. They suggest that the appropriate contribution of each course to the curriculum can be ensured through assignment of learning objectives to specfic courses.

A helpful tool for managing data for the overall curriculum is a Program Goals Matrix. A Program Goals Matrix links each course in the curriculum with outcomes associated with that course. Outcomes associated with a given course would typically be a subset of the total set of outcomes. Because the application of engineering standards and realistic constraints and design considerations (P.1 – P.9) must be demonstrated (see Figure 1), it would be valuable to include these in the matrix to demonstrate coverage of these concepts throughout the curriculum. Table 3 illustrates a typical Macro Program Goals Matrix. For purposes of this paper, "Macro" refers to a matrix associated with the entire curriculum and "Micro" refers to a similar matrix for a single course. In Table 3, "X" represents where an outcome is being included and assessed in a given course. Although the Program Goals Matrix is a simple concept, the authors have found that creating a matrix can be somewhat time-consuming. Not only does the initial planning and coordination with a number of faculty members require a considerable amount of time initially, but the process is actually iterative between constructing the Macro matrix and assessing individual courses. Nonetheless, the time is

Table 3. Macro Program Goals Matrix

Course No.	O.1	O.2	... etc...	P.8	P.9
CIVIL 101	X				X
CIVIL 102		X	X	X	
... etc...					

well spent for a number of reasons, including

- Although there is an initial investment of time, program goals matrices provide a management tool that will ultimately promote efficiency so that valuable time is not taken from student learning.

- Macro matrices provide a way to track how comprehensively each outcome is supported by a variety of courses throughout the curriculum.

- The matrix format helps demonstrate the inter-relationships of various curriculum elements.

- Program goals matrices help create and improve a curriculum that is not just a random collection of courses, but rather a well-integrated curriculum that provides a learning experience that continues to enhance previous lessons learned, and at the same time challenges students to broaden their knowledge both in scope and depth.

Assessment of Individual Courses

The assessment process for individual courses can be very similar to the overall process for academic programs described earlier (see Table 1). An iterative process to promote continuous improvement is depicted in Figure 2.

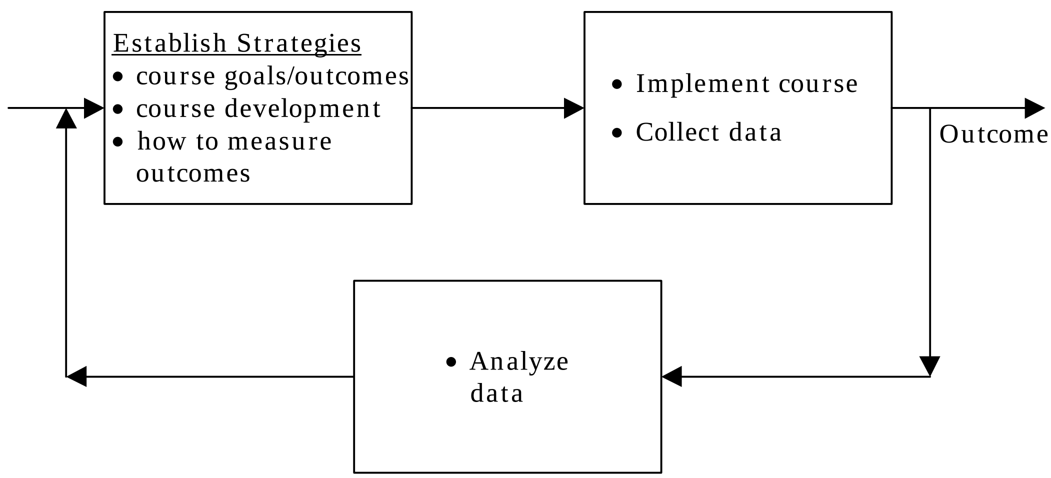

Figure 2. Continuous Improvement Schematic for Individual Courses

In establishing goals for individual courses, a Micro Program Goals Matrix may be used. This type of matrix is much more detailed than the simple grid relationship depicted in Table 3. A Micro matrix enables a professor to not only provide detailed descriptions of goals and objectives, but also to tie the goals and objectives to EC 2000 Criteria[1] if this is deemed to be valuable. Two approaches to assessment, including examples of Micro Program Goals Matrices are discussed in the following sections.

Assessment Example "A"

The way the new ABET criteria are written appears to offer a great deal of flexibility in the way assessment is accomplished. Although programs must demonstrate that specific requirements associated with Criteria 3 and 4 have been met, there appears to be no specific methodology that must be used.

One method that might be used for setting course goals would involve directly tying course goals to Criterion 3 outcomes and the Criterion 4 professional component. Table 4 indicates how this could be done using a Micro Program

Table 4. Program Goals Matrix for Geomatics

Designation	Outcome
O.1	*An ability to apply knowledge of mathematics, science, and engineering*
	1. Students enrolled in Geomatics should be able to apply knowledge of basic surveying, mapping, and photogrammetric computational techniques (e.g. traverse, triangulation and trilateration, leveling, angle and direction, state plane coordinates, correction and error analysis, and area, astronomical position and direction determination calculations and the geometry of aerial photographs).
	2. Students enrolled in Geomatics should be able to use basic surveying measurement techniques and understand the theory used in Global Positioning Systems (GPS).
O.2	*An ability to design and conduct experiments, as well as to analyze and interpret data*
	1. Students enrolled in Geomatics should be able to recognize and assemble pertinent information, draw conclusions, and set priorities as they pertain to mapping and Geographic Information Systems (GIS).
	2. Students enrolled in Geomatics should be able to measure units of space, water, land and structures (e.g. boundaries, areas, shapes, elevations, directions, slopes, distances, angles, heights, locations and alignments).
	3. Students enrolled in Geomatics should be able to analyze measurement data through application of appropriate statistical measures using the equipment and hardware of the profession.
O.3	*An ability to design a system, component, or process to meet desired needs*
	1. Students enrolled in Geomatics should be able to design a Photogrammetric Flight Plan that meets established mapping criteria
... etc...	
P.1	*Application of engineering standards and realistic constraints*
	1. Students enrolled in Geomatics should be knowledgeable of recognized minimum standards for the conduct of surveys, and how these standards apply to work in progress.
P.6	*Ethical considerations*
	1. Students enrolled in Geomatics should have knowledge of prevailing professional standards, and ethics.
... etc...	

Goals Matrix for a course in Geomatics. Only a portion of the matrix is shown; the entire matrix could be related to as many of the criteria as appropriate.

Measurement of outcomes could be based on a linkage between the Micro Program Goals Matrix and the course material. One approach might be for the instructor to make a determination of the relationship of each homework assignment, exercise, or test question to the Micro Program Goals Matrix. For example, suppose Question 1 on a quiz pertains to Matrix elements O.1, O.2, O.7, and P.2. Student performance for those elements could then be related to Question 1 in the following manner. If all students achieved maximum credit on Question 1, the proficiency would be 100 percent. Proficiency, therefore, would represent the per cent achievement of all students on that one question. If for example, two students were in the class, and one received half credit while the other received full credit for the question, the proficiency would be 75 percent. This would provide a measurement of the Matrix elements associated with Question 1.

Measurements can then be accumulated throughout the entire course for all Matrix categories, and summed at the end of the course for assessment purposes. Performance groupings might be based on the following proficiencies (Table 5). Frequencies of each measurement category could then be summed, and plotted to show for each course the number of measurements made for each matrix element, and the corresponding proficiency.

At the conclusion of each course, a faculty member can then review the course goals and objectives, and evaluate the current student population proficiency performance. Judgment can then be applied as to what areas need improvement, and possible reasons why performance occurred at the levels indicated. A summary could then be included in a course folder containing the course goals and objectives, the Micro Goals Matrix, evidence of student work, evidence of performance measurements, and a written assessment of the course.

Table 5. Performance Ratings for Example Assessment

Performance	Rating
90 - 100	Excellent
80 - 89	Very Good
70 – 79	Good
60 – 69	Poor
< 60	Unacceptable

Assessment Example B

Assessment Example A illustrates how course goals could be tied directly to Criterion 3 outcomes and the Criterion 4 professional component. Another approach would be assessing student learning based on course goals that outline strategies for teaching the course material. This approach is similar to that described by Aldridge and Benefield[3], although more detail is provided here. Table 6 provides an example for a Civil Engineering course in Structures. As indicated in Table 6, the EC 2000[1] outcomes related to the six course goals have been identified but are not linked to specific goals.

Table 6. Program Goals Matrix for Structures

Related EC 2000 Outcomes	Course Goals/Outcomes
O.1 O.5 O.11	Upon completion of the course the student should: 1. have an understanding of the use of equations of equilibrium to calculate reactions 2. have an understanding of the relationship between load-shear-moment and be able to draw the corresponding diagrams 3. be able to determine the stability and the degree of determinacy of a structure 4. be able to compute and use influence diagrams 5. use the flexibility method to compute forces in an indeterminate structure 6. be able to use the flexibility method to compute forces in an indeterminate structure 7. be able to use moment distribution to compute forces in an indeterminate structure

Designing tests with assessment in mind may facilitate assessment of course goals. For example, printing the objectives directly on the test

- helps to document assessment of student learning,
- aids the professor in ensuring continuous improvement, and
- helps students understand how test questions relate to course objectives.

Further, tests may be graded using course objectives as a guide. One way to do this is to staple an assessment cover sheet directly to the test before returning it to the student. A portion of a test assessment sheet is shown in Table 7.

Performance can be measured for the various objectives by recording individual student grades for each test question. Performance ratings developed for the course can aid the professor in analyzing records. After analyzing course performance, a professor can summarize the assessment in a file for later use in improving the course. An

Table 7. Sample Test Assessment Sheet

Assessment of Test 2		
for Smith .	Score 87 % .	
Problem 1: Objective to assess the students' understanding of the computation of deflections		
Major Task	**Maximum Possible Points**	**Earned Points**
1. Draw load moment diagram by superposition	4	2
2. Draw virtual load moment diagram	4	0
3. Compute deflection by visual integration	4	4
4. Execute the mathematics	2	2
Total Score	14	8
Problem 2: Objective to compute the forces in an indeterminate frame by the force method		
etc.		

example sheet illustrating assessment and recommendations for improvement for a Structures course is provided in Table 8.

Concluding Comments

Although it is not possible now to determine how evaluators will view specific approaches to assessment, it is clear that the assessment process described in the EC 2000 Criteria[1] will need to include some method for assessing student learning associated with classroom instruction. The Criteria do not require the use of a specific methodology, but leave room for creativity in demonstrating that assessment guidelines have been followed. Assessment Examples A and B discussed in this paper, while similar in some aspects, represent two different approaches to assessment. Assessment Example A is a more direct approach, using EC 2000 Criteria[1] as a framework for developing course goals and determining how well those goals are met. In Assessment Example B, course goals are expressed more in terms of the unique course material, although a clear link to the Criteria is made. Until additional experience is gained with the EC 2000 Criteria[1], one example cannot be shown to be superior to the other. In fact, there is no reason why individual professors at the same school cannot use different approaches as long as the Criteria are being met through the combined efforts of these individuals.

Both approaches at assessment of student learning require additional effort and time. The initial time required for planning and coordination among faculty members is potentially an excellent investment that will eventually pay high dividends in terms of quality instruction and improved student learning. Much of this initial investment of time will not be required on a continuing basis, nevertheless, regardless of the efficiencies that are achieved, a thorough effort at assessment of classroom instruction will almost certainly take additional time each academic term. It remains to be seen how much engineering education will be impacted after a number of years of experience with EC 2000, but based on the authors' early experience with EC 2000, there does appear to be potential for significant improvement through conscientious efforts.

Table 8. Course Assessment Sheet

Performance Ratings	
Average Score $\geq$ 90%	Very Good
80% $\leq$ Average Score < 90%	Good
70% $\leq$ Average Score < 80%	Fair
Average Score < 70%	Poor

Assessment of Course Goals	
Goal 1	Very Good (most had a good understanding)
Goal 2	Very Good (most had a good understanding)
Goal 3	Very Good (most had a good understanding)
Goal 4	Fair to Good (some had trouble separating moment diagrams and influence diagrams)
Goal 5	Good for trusses; Fair for frames (some had trouble drawing moment diagrams by superposition
Goal 6	Good (most understood the concept but had problems computing deflections)
Goal 7	Good (most of the students seemed to grasp the process but needed more work on the theory)

Recommendations for Improvement
1. This course was taught in a seven week summer period. This is too short a time period for students to gain the necessary skill level by practicing through problem sets. Recommendation: If the course is taught again in the summer, the course should be taught over a ten week period; however, it is preferable to teach the course during the regular Fall or Spring semester.
2. Students have a great deal of difficulty separating the concepts of moment diagrams and influence diagrams. It is possible that adding discussion of virtual work would improve understanding of the concept of Muller-Breslau principle. Recommendation: There appeared to be some room to add discussion of virtual work. This should be verified when the course is taught during a regular semester.
3. Other than noted above, this course appears to have the proper content.

References

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3. Aldridge, D. M. and L. M. Benefield (May-June, 1998) "A Model Assessment Plan," *ASEE Prism*, Washington, D. C.

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