Improving Undergraduate Engineering Education in the US and Abroad Using EC 2000

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Abstract: A needs-based assessment process was developed with the assistance of our Advisory Board (constituency). Educational objectives, program outcomes, assessment tools and methods were established, and results were measured. When a consistent weakness is detected, corrective actions are recommended and implemented to improve our undergraduate ME program.

Keywords: education, abet, assessment, improvement

1. Introduction

The Accreditation Board for Engineering and Technology (ABET) has approved a new set of criteria for accrediting engineering programs. It is called Engineering Criteria (EC) 2000 [1]. These criteria are being phased in over a three year period starting in the fall of 1998. The new guidelines are less descriptive than the old ones and focus on the program's resources and processes for accomplishing continuous improvement in engineering education.

ABET has published eight criteria that must be satisfied. Criteria 2 and 3 are program educational objectives and program outcomes & assessment, respectively. The assessment process must be based upon the needs of the constituents and have "a process based on the needs of the constituents in which the objectives and outcomes are determined and periodically evaluated" [1]. ABET expects that the constituents will have a "high degree of involvement in assessment and improvement and will have a sustained strategic partnership" with the engineering program [2]. In addition, the processes, methods and results must be documented [1].

Loyola Marymount University's (LMU's) Mechanical Engineering (ME) Department has developed an assessment process and improvement methods that involve our constituents. The process is very time-intensive and requires a direct involvement of the faculty. Due to the fact that our engineering programs are coming up for accreditation review in the fall of 2000, we are sharing our results in order to help other engineering programs improve their assessment methods.

The purpose of this paper is to discuss our processes that were developed to satisfy the requirements of Criteria 2 and 3 in EC 2000. In addition, recommendations will be given on our improvement methods and documentation procedure to continuously improve engineering programs. Finally, we will demonstrate how our strengths and weakness can be measured and reported in a self study report.

2. Advisory board and assessment process

Our assessment process was based upon the needs of our constituents and was driven by our Advisory Board. The process was used as a roadmap to plan the activities that were required for assessment, and it is shown in Fig. 1. It is compatible with the "2-loop" assessment process that has been suggested by ABET [3], Jakubowski and Calder [4], Aldridge and Benefield [5]. For the basic definitions of terms, the reader should refer to other publications [4, 6].

In Fig. 1, the process starts with our Advisory Board and establishes their needs. In 1998, the ME Department established an Advisory Board, which consisted of representatives from industry, graduate schools, ME alumni, ME students, professional societies, and the ME faculty [7]. The outside members from industry represented our largest constituency, since ~70% of our graduates seek industrial careers after graduation. Our advisory board was formed to ensure that the constituents' needs were being addressed, that our educational objectives and program outcomes were related to their needs, and that our processes and methods were adequate for improvement.

In Fig. 1, the dotted lines around the shaded boxes show the linking of the constituent needs to educational objectives and program outcomes. Next, the program outcomes were linked to the curriculum. Then the curriculum is linked to the learning objectives and course topics, which are published in the course syllabi. The assessment tools, educational practices and methods are formulated. Data are gathered to both evaluate the educational objectives and assess the program outcomes. These data are analyzed and interpreted against our achievement expectations. When consistent weaknesses are identified and confirmed by our Advisory Board, corrective actions

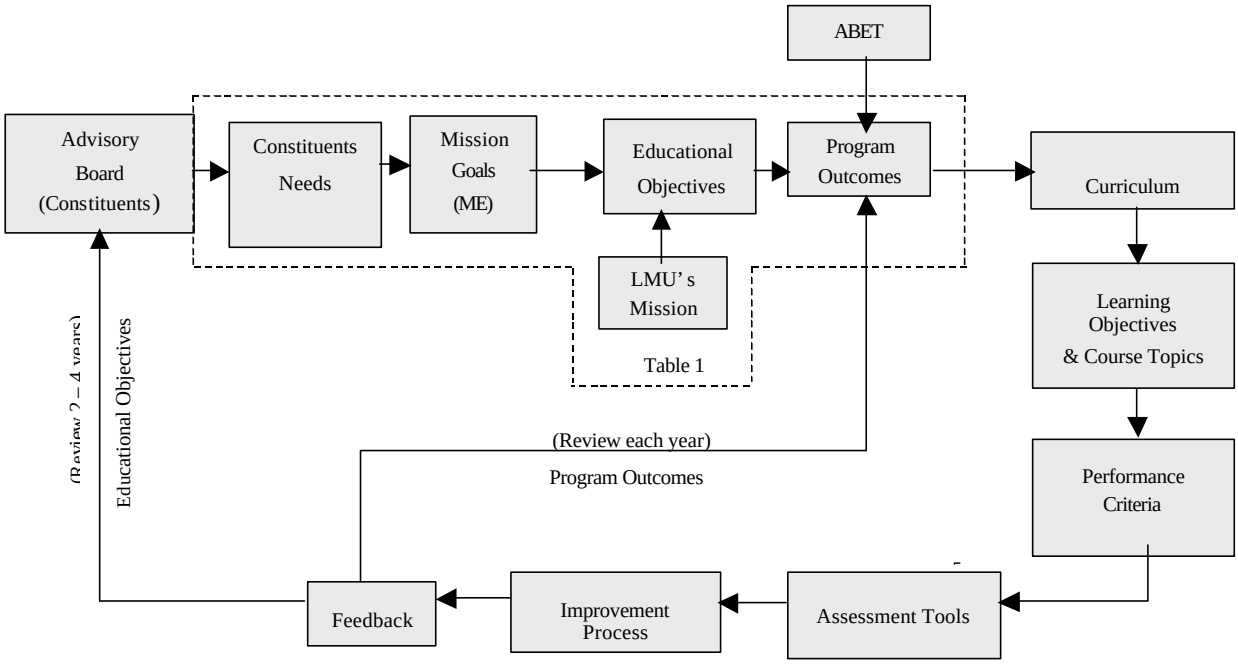

Fig. 1. Assessment Process

are recommended by our faculty to make improvements. These improvements are fed back to our Advisory Board (i.e., indirectly to our educational objectives) and will be reviewed every 2-4 years to ensure that our constituents' needs are being met [7]. Because Fig. 1 represents a "double-loop" process, our improvements are also fed back into program outcomes and are reviewed annually.

The outside representatives on our Advisory Board (from industry, graduate schools, alumni, students, and professional societies) unanimously agreed that the process in Fig. 1 was sufficient for improving our program [8].

3. Links of needs/mission ⇔ objectives ⇔ outcomes

In order to insure that all of the constituents' needs and LMU's mission were related to our educational objectives and program outcomes, Table 1 was prepared to show these links. From Fig. 1, the dotted lines around the shaded boxes show this linking process. The constituents' needs were determined from a questionnaire and Advisory Board meeting [7]. In Table 1, our educational objectives are numbered (1) - (5), and the program outcomes are numbered (a) - (n). ABET's requirements are listed as (a) - (k), and the extra ME program outcomes are shown as (l) - (n).

The numbers in brackets opposite each item of the constituents' needs and LMU mission show the link with the educational objectives. Likewise, the letters in brackets opposite each educational outcome show the link with the program outcomes. When the links of needs/mission ⇔ objectives and objectives ⇔ outcomes were satisfied, check marks ( ) were placed after the items in constituents' needs/LMU mission and program outcomes. This linking process replaced the quality function deployment (QFD) spreadsheets [9, 10].

Our outside members on the Advisory Board unanimously agreed that both our educational objectives and program outcomes had met their needs [8]. Based on their approval, our educational objectives were published in LMU's Undergraduate Bulletin.

4. Assessment tools

Assessment tools were used to evaluate our educational objectives and to assess our program outcomes. The following six assessment tools were used: senior survey, alumni surveys, Engineering Benchmark Inc. (EBI) survey, fundamentals of engineering (FE) exam, senior exit interviews and course evaluations. Under each assessment tool, we developed our educational practices and methods that specified how each tool would be used in the assessment process. Table 2 shows an example of the educational practices and methods that were defined for the FE exam

(assessment tool). This example was used because data on FE exam have been continually analyzed over the last 5 years. In addition, the FE exam demonstrated the proficiency of our students in meeting the program outcomes.

Table 1. Links Between Constituents' Needs, LMU's Mission, Educational Objectives and Program Outcomes.

Constituents' Needs	**Educational Objectives**	**Program Outcomes**
• Solid foundation in basic math, science & ME [2]	1. Prepare for employment, graduate studies & continuous learning [i, j, l]	a. Apply math, science and engineering
• Communication skills:		b. analyze, interpret data
• Professional awareness [1, 5]		c. Design system, part, process to meet desired needs
• Computer skills and soft-ware tools [2]	2. Broad fundamentals & anal. problem solving skills for ME [a, e, j, k, m]	d. Function on multi-disciplinary teams
• Exposure to many engrg. disciplines [2, 3, 5]		e. Identify, formulate and solve engineering problems
• Define & solve problems [2, 3, 4]	3. Teams, creative prob. solving, communication for ME design process [c, d, e, g, h, j, k, m, n]	f. Ethical & professional responsibilities
• Self-motivated, responsible engineer. [5]		g. Communicate effectively
• Teamwork & leadership skills [3, 5]		h. Broad education of engrg. global, societal issues
• Design constraints, trade-offs & optimization [2, 3]	4. Applied research, exper. studies, & design projects [b, c, d, g, k, m]	i. Life-long learning
• Continuous learning [1]		j. Knowledge of contemporary issues
• Practice-oriented, design focused program [3, 4, 5]		k. Skills and tools for engrg. practice
• Critical thinking & curiosity [3]	5. Professionalism, ethics & service [f, g, h, j, k, l, n]	l. Interaction of students with practicing engineers
LMU's Mission		m. Skilled in materials, mfg. processes and part sizing
• Encourage learning [1]		
• Educate whole person [1, 5]		
• Service of faith and promoting justice [5]		n. Interpersonal & humanistic relationships

The outside members on our Advisory Board (i.e., representatives from industry, graduate schools, alumni, students, and a professional societies) unanimously agreed that our current assessment tools were sufficient for measuring our educational objectives and program outcomes [8].

Table 2. Example of Assessment Tool: FE Exam – Educational Practices and Methods

Educational Practices	**Methods**
Type of exam	Standardized exam in mathematics, science and engineering that compares the ability of our ME students with those nationally and state-wide. Our students took the general engineering exam.
Use in assessment	The passing % of our students was compared with the national/state averages from 1995-99. The students' ability in various subjects was compared to the national and state averages.
Responsible people	The faculty strongly encouraged the students to take the FE exam as a first step toward becoming a registered professional engineer.
Timetable	Conducted twice a year: fall and spring between 1995-99. The results were combined in the year that the students took the exam, i.e., spring and fall 1999 data were reported in 1999.
Reported data	Data were reported for the passing % of our students compared to the national and state averages for 1995-99. The data were averaged between the morning and afternoon sessions for the various subjects. In addition, a weighted average was calculated for each of the subjects.
Achievement expectations	90% of the national and state averages were used as the performance standard for the subjects.
Method of data analysis	If our students scored <90% of the national and state average, they were considered deficient (weak) in that subject. If they scored 90% of the average, then they were considered proficient (strong) in that subject. A consistent weakness was at least 3 out of 5 years scoring <90%.

5. Improvement process and results

In searching for continuous improvement, a process was developed for implementing changes (see Fig. 2). Using our assessment tools, data are collected and compared with our achievement expectations. This generated a performance gap. A positive gap (when the data exceed the expectations) indicated adequacy in meeting the expectation, which was considered a strength. A negative gap (when the data fell below the expectations) indicated inadequacy, which was considered a weakness. [Weaknesses were viewed as opportunities for improvement.] The negative gaps were reviewed by our ME Advisory Board and/or the President's Council to confirm their validity. If the gap is consistently negative, then corrective actions are recommended by the faculty, and changes are implemented. These changes are documented and are reviewed periodically (see Fig. 1). The outside members on our Advisory Board (from industry, graduate schools, alumni, students, and a professional societies) unanimously agreed that our improvement process (Fig. 2) is adequate for improving the ME program [8].

The assessment results are reported on documentation tables for each of the 14 program outcomes (a) - (n). These tables listed the assessment tools and strengths/weaknesses for each program outcome, and these have been used for summarizing the data in our self study report for ABET. When a weakness is consistent (i.e., occurring in at least two assessment tools), then it is recommended for corrective action at the bottom of the sheet. When the corrective actions are actually implemented, the date and faculty member who implemented the changes are recorded on the sheet. In this way, a historical record of the changes is documented. The typical corrective actions that have been recommended for curriculum change are: modifying course content, changing the learning objectives or course topics, suggesting different teaching methods, using different texts, changing instructors, and providing more inter-departmental coordination.

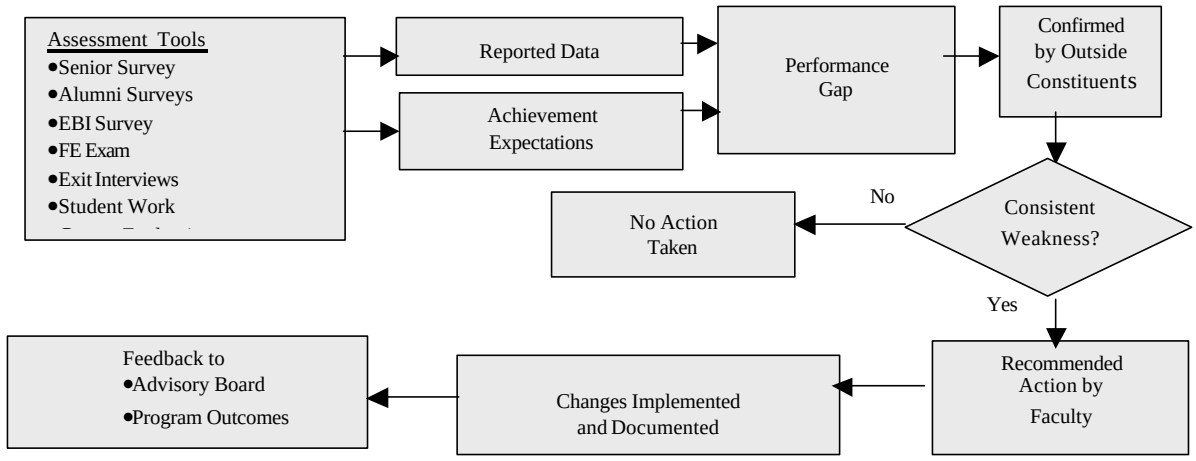

Fig. 2. Improvement Process

Table 3. Documentation of Assessment for Program Outcome (g): Ability to Communicate Effectively

Assessment Tool	Strength	Weakness	Consistent Weakness
Course Evaluations	NA*	NA*	NA*
Senior Survey	Communicating orally, in prepared talks, and in writing	None indicated	None
Exit Interviews	None indicated	None indicated	None
FE Exam	NA*	NA*	NA*
Alumni Surveys	Technical report writing	None indicated	None
EBI Survey	Communicating in written reports	Communicating in oral reports	Not a consistent weakness
Corrective Actions: None are recommended at this time, May 1, 2000.			
* NA = Not applicable for assessing Program Outcome (g)			

An example of assessment documentation is shown in Table 3 for program outcome (g): ability to communicate effectively. The weakness in oral communication is not consistent, and no corrective actions are taken. Also, in Table 3, the strengths were a measure of our students' proficiency in meeting program outcome (g). For example, the results clearly indicate that our students are proficient in both oral and written communication skills.

6. Conclusions

Our needs-based assessment process was driven by our ME Advisory Board. The process was used as a roadmap to plan the assessment activities. In this way our educational objectives and program outcomes could be linked to learning objectives and course topics. Our Advisory Board consisted of a broad range of representatives from industry, graduate schools, alumni, students, and professional societies, in addition to the ME faculty. Based on the needs of our constituents, the educational objectives of the program were established. In order to insure that all of the constituent's needs, LMU's mission and program outcomes were related to our educational objectives, a table has been prepared to show these links.

Each program outcome was assessed by the FE Exam, senior survey, EBI engineering survey, alumni surveys, exit interviews and course evaluations. The strengths and weaknesses of our program outcomes were established and reviewed with our Advisory Board. When a consistent weakness was determined, corrective actions were recommended by the faculty and implemented to improve the program. The changes were fed-back to our program outcomes and educational objectives (indirectly), where the results will be reviewed annually and every 2-4 years, respectively.

We firmly believe the implementation of EC 2000 has improved the quality of our ME program at LMU. It is a continuous improvement process that is very time-intensive. However, it offers the advantage of strengthening undergraduate engineering education.

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