Accreditation Criteria for Engineering Programs – Implementing EC-2000 Criteria

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Abstract – The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET) accredits engineering programs. The U.S. Department of Education and Council for Higher Education Accreditation recognizes ABET for its responsibility in engineering accreditation. State licensing boards for engineers require a four-year engineering degree from an institution with an ABET program.

The accreditation criteria of EC-2000 of ABET requires a structured plan to measure and evaluate the attainment and evaluation of learning objectives and outcomes, as defined by engineering programs. This article focuses on the application of the ABET EC-2000 criteria that requires engineering programs to formulate curriculum based on program outcomes. It concentrates on three topics: (1) formulating the required learning outcomes, (2) generating a program that enables faculty to achieve the required learning outcomes, and (3) assembling a plan of curriculum development that satisfies accreditation standards and fulfills the university's educational goals. This article will propose a plan of action to meet the EC-2000 criteria for an engineering program at a local university.

The implications of the EC-2000 guidelines are that educators in engineering develop curriculum and assessment tools based on program outcomes. ABET does not stipulate the methods used in the development and assessment process. However, ABET demands that institutions demonstrate the pedagogy used to achieve learning objectives as well as evidence of assessment and continuous improvement. As a consequence of this freedom in program development, engineering faculty now have the flexibility to meet student, industry, and institutional needs.

Keywords: accreditation, engineering education, assessment, curriculum, online learning

I. Introduction

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET) accredits four engineering programs at Christian Brothers University (CBU). The U.S. Department of Education and Council for Higher Education Accreditation recognizes ABET as the sole accrediting agency for engineering programs [1]. State licensing boards for engineers require a four-year engineering degree from an institution with an ABET approved engineering program.

EC-2000 is a publication by ABET that identifies the learning outcomes necessary to maintain ABET accreditation [2]. In this publication, ABET defines the following learning outcomes that must be demonstrated in an accredited engineering program: (a) ability to apply knowledge acquired, (b) ability to design and conduct experiments, (c) ability to design systems, (d) ability to function on multi-disciplinary teams, (e) ability to formulate and solve problems, (f) understanding professional responsibility, (g) ability to communicate, (h) understanding the impact of engineering solutions in a global context, (i) recognition of need for life-long learning, (j) knowledge of contemporary issues, and (k) ability to analyze and interpret data.

At Christian Brothers University, a plan was prepared to implement these learning outcomes in the School of Engineering. This plan is summarized in Table 1, which shows a listing of the ABET EC-2000 learning outcomes, and the associated courses from the School of Electrical and Computer Engineering [3].

Table 1
Engineering Courses and ABET EC-2000 Learning Outcomes

Course	ABET EC-2000 Learning Outcomes										
	a	b	c	d	e	f	g	h	i	j	k
COMPUTERS IN ENGINEERING PROBLEM SOLVING			x		x						
ENGINEERING INSTRUMENTATION	x			x	x	x	x			x	x
ELECTRIC CIRCUIT ANALYSIS I			x		x						x
ELECTRIC CIRCUIT ANALYSIS II			x		x						x
DIGITAL DESIGN			x	x	x		x			x	x
MICROPROCESSOR ARCHITECTURE AND PROGRAMMING			x	x	x		x	x		x	x
ENGINEERING ECONOMY				x	x	x	x	x	x	x	x
LINEAR CONTROL SYSTEMS			x		x	x	x	x		x	x
ELECTRONICS I			x		x						x
ELECTRONICS II			x		x						x
SYSTEMS, SIGNALS AND NOISE			x		x					x	x
JUNIOR LABORATORY I	x	x					x	x			x
ELECTROMAGNETIC FIELD THEORY	x	x	x				x	x			x
ELECTRICAL AND COMPUTER ENGINEERING PROJECT	x	x	x	x	x	x	x	x	x	x	x

This plan affects courses throughout the Engineering degree program. As a consequence of the widespread impact of this plan, an effort on the part of the entire engineering faculty will be required for successful implementation. The Electrical and Computer Engineering (ECE) Department tentatively approved the plan at the department meeting on September 12, 2002, for implementation in the fall 2002 semester.

II. Framework

To implement the plan, a framework for developing curriculum and assessing student learning is needed [2], [4]. Bloom's taxonomy provides a framework for developing and assessing curriculum. Bloom's taxonomy is a methodical approach to defining learning outcomes and objectives. Bloom's taxonomy identifies six cognitive categories that describe levels of learning. Educators use the six categories to evaluate the level of learning of defined learning outcomes and objectives. The six categories are knowledge, comprehension, application, analysis, synthesis, and evaluation. Since the development of Bloom's taxonomy, the literature has identified an additional category known as valuation [2], [4], [5], [6]. Valuation is defined as the ability to represent attributes applicable to engineering problems. Table 2 presents the cognitive and affective categories along with the related attributes of each.

Table 2
Cognitive and Affective Categories

Cognitive Domain	
Category	Levels of Learning
KNOWLEDGE	Student recalls previously learned information
COMPREHENSION	Student describes prior learning
APPLICATION	Student illustrates the use of data and principles to complete a problem
ANALYSIS	Student distinguishes, classifies, and relates assumptions, objects, and ideas and determines how the parts are related
SYNTHESIS	Student formulates, integrates, and assembles ideas into a product
EVALUATION	Student appraises, evaluates, and compares problems based on evidence and criteria
Affective Domain	
Valuation	Student demonstrates the impact and worth of an experiment or problem on the local and global community

The implications of the EC-2000 guidelines are that educators in the engineering discipline may develop curriculum and assessment tools based on program outcomes [2], [4]. ABET does not stipulate the methods used in the development and assessment process [7]. Moreover, ABET requires that engineering programs demonstrate that the curriculum accomplishes the learning objectives and outcomes and provide verification of assessment and continuous improvement of the curriculum. As a consequence of this freedom in program development, engineering faculty have the flexibility to meet student, industry, and institutional needs [8], [9].

III. Attributes

ABET EC-2000 learning outcomes do not prescribe the learning components or attributes necessary to accomplish instructional goals. Instead, institutions must demonstrate how learning objectives were achieved. Therefore, in order to implement the "a thru k" learning outcomes, each outcome will have to be assigned to specific course content. To provide greater clarity, attributes may contain subcomponents that identify the instructional activity of a particular course. In this way, every lecture topic can be mapped to an attribute of an ABET EC-2000 learning outcome [4]. For example, an engineering course titled *ECE Project* must meet the objective of EC-2000, item c – *ability to design systems*. The syllabus for this course is used to identify the attributes that map to this key-learning outcome. Below is a statement of course goals listed in the syllabus of the ECE Project class:

1. Learn proper library search methods for information on selected subject.
2. Organize the problem statement and design specifications.
3. Present alternate solutions and list advantages and disadvantages of each.
4. Present final solution and reasons for choice involving realistic constraints such as economic factors, reliability, aesthetics, and ethics.
5. Provide an economic evaluation of the project.
6. Perform testing of the overall solution in the process of constructing and evaluating for performance against the original design objectives.
7. Meet progress report deadlines.
8. Learn how to organize a written presentation.
9. Learn and use good techniques in the oral presentation of the subject.

The selection of attributes and subcomponents characterizes the learning outcomes but does not address the type of understanding that a student must demonstrate. Introductory courses and advanced courses may require the ability to design and contain similar attributes, but the student is required to demonstrate different levels of understanding. To represent these levels of understanding, the categories found in Table 2 are utilized to categorize instructional components for the Electrical and Computer Engineering Project course. A two-tiered method is utilized to demonstrate the framework that enables the degree of detail necessary to define attributes and subcomponents. Table 3 illustrates some of the attributes for learning outcome (c) – ability to design systems for Electrical and Computer Engineering Project. Each row describes an attribute of the learning outcome (c), and each column of the cognitive categories describes the expected level of comprehension at various degrees of complexity.

Table 3
Learning Outcome (c) –Ability to Design Systems

	Cognitive Categories				
Attributes (c)	*Knowledge*	*Comprehension*	*Application*	*Analysis*	• • •
Learn proper library search methods	Recite search methods; name established methods	Identify different search methods; report steps necessary to carry out research	Select and perform appropriate research	Appraise the appropriate methods at the various stages of a design project	
Organize the problem statement	Recite definitions; list established methods	Appraise the difference in methods; identify different steps in the process	Select and employ the appropriate method to define the problem	Assemble a needs statement to appraise information concerning the problem statement	
Present alternate solutions	Recite definitions; list established method used to discover alternative solutions	Describe difference in methods to discover alternative solutions;	Illustrate and interpret the various solutions at appropriate stages in the design process	Experiment and test the designs in order to revise plans as needed	
• • •					

Each attribute may have subcomponents to provide detail and are often necessary to describe the different levels of understanding that are expected of students for specific attributes of learning outcomes [10]. Table 4 illustrates some of the subcomponents related to “organize the problem statement” listed on Table 3.

Table 4: Subcomponent for Organizing the Problem Statement for Learning Outcome (c) –Ability to Design Systems

	Cognitive Domain		
Subcomponent of Problem Statement	*Knowledge*	*Comprehension*	• • •
Significant	Recite definitions; list established method used to discover significance	Describe the implication of a problem	
Manageable	List definitions; list techniques to determine schedule	Describe a specific method to create a timetable	
• • •			

Given a problem statement I can: a) Determine if the stated problem statement is significant using established methods.

b) Divide a problem into manageable tasks and provide a timeline.

IV. Assessment

The attribute framework enables the development of surveys that provide a measurable indication of the level of learning in terms of components that contribute to the specific ABET EC-2000 learning outcomes. Table 4 illustrated the use of the framework to develop survey questions that isolate the desired area of learning to be assessed, as illustrated by the boxes, arrows, and survey questions. In addition, the survey questions focus on the performance at varying levels of complexity and measure the tactics that a student utilizes in determining a solution to a problem. ABET's accreditation criteria does not specifically identify sections for online learning. However, each program must have a documented assessment process.

V. Pre-Course and Post-Course Test

Pre- and post-tests measure the students' level of knowledge prior to the courses and at the completion of the courses [10] employing a five-point forced choice scale and open-ended questions. The attribute framework developed provides the basis for the test. The pre-tests are moderately difficult with an expected score of 50% to provide evidence of improvement. An analysis of the test results will contain:

1. Graphs of the results of each pre-test versus test questions.
2. Graphs of the results of the individual related test questions.
3. Graphs of the results of the class grade, pre-test, and final exam
4. Scatter plots of pre-test versus final exam.

VI. Summary

EC-2000 impacts educators of engineering programs by requiring the development of curriculum to meet stated program outcomes and then mandating the use of assessment tools to measure achievement. ABET mandates that administrators and faculty produce key deliverables such as evidence of assessment and plans for continuous improvement. ABET does not stipulate a pedagogy toward accreditation. Administrators and faculty will benefit from models that guide program development.

ABET requires that engineering programs assess the quality and performance of the students and graduates. Institutions must evaluate, provide guidance, and monitor students to demonstrate compliance with program objectives. Engineering programs must demonstrate compliance with published learning outcomes and objectives and provide evidence of an educational process consistent with these learning outcomes and objectives. Moreover, engineering programs must provide an ongoing assessment plan to ensure the achievement of the objectives of the curriculum and a process that enables the continuing evaluation to improve the effectiveness of the curriculum.

Engineering faculty must focus on developing learning outcomes and objectives that meet institutional and instructional goals. A structured method of formulating and implementing engineering curriculum, evaluating programs, and providing constructive feedback for improvement must be developed for each engineering program based on institutional and engineering curriculum objectives.

Engineering faculty must collaborate with industry on developing program objectives to ensure reliability and validity of the programs. In addition, engineering faculty must stress the impact and worth of the practice of engineering and institutional programs on the local and global community. Accordingly, engineering faculty must utilize attributes formulated in the affective domain to demonstrate the value of the engineering profession to the community.

The institutional mission and educational goals of institutions formulate the structure for the ABET EC-2000 learning outcomes. These educational goals enable a convergence of the definitions established in the eleven learning outcomes. The accreditation criteria of EC-2000 call for clear educational goals and measurable outcomes. This approach establishes a model that enables the generation of learning objectives from educational goals that assist faculty in defining the learning outcomes and the attributes associated with curricula needs.

References

[1] Accreditation Board for Engineering and Technology (ABET). (2002). *ABET Homepage*. Retrieved April 8, 2002, from the World Wide Web: http://www.abet.org/

[2] Besterfield-Sacre, M., Shuman, L. J., Wolfe, H., Atman, C. J., McGourty, J., Miller, R. L., Olds, B. M., & Rogers, G. M. (2000, May). Defining the outcomes: A framework for EC-2000. *IEEE Transaction on Education*, *43*(2), 100-110.

[3] Christian Brothers University. (2002). *Christian Brothers University*. Retrieved April 10, 2002, from the World Wide Web: http://www.cbu.edu.

[4] Safoutin, M. J. & Atman, C. J. (2000). A design attribute framework for a course planning and learning assessment. *IEEE Transaction on Education, 43*(2), 188-199.

[5] Huitt, W. (2000). *Bloom, et al.'s Taxonomy of the Cognitive Domain*. Retrieved May 21, 2002, from the World Wide Web: http://teach.valdosta.edu/whuitt/col/cogsys/bloom.html.

[6] Huitt, W. (2001). *Krathwo,l et al.'s Taxonomy of the Affective Domain*. Retrieved May 21, 2002, from the World Wide Web: http://teach.valdosta.edu/whuitt/col/affsys/affdom.html.

[7] Tornkvist, S. (1998). Creativity: Can it be taught? The case of engineering education. *European Journal of Engineering Education, 23*(1), 5-13.

[8] Costlow, T. (2000, February 14). As of 2001, no more cookie-cutter engineering programs. *Electronic Engineering Times* (1100), 5-6.

[9] Hutchins, G. B. (1998). Times, they are a changin'. *IIE Solutions, 30*(12), 18-19.

[10] Finelli, C. J. & Wicks, M. A. (2000). An instrument for assessing the effectiveness of the circuits curriculum in an electrical engineering program. *IEEE Transactions on Education, 43*(2), 137-142.

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