ABET Criteria and Continuous Process Improvement

David Elizandro, Jessica Matson, and Jane Fraser
Tennessee Technological University/Colorado State University--Pueblo

Abstract

The ABET 2000 Criteria shifted accreditation emphasis from prescribing a curriculum to articulating characteristics of a strategic management processes to administer programs and a minimum set of Program Outcomes for accredited programs.

There have been broad interpretations of the ABET 2000 Criteria by programs seeking accreditation. Similarly, governing professional societies have taken different approaches to articulating Program Criteria. The recently approved 2005-06 Criteria reflect the first iteration in continuous improvement of the ABET 2000 continuous improvement process. Specifically, the most significant improvements are clarification of the relationship between Program Objectives and Program Outcomes and the definition of engineering topics.

Although these clarifications are an improvement, there are other issues related to the ABET Criteria that may be addressed. For example, another area where ABET may choose to clarify is Criterion 8 which addresses the governing societies' role in the strategic planning process. This paper examines current Program Criteria for several programs, proposes revisions to General Criterion 8, and presents sample Program Criteria for industrial engineering.

Introduction

The ABET 2000 Criteria shifted accreditation emphasis from a prescribing a curriculum to articulating characteristics of strategic management processes to administer programs and a minimum set of Program Outcomes for accredited programs. As with the ABET 2000 Criteria, the recently approved ABET 2005-06 Criteria[1] require that a program is administered using well defined processes for each criterion and that constituents are an integral part of the planning process. In the Self-Study Questionnaire[2], the ABET definition of well-defined processes necessary to administer engineering programs is:

> *Processes for all elements of criteria are quantitatively understood and controlled; clearly tied to mission, program objectives, and constituent needs; seen as benchmarks by other institutions.*

Participants in the strategic planning process include ABET, professional society(ies), university, college, faculty, alumni, industry representatives, and students. The importance of the faculty's ability to manage the strategic planning process is documented in ABET criterion 5. Therefore faculty must be actively involved in every aspect of the process. ABET, governing societies, the university, and the college have regulatory authority in the process. Other constituents volunteer time and effort to the process. As discussed by Elizandro and Matson[3], typical program differences within a discipline reflect constituent differences characterized by, but not limited to:

1. University and college strategic plan
2. Number and interests of the faculty.
3. Number and academic preparation of students entering the program.
4. Organizations that recruit program graduates (industry and graduate programs).
5. Governing professional societies.

Based on presentations in professional meetings, it is evident that there have been broad interpretations of the ABET 2000 Criteria. The recently approved 2005-06 Criteria[1] reflect the first iteration in improvements to the ABET 2000 Criteria. Specifically, the most significant improvements are in Criterion 2, 3, and 4. Respectively, these are clarifications of Program Objectives, Program Outcomes, and engineering topics. The following is a brief discussion on each of the Criterion.

Current ABET Criteria.

According to criterion 1[1], the institution must evaluate, advise, and monitor students to determine its success in meeting program objectives. In addition, "the institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere. The institution must also have and enforce procedures to assure that all students meet all program requirements."

Common features of programs that satisfy Criterion 2 and 3 are:

1. Three to five Program Objectives that characterize the "career and professional accomplishments that the program is preparing graduates to achieve."
2. An articulation of Criterion 3 *a-k* Program Outcomes that support one or more Program Objectives and reflect the students' technical competence and understanding of engineering at the time of graduation.
3. An assessment process for Program Objectives and Outcomes.

In Criterion 2, Program Objectives characterize program graduates within the first few years after graduation. According to the Criterion[1], accredited programs must have:

(a) detailed published educational objectives that are consistent with the mission of the institution and these criteria
(b) a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated
(c) an educational program, including a curriculum, that prepares students to attain program outcomes and that fosters accomplishments of graduates that are consistent with these objectives
(d) a process of ongoing evaluation of the extent to which these objectives are attained, and the results of which shall be used to develop and improve the program so that graduates are better prepared to attain the objectives.

In Criterion 3 *a-k*[1], Program Outcomes must support one or more Program Objectives and reflect the graduate's technical competence and understanding of engineering. There must be processes to affect these outcomes and an assessment process that indicates the degree to which the outcomes are achieved. There must also be evidence that assessment results are used for program development.

In Criterion 3[1], accredited programs must demonstrate that their students attain:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

In addition, an accredited engineering program must demonstrate that students attain any other articulated program outcomes necessary to support educational objectives.

Based on Criterion 4[1], students "must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include multiple realistic constraints." Previous Criteria have specified the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political. The professional component must also include[1]:

(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline
(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.
(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

According to Criterion 5[1], faculty must have the competencies to cover the program's curricular areas and be able to support "adequate levels of student-faculty interaction, student advising and counseling, university service, professional development, and interactions with industrial and professional practitioners, as well as employers of graduates."

Faculty must also have qualifications and authority "to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes." Indicators of faculty competency include "education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and licensure as Professional Engineers."

From Criterion 6[1], "classrooms, laboratories, and associated equipment must be adequate to accomplish the program objectives" in an "atmosphere conducive to learning." Facilities must "foster faculty-student interaction" and "create a climate that encourages professional development and professional activities." Students must have access to "modern engineering tools." Computing and information infrastructures must support the "scholarly activities of the students and faculty and the educational objectives of the program."

Based on Criterion 7[1], "institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the program." Resources must be sufficient to "attract, retain, and provide for the continued professional development" of the faculty and to "acquire, maintain, and operate facilities and equipment appropriate for the program." Also, sufficient "support personnel and institutional services" must be available for "program needs."

From Criterion 8[1], each program must satisfy any applicable Program Criteria, which "provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline." However, according to Criterion 8, "Program Criteria are limited to the areas of curricular topics and faculty qualifications." The following section examines the current versions of the Program Criteria.

Selected Program Criteria

Based on the spectrum of detail in various Program Criteria as presented in Table 1 for curriculum and Table 2 for faculty, it is apparent that there is not a consensus among professional societies on articulating Program Criteria. The Program Criteria[1] shown in the tables were selected because either they are considered one of the major disciplines (i.e., chemical, civil, electrical, and mechanical) or they have some relationship to industrial engineering (i.e., engineering management and manufacturing engineering). The Program Criteria for industrial engineering have been omitted from Tables 1 and 2 and are detailed in following sections.

As Table 1 shows, some governing societies have developed Program Criteria that list specific topics or courses (e.g., chemical engineering), some require competencies in "major areas", (e.g., civil engineering and manufacturing engineering), and others (not shown) require a combination. An understanding of specific professional responsibilities is listed for some disciplines, and specific skills or competencies are listed for others. Comparisons with the 2005-06 General Criteria indicate that some duplication exists between Program Criteria and General Criteria. It is also clear that some governing societies have not moved far away from the "bean-counting" that was to be eliminated with the new ABET 2000 Criteria.

Table 1. Program Criteria Related to Curriculum.

Program Type	Program must demonstrate that graduates have
Chemical Engineering	Thorough grounding in chemistry. Working knowledge of advanced chemistry such as organic, inorganic, physical, analytical, materials, chemistry, or biochemistry, selected as appropriate to the goals of the program. Working knowledge, including safety and environmental aspects, of material and energy balances applied to chemical processes; thermodynamics of physical and chemical equilibria; heat, mass, and momentum transfer; chemical reaction engineering; continuous and stage-wise separation operations; process dynamics and control; process design; and appropriate modern experimental and computing techniques.
Civil Engineering	Proficiency in mathematics through differential equations, probability and statistics, calculus-based physics, and general chemistry. Proficiency in a minimum of four recognized civil engineering areas. Ability to conduct laboratory experiments and to critically analyze and interpret data in more than one of the recognized major civil engineering areas. Ability to perform civil engineering design by means of design experiences integrated throughout the professional component. Understanding of professional practice issues such as procurement of work, bidding versus quality-based selection processes, how design professionals and the construction professions interact to construct a project, the importance of professional licensure and continuing education, and/or other issues.
Electrical Engineering	Curriculum that provides both breadth and depth across the range of engineering topics implied by the title of the program. Knowledge of probability and statistics, including applications appropriate to the program name and objectives. Knowledge of mathematics through differential and integral calculus, basic sciences, computer science, and engineering sciences necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components, as appropriate to program objectives. Electrical: Knowledge of advanced mathematics, typically including differential equations, linear algebra, complex variables, and discrete mathematics. Computer: Knowledge of discrete mathematics.

Table 1. Program Criteria Related to Curriculum (continued).

Program Type	Program must demonstrate that graduates have
Engineering Management	Understanding of the engineering relationships between the management tasks of planning, organization, leadership, control, and the human element in production, research, and service organizations. Understanding of and dealing with the stochastic nature of management systems. Capability of demonstrating the integration of management systems into a series of different technological environments.
Manufacturing Engineering	Proficiency in materials and manufacturing processes: understanding the behavior and properties of materials as they are altered and influenced by processing in manufacturing; Proficiency in process, assembly and product engineering: understanding the design of products and the equipment, tooling, and environment necessary for their manufacture; Proficiency in manufacturing competitiveness: understanding the creation of competitive advantage through manufacturing planning, strategy, and control; Proficiency in manufacturing systems design: understanding the analysis, synthesis, and control of manufacturing operations using statistical and calculus based methods, simulation and information technology; Laboratory experience: Ability to measure manufacturing process variables in a manufacturing laboratory and make technical inferences about the process.
Mechanical Engineering	Knowledge of chemistry and calculus-based physics with depth in at least one. Ability to apply advanced mathematics through multivariate calculus and differential equations. Familiarity with statistics and linear algebra. Ability to work professionally in both thermal and mechanical systems areas including the design and realization of such systems.

Table 2 shows a range of faculty requirements from none to restricting design instruction to faculty who are qualified "by virtue of professional licensure, or by education and design experience." Although not reflected in the table's selected entries, qualifications (such as licensure, experience, or continuing education) of faculty teaching design and/or upper division courses are addressed by many of the Program Criteria. Some of the Program Criteria duplicate the specifications in Criterion 5 of the General Criteria, particularly in stating that faculty must have "authority to define, revise, implement, and achieve program objectives."

Current Industrial Engineering Program Criteria

The Institute of Industrial Engineers, IIE, is the lead professional society for industrial engineering programs and therefore has primary responsibility for the Program Criteria for

Table 2. Program Criteria Related to Faculty

Program Type	Program must demonstrate that
Chemical Engineering	No requirements specified
Civil Engineering	Faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience. Program is not critically dependent on one individual.
Electrical Engineering	No requirements specified
Engineering Management	The major professional competence of the faculty must be in engineering, and the faculty should be experienced in the management of engineering and/or technical activities.
Manufacturing Engineering	Faculty members maintain currency in manufacturing engineering practice.
Mechanical Engineering	Faculty members responsible for the upper-level professional program are maintaining currency in their specialty area.

industrial engineering. Program Criteria for industrial engineering programs visited in 2005-06 will be as follows[1]:

> *1. Curriculum*
> *The program must demonstrate that graduates have the ability to design, develop, implement, and improve integrated systems that include people, materials, information, equipment and energy. The program must include in-depth instruction to accomplish the integration of systems using appropriate analytical, computational, and experimental practices.*
>
> *2. Faculty*
> *Evidence must be provided that the program faculty understand professional practice and maintain currency in their respective professional areas. Program faculty must have responsibility and sufficient authority to define, revise, implement, and achieve program objectives.*

Program Criteria for the curriculum are essentially a restatement of the generally accepted definition of industrial engineering[4]:

> *Industrial engineering is concerned with the design, improvement, and installation of integrated systems of people, material, information, equipment, and energy.*

As shown in Table 1, the Program Criteria for manufacturing engineering, in contrast to industrial engineering, outline topical areas that must be addressed in the curriculum. The Program Criteria for faculty in industrial engineering programs are a brief restatement of ABET's General Criterion 5.

Because ABET now articulates process descriptions and provides boilerplate program outcomes rather that prescribing details of program content, the responsibility for determining acceptable program content has shifted to the program evaluators who represent ABET and the governing society(ies). To date, training sessions for ABET evaluators of industrial engineering programs have focused on definition and interpretation of terms used in the ABET 2000 Criteria. Program administrators and ABET program evaluators' judgments have been the basis for applying Criteria definitions to industrial engineering programs.

As part of the process to improve effectiveness and efficiency of the ABET processes, it is important for IIE to clarify the Program Criteria. Program administrators can then be certain that their program satisfies the Program Criteria and know what to expect during an ABET visit. It will also be easier for an ABET visitor to be an effective representative of ABET and IIE. Finally, it also provides an opportunity to define industrial engineering in a way that will advance the profession.

Proposed General Criteria - Criterion 8

Based on the previous sections, there is evidence that ambiguity in Criterion 8 of the General Criteria has resulted in significant variability in the Program Criteria developed by the governing societies. Rather than limiting the role of governing societies to curriculum and faculty issues, ABET should direct professional societies to:

> *As necessary, extend each General Criterion to address unique characteristics of their respective discipline and remain silent on those portions of the General Criteria viewed by the society as "boilerplate" specifications for all accredited programs.*

ABET accredits individual programs; however, there may be economies of scale gains when the portions of the General Criteria viewed as "boilerplate" specifications for all accredited programs are implemented at the college level.

Similar to the General Criteria, the Program Criteria must nurture an environment that assures quality and the systematic improvements in engineering education for the respective discipline that satisfy the needs of program constituents without being excessively prescriptive.

Utilizing the General and Program Criteria to administer the degree program ensures that constituent requirements for ABET and governing professional societies have been satisfied. With the General and Program Criteria as the basis for strategic planning at the program level, Criterion 8 should direct program administrators to:

> *As necessary, extend the General and Program Criteria to address characteristics of the degree program necessary to meet the needs of other program constituents.*

Figure 1 represents the relationships between Criteria articulated by ABET, professional society(ies), and individual programs. At each level, the Criteria are baseline Criteria plus extensions of the baseline. Extensions are either additions or specific interpretations of the Criteria for the profession or program.

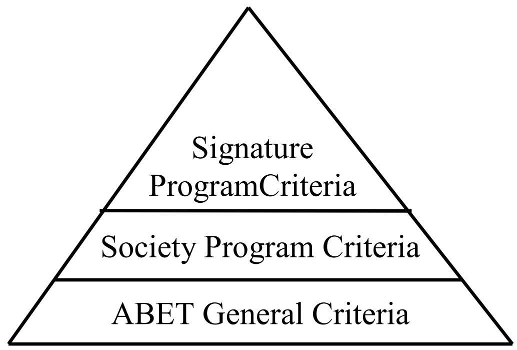

Figure 1. Accreditation Criteria

The following sections present, for purposes of discussion, extensions to General Criteria for the industrial engineering discipline, based on the proposed modifications to General Criterion 8.

Proposed Industrial Engineering Program Criteria

From the above definition, the responsibility of IIE is to, as appropriate, extend the General Criteria to address unique characteristics of industrial engineering and remain silent on those portions of the General Criteria viewed by IIE as "boilerplate" specifications for all accredited programs. The assumption for this paper is that from an industrial engineering perspective, the approach to implementation of General Criteria 1, 2, 4, 6, and 7, is common to all engineering disciplines; therefore no additional clarification is needed for these. However, as previously discussed, there may be economies of scale gains when the common General Criteria are implemented at the college level.

From previous sections, the Program Objectives, Program Outcomes, and expected competency levels of Program Outcomes are dependent on the program constituents. There are also specific issues in industrial engineering concerning qualifications of faculty. Therefore, Criterion 3 (Program Outcomes) and Criterion 5 (Faculty) should be extended by IIE for industrial engineering programs. In a similar manner to the conclusion on Criteria 1, 2, 4, 6, and 7, Program Outcomes *g*, *h*, and *i* may be considered common outcomes for all engineering disciplines from an industrial engineering perspective. Again, there may be economies of scale gains when these outcomes are implemented at the college level.

For purposes of discussion, Table 3 presents examples of extended Program Outcomes for the industrial engineering discipline. Each of these is an example of interpreting Program Outcomes. The implementation levels for the General and Program Criteria are degree program specific. For example, Criterion 3 *k-iii* may be achieved in one program by having students develop manual information systems; in another program, students may have experience with automated systems.

Table 4 presents selected signature program outcomes that were available on websites for accredited industrial engineering degree programs. In some cases, it is clear that these outcomes are signatures of the respective program. However, some of these may be appropriately included as extensions for all industrial engineering programs.

Table 3. Example IIE Extensions of General Criterion 3 a-k.

Criterion 3	Outcome
a.	An ability to apply knowledge of mathematics, science, and engineering. i. *An ability to apply mathematics, science, and engineering science to problems in logistics, manufacturing, and/or service organizations as reflected in the Program Objectives.*
b.	An ability to design and conduct experiments, as well as to analyze and interpret data. i. *An ability to measure process performance characteristics.* ii. *An ability to determine causal relationships in processes.* iii. *An ability to determine uncontrollable process variability.*
c.	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. i. *An ability to identify important design criteria.* ii. *An ability to identify important design constraints.* iii. *An ability to assess efficiency and effectiveness.* iv. *An ability to select appropriate techniques, skills, and industrial engineering tools.*
d.	An ability to function on multidisciplinary teams i. *An ability to lead and manage team projects.*
e.	An ability to identify, formulate, and solve engineering problems. i. *An ability to identify, formulate, and solve problems related to integrated systems that include people, material, information, equipment, and energy.*
f.	An understanding of professional and ethical responsibility i. *A knowledge of the code of ethics endorsed by IIE.*
j.	A knowledge of contemporary issues. i. *knowledge of contemporary issues related to the Program Objectives*
k.	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. i. *An ability to design and develop mathematical and statistical models.* ii. *An ability to design and develop graphics models.* iii. *An ability to design and develop information systems for process management.* iv. *An ability to use project management tools.* v. *An ability to perform economic analysis of projects.*

As previously described, Criterion 5 enumerates indicators of faculty competency. Indicators such as communication skills, enthusiasm for program development, and professional engineering registration are common to all engineering disciplines. However, perhaps education, engineering experience, teaching experience, scholarship, and participation in professional societies are indicators that should be extended by IIE.

Table 4. Signature Criterion 3 Program Outcomes from Selected IE Programs.

Program	Program Outcome
University of Alabama	An ability to understand the human components of a system An ability to construct conceptual and mathematical models of operational and economic decision situations
University of Arizona	The ability to formulate a problem in technical terms including the relevant aspects from the mathematical, business, natural, social, and engineering sciences The ability to account for stochastic behavior and to perform sensitivity analyses The ability to develop customized solution software.
Cal Poly San Luis Obispo	An ability to evaluate engineering decisions with respect to cost, quality, and productivity An ability to recognize equipment, processes, and techniques used in major manufacturing industries
California State University – Fresno	An ability to lead quality and productivity improvement projects Knowledge of simulating and predicting the systems behavior under pre-specified conditions
Iowa State University	Be able to integrate the engineering and business process of an organization Have a global perspective of enterprise
University of Iowa	An awareness of the role of research in the evolution of industrial engineering practice

The authors provide the following comments related to Criterion 5 as a basis for discussion. Since IIE is the governing society for industrial engineering, IIE membership for faculty is a reasonable expectation. Also, engineering, teaching, and scholarship experience relevant to industrial engineering is important. Specific degree requirements may also be important to the long-term viability of the program.

Conclusions

There have been broad interpretations of the ABET 2000 Criteria by programs seeking accreditation. Similarly, governing professional societies have taken different approaches to articulating Program Criteria. The recently approved 2005-06 Criteria reflect the first iteration in continuous improvement of the ABET 2000 continuous improvement process. As part of the process to improve effectiveness and efficiency of the ABET processes, another area where ABET may choose to clarify is Criterion 8, which addresses the governing societies' role in the strategic planning process.

The challenge to each society is to, as appropriate, extend each of the ABET Criteria to address unique characteristics of the respective discipline and remain silent on those portions of the Criteria viewed as "boilerplate" specifications for all accredited programs.

With the General and Program Criteria as the basis for strategic planning at the program level, Criterion 8 should direct program administrators may, as necessary, extend the General and Program Criteria to address characteristics of the degree program necessary to meet the needs of other program constituents.

With this approach, program administrators can ensure that the program is administered using well defined processes for each criterion and that constituents are an integral part of the planning process. It will be much easier for program administrators to certify that the program satisfies all relevant criteria. Equally important, it will enable ABET program evaluators to be a more effective representative of ABET and the governing society.

References

1. Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, *Criteria for Accrediting Engineering Programs Effective for Evaluations During the 2005-2006 Accreditation Cycle*, November 2004.
2. Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, *Self-Study Questionnaire*, 2004.
3. Elizandro, D. and J. Matson, "Fuzzy Logic to Assess ABET-Accredited Degree Program Emphasis," *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition, Nashville, TN, June 2003.*
4. Institute of Industrial Engineers, "Definition of Industrial Engineering," http://www.iienet.org/public/articles/details.cfm?id=468, accessed January 5, 2005.

DAVID ELIZANDRO
David Elizandro is Professor of Industrial Engineering at Tennessee Tech University and a licensed P.E. He earned a B.S. in chemical engineering, M.B.A., and Ph.D. in industrial engineering from the University of Arkansas. He previously served as Dean of Mathematics, Science, and Engineering at University of the Incarnate Word, IME Department Chair at Tennessee Tech, and Head of Computer Science at Texas A&M University-Commerce.

JESSICA MATSON
Jessica Matson is Professor and Chairperson of the Industrial and Systems Engineering Department at Tennessee Technological University. She received her B.S. from Mississippi State University and her M.S. and Ph.D. from the Georgia Institute of Technology, all in industrial engineering. She has previously served on the faculty of Mississippi State University and the University of Alabama and is a licensed P.E. (Mississippi).

JANE FRASER
Jane Fraser is Professor and Chair of the Department of Engineering at Colorado State University–Pueblo. She earned a B.A. in Mathematics from Swarthmore College and M.S. and Ph.D. degrees in industrial engineering/operations research from the University of California at Berkeley. She has previously served on the faculty of Ohio State University and Purdue University.