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**TO**: Engineering Accreditation and Assessment Unit
**SUBJECT:** ABET EC2000 REQUIREMENTS:

# RATIONALE FOR AN ABET EC2000 ROAD MAP

1. Introduction:

In a major shift influenced by pressure from industry and global competition, the Accreditation Board of Engineering and Technology (ABET) has introduced the new Engineering Criteria 2000 (EC2000) [1], which addressed the effectiveness of engineering education programs by focusing on assessment and evaluation process that assures the achievement of educational objectives and outcomes [2].

As explained in the excellent paper of Felder and Brent [3], the departures of the new system from prior practices occur in Criterion 2 (program objectives) and Criterion 3 (program outcomes and continuous program improvement). To comply with ABET, attention must be given to the program level as well as to the course level practices.

2. Program level:

To comply with ABET engineering criteria, a program must first formulate "program educational objectives" (broad goals) that address institutional and program mission statements and are responsive to the expressed interests of various groups of program constituencies (i.e. students, faculty, alumni and employers). In fact a curriculum must be developed sequentially, beginning with an institutional statement of goals and ending with the assessment of each student prior to graduation and after [4]. To be as clear as possible we summarize the main steps required to ensure compliance with criteria 2, 3 and 4 of EC 2000 as outlined by Felder and Brent [3] on the program level:

1. Formulate and/or revise the *program educational mission statement* which maps college and university mission statements into the program field of specialization.

2. Formulate *program educational objectives*—"broad, general statements that communicate how an engineering program intends to fulfill its educational mission and meet its constituencies' needs [4]." *Example*: Provide students with a solid grounding in the basic sciences and mathematics, an understanding and appreciation of the arts, humanities, and social sciences, and proficiency in both engineering science and design. *Program educational objectives are intended to be statements that describe the expected accomplishments of graduates during the first several years following graduation from the program.* Program constituencies must be involved in the "set-up – assessment – modification" cycle of the program educational objectives. *Each engineering program for which an institution seeks accreditation or re-accreditation must have in place:*
    1. *detailed published educational objectives that are consistent with the mission of the institution and these criteria*
    2. *a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated*
    3. *a curriculum and processes that prepare students for the achievement of these objectives*
    4. *a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program*

3. Formulate a set of *program outcomes*—"more specific statements of program graduates' knowledge, skills, and attitudes that serve as evidence of achievement of the program's educational objectives." *Example*: The program graduates will be able to analyze important social and environmental problems and identify and discuss ways that engineers might contribute to solutions, including technological, economic, and ethical considerations in their analysis. In Criterion 3, ABET specifies eleven outcomes (Outcomes 3a–3k, listed in Table 1). Program outcomes must encompass Outcomes 3a–3k but should not be verbatim copies of them. To meet the requirements of the

engineering criteria, the program outcomes should clearly have been formulated to address all of the program educational objectives. It was stated that:

*Program outcomes are intended to be statements that describe what students are expected to know or be able to do by the time of graduation from the program. Engineering programs must demonstrate that their graduates have the ABET a to k abilities in addition to what is specified in the professional component (criterion 4)*

Table 1: ABET EC2000 a-k Program Outcomes

| | |
|---|---|
| (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 |
| (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 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. |

4. Develop each outcome into *outcome elements*—different abilities specified in a single outcome that would generally require different assessment measures. Besterfield-Sacre et al. [5] break each of outcomes 3a–3k into separate elements. For some outcomes, such as Outcome 3b, the elements are literally extracted from the outcome statement: Outcome 3b—ability to design and conduct experiments, as well as analyze and interpret data is broken into: designing experiments, conducting experiments, analyzing data, interpreting data. For others, such as Outcome 3e, the elements are derived from an analysis of the specified abilities: Outcome 3e—ability to identify, formulate, and solve engineering problems is divided into: problem identification, problem statement construction and system definition, problem formulation and abstraction, information and data collection, model translation, validation, experimental design, solution development or experimentation, interpretation of results, implementation, documentation, feedback and improvement.

5. For each outcome or outcome element define *outcome attributes*—actions that explicitly demonstrate mastery of the abilities specified in an outcome or outcome element. The main thrust of the work of Besterfield-Sacre et al. [5] is to define attributes at the six levels of Bloom's taxonomy of cognitive objectives [6] and at the valuation level of Krathwohl's taxonomy of affective objectives [7] for each of Outcomes 3a–3k. *Examples*: Attributes proposed by Besterfield-Sacre et al. [5] for the element "Problem statement construction and system definition" of Outcome 3e include:
    - describes the engineering problem to be solved,
    - visualizes the problem through sketch or diagram,
    - outlines problem variables, constraints, resources, and information given to construct a problem statement, and
    - appraises the problem statement for objectivity, completeness, relevance, and validity

6. For each outcome or outcome element define *outcome indicators*—the instruments and methods that will be used to assess the students' attainment of the program outcomes [8]. *Examples*: Alumni, employer, and industrial advisory board surveys, exit interviews with graduating seniors, student portfolios, capstone design course performance ratings, performance on standardized tests like the FE Examination and the GRE, and job placement data of graduates.

7. For each outcome indicator define *Performance targets*—the target criteria for the outcome indicators.
   *Examples*:
   - The [average score, score earned by at least 80%] of the program graduates on the [standardized test, standardized test item, capstone design report, portfolio evaluation] must be at least 75/100.
   - The [median rating for, rating earned by at least 80% of] the program graduates on the [self-rating sheet, peer rating sheet, senior survey, alumni survey, employer survey, final oral presentation] must be at least [75/100, 4.0 on a 1–5 Likert scale, "Very good"].

8. Device the program core into a set of courses designated to address some or all of the program outcomes. Required courses in the major field of study would be obvious candidates for the core. Required courses given in other programs, such as mathematics, physics, chemistry, and English—might be included as long as they consistently address outcomes. Elective courses or courses whose content varies from one offering to another (so that the outcomes might not be addressed in a particular offering) would not be included.

9. Prepare a program outcome assessment matrix with columns for program outcomes and rows for outcome indicators and core courses (Table 3 in Ref. [3]). Place a 1, 2, or 3 in the matrix to indicate that an outcome indicator or core course addresses an outcome: marginally, moderately, or substantively, basing the entries for each course on an examination of course materials and the course assessment matrix by a faculty review committee.

10. Implement the program outcome assessment methods selected from the A*ssessment Plan* whose explanation follows and evaluate the performance targets. Insert asterisks next to the 1's, 2's, and 3's for an outcome indicator to indicate that the corresponding performance target has been met. If the assessment for a particular outcome indicates shortcomings or room for improvement, initiate appropriate actions to improve instruction in the relevant courses. The program outcome assessment matrix should indicate which courses might be modified, and the course assessment matrix for each of those courses should suggest areas that need strengthening and possible instructional modifications.

3. Course Level:

Once the program core, i.e. the required courses in the program curriculum that will collectively be designated to address the knowledge, skills, and attitudes enumerated in the program outcomes, have been identified the following steps are to be carried out.

1. For each required course in the core, formulate the *course goal* in a short, agreed upon clear statement.

2. For each required course in the core, formulate *course outcomes* that include some program outcomes or outcome elements. Course outcomes are knowledge, skills, and attitudes that the students who complete the course are expected to acquire. In order to satisfy program outcomes it is advisable that the outcomes of each course address at least one outcome in each of the two categories that encompass the eleven ABET outcomes a - k.(i.e. technical and non-technical outcome categories) and at least one outcome that addresses criterion 4 if the course is one of the advanced specialized courses.

3. For every course in the core, define observable outcome-related learning objectives that are guaranteed to be in place regardless of who happens to teach the course and define assessment methods for each core objective [3& 5]. Each of these learning objectives should map onto one or more program outcomes, and all program outcomes should be addressed by objectives in several core courses—the more, the better.

4. Prepare a course assessment matrix with columns for program outcomes and rows for outcome-related course learning objectives (Table 2 in Ref. [3]). Place a 1, 2, or 3 in the matrix to indicate that an objective addresses an outcome marginally, moderately, or substantively. The entries should reflect a consensus of all faculty members who are likely to teach the course before the next accreditation visit.

4. Teach each course in a manner that addresses all of the targeted program outcomes (Appendices C–E in Ref. [3]). Use the guide lines in Ref. [3] which outlines instructional methods that address each of the Criterion 3 outcomes (including general instructional methods, problem-based learning methods, co-operative learning methods).

5. Implement the assessment methods selected from the *Assessment Plan* whose explanation follows and place asterisks next to the 1's, 2's, and 3's in the course assessment matrix when a learning objective is judged to have been met.

4. Course articulation matrix:

The course articulation matrix [9] is a form that indicates how different course activities can insure the achievement of course outcomes and the degree of this achievement in terms of progressive increase in the students levels of learning [6]. Although it is not a mandatory element of ABET EC2000 documentations, it is a highly recommended tool demonstrate that the course is designed, implemented and assessed in a way to satisfy ABET requirements.

Historically, the idea of the articulation matrix goes back to the fall of 1996, when a task force of faculty from three universities and several community colleges in Arizona State started working on course issues of a first year engineering design course [9]. They were faced with the standard articulation issues of:

1. What topics, skills, etc. to include in a first year design course, and
2. How to ensure (establish) that a proposed course was in fact satisfactory.
3. How to address the first two issues in a manner such that a school still had the flexibility to develop its own unique character for the course, utilizing the school's interests and strengths.

To answer these questions the work group used Tyler's approach [10] which involves answering four basic questions:

1. What educational purposes should the school seek to attain?
2. What educational experiences can be provided to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained?

This old approach goes in line with Criterion 2 of ABET Engineering Criteria EC2000 [1] which requires schools to: define a set of learning objectives (i.e., answers to question 1); define a strategy to accomplish the learning objectives (i.e., answers to questions 2 and 3); and define an assessment process to measure achievement of the learning objectives (i.e., answers to question 4). This is to be carried out and documented for both curriculum and course levels.

In fact, Criterion 2 *(Program Educational Objectives)* is as follows:
Although institutions may use different terminology, for purposes of Criterion 2, program educational objectives are intended to be statements that describe the expected accomplishments of graduates during the first several years following graduation from the program. To satisfy this, each engineering program for which an institution seeks accreditation or re-accreditation must have:

(a) 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) A curriculum and processes that prepare students for the achievement of these objectives, and

(d) A system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.

Learning objectives are two-dimensional vectors consisting of a competency (subjects, topics or skills) and a degree to which the competency is to be learned or mastered (based on Bloom's Taxonomy levels of learning, LoL [6] and on Krathwohl and Bloom's degree of internalization [7] which will be addressed later on).

Since there is often a hierarchy associated with competencies, the matrix allows this by having competency categories as well as competencies under each category.

In the process explained by McNeill and Bellamy [9], in-class and out-of-class activities are added, one at a time, to the matrix indicating in the body of the matrix which learning objectives are impacted by the activity, and finally indicating the level of learning attainable by this activity.

In order to evaluate the matrix to confirm that the proposed course is complete, there are four considerations to be taken care of. They are,

1. There is at least one Course Activity that impacts each of the competencies (i.e., no empty rows).
2. There is at least one competency impacted by each course activity (i.e., no empty columns).
3. Each row has an adequate number of appropriate course activities that insures progressive evolution between an entry, lower, level of learning to an exit, higher, level of learning.
4. At least 75% of the competencies for a competency category have course activities at the LoL stipulated for the competency category

5. Assessment Plan:

Once program outcomes have been formulated, outcome indicators and performance targets specified, and the outcome-related learning objectives drafted for all core courses, a plan should be made for assessing the degree to which the objectives are being met. The assessment plan should also specify who is responsible for each part of the assessment, when the assessment will be performed, and who will receive the results [11].

As indicated in Ref. [3], *Triangulation* (using multiple methods to obtain and verify a result) is an important feature of effective assessment [5]. The more tools used to assess a specific program outcome or course learning objective, the greater the likelihood that the assessment will be both valid and reliable. For completeness, here are some possible program-level (P) and course-level (C) assessment tools as given in Ref. [3]:

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|---|---|
| • Exit surveys, exit interviews (P) | • Alumni surveys and interviews (P) |
| • Employer surveys and interviews (P) | • Job offers, starting salaries (P) |
| • Admissions to graduate school (P) | • Self-analyses, learning logs, journals (P, C) |
| • Performance in co-op, internship assignments, and problem-based learning situations (P, C) | • Assignments, reports, and tests in the capstone design course (P, C) |
| • Standardized tests (e.g., FE Examination, GRE, Force Concept Inventory in physics) (P, C) | • Written tests or test items clearly linked to course learning objectives (C) |
| • Peer evaluation, self-evaluation (P, C) | • Written project reports (C) |
| • Written critiques of documents or oral presentations (C) | • Student surveys, individual and focus group interviews (P, C) |
| • Oral presentations (live or on videotape) (C) | • Student portfolios (P, C) |
| • Research proposals, student-formulated problems (C) | • Abstracts, executive summaries, papers (C) |
| • Letters, memos (C) | • Classroom assessment techniques (C) |
| • Behavioral observation, ethnographic and verbal protocol analysis (analyzing transcripts of student interviews or working sessions to extract patterns of problem-solving, thinking, or communication) (P, C) | |

6. Tentative Departmental Work Plan

| Task | Description | Precedence | Duration | Remarks |
|---|---|---|---|---|
| a. Getting Started | | | | |
| 1 | Organize familiarization workshops | | | Before starting |
| 2 | Form Departmental committees | 1 | 15 days | |
| 3 | Define Program educational mission statement | 2 | 1 month | |
| 4 | Define constituencies | 2 | 15 days | |
| 5 | Establish alumni data base | 4 | 3 months | |
| b. Program Educational Objectives | | | | |
| 6 | Setup (formulate) objectives | 2 | 1 month | |
| 7 | Publish objectives (website, brochures, fliers, etc.) | 6 | 4 months | |
| 8 | Setup a process for periodic evaluation and modification | 2 | 1 month | |
| 9 | Design constituencies feedback forms | 2 | 1 month | |
| 10 | Obtain feedback from constituencies | 5, 9 | 1 month | |
| 11 | Evaluate feedback | 10 | 1 month | |
| 12 | Modify objectives if needed | 11 | 1 month | |
| c. Program Outcomes | | | | |
| 13 | Formulate outcomes | 6 | 1 month | |
| 14 | Map outcomes into ABET a-k and professional component | 13 | 15 days | |
| 15 | Map outcomes into Program objectives | 13 | 15 days | |
| 16 | Break each outcome into outcome elements | 13 | 45 days | |
| 17 | Define for each outcome element, its attributes (or mastery actions) and its indicators (or assessment tools) and the corresponding performance targets. | 16 | 45 days | |
| d. Program Core Courses | | | | |
| 18 | Define program core courses to address program outcomes | 6 | 15 days | |
| 19 | For each core course, state the course goal and formulate course outcomes that include some program outcomes or outcome elements (technical, non-technical & professional) | 18 | 15 days | |
| 20 | For each course, define outcome related learning objectives | 19 | 15 days | |
| 21 | For each course, map course learning objective to course outcomes using a course assessment matrix | 19, 20 | 15 days | |
| 22 | For each course, devise suitable instructional methods | 20 | 15 days | |
| 23 | For each course, select suitable assessment plan | 22 | 15 days | |
| 24 | Prepare the course articulation matrix | 23 | 15 days | |
| 25 | Implement the course for one semester | 24 | 1 semester | |
| 26 | Prepare a-to-k course file | 24 | 1 semester | |
| 27 | Collect the course assessment results and evaluation data | 23 | 1 semester | |
| 28 | Analyze course assessment and evaluation data | 27 | 15 days | |
| 29 | Revise and modify core courses | 27 | 1 month | |
| e. Assessment and Evaluation | | | | |
| 30 | Select general program and course assessment and evaluation tools | 17 | 15 days | |

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|---|---|---|---|---|
| 31 | Design general assessment and evaluation tools and surveys | 30 | 15 days | |
| 32 | Map assessment and evaluation tools into program and course outcomes | 31 | 15 days | |
| 33 | Apply program assessment and evaluation tools and collect data | 31 | 1 month | |
| 34 | Analyze assessment and evaluation results | 33 | 1 month | |
| 35 | Prepare Program revision and modification plan | 27, 34 | 1 month | |
| 36 | Restart a new continuous improvement cycle | 35 | 1 semester | |

## REFERENCES


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