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Resources

Assessment White Paper

A Framework for the Assessment of Engineering Education

By The Joint Task Force on Engineering Education Assessment

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Assessment is an ongoing process aimed at understanding and improving learning.... When it is embedded effectively within larger institutional systems, assessment can help us focus our collective attention, examine our assumptions, and create a shared academic culture dedicated to assuring and improving the quality of higher education....

Thomas A. Angelo, Director of the Assessment Forum, American Association for Higher Education

I. Introduction

Program assessment, properly implemented, can increase our understanding of engineering education and improve teaching and learning. With a common understanding of the purpose and value of assessment, the engineering community can identify those capabilities likely to be needed by engineering graduates throughout their professional careers, and the ways to best develop those capabilities.

Undergraduate engineering education is a foundation for lifelong learning. As such, it has an obligation, especially to those expecting to enter a profession, to educate broadly in the tradition of a liberal education. This means not only creating a base for further study, but enabling graduates to become thoughtful practitioners and to assume leadership in the profession. Thus, assessment of undergraduate engineering education is a significant concern of the engineering community and the profession.

Background

Recognizing the importance of assessing engineering education programs, the major stakeholder organizations in engineering education in the United States formed the Joint Task Force on Engineering Education Assessment in 1994. The aim was to examine the value of using the Fundamentals of Engineering (FE) examination in undergraduate engineering education assessment. Represented on the task force were the National Council of Examiners for Engineering and Surveying (NCEES), which prompted the report and served as the group's secretariat; the Accreditation Board for Engineering and Technology (ABET); the American Society for Engineering Education (ASEE); the ASEE Engineering Deans Council (EDC); and the National Society of Professional Engineers (NSPE).

The task force report, published on July 7, 1994, recommended that the FE examination be restructured so that it more broadly measures outcome of the total engineering education experience. The sponsoring organizations recognized that a restructured FE examination would constitute only one part of the assessment process, knowledge-based specifications. It is extremely important, the report said, that other components of the assessment process be defined as well. In order to do that, the report further recommended that a new task force be formed by the same organizations to define a range of tools that could be used in a many-faceted assessment process.

This second task force, the Joint Task Force on Engineering Education Assessment, was created in 1995 and developed the following Statement of Objective:

- **To review the current status of higher education assessment activities and propose a comprehensive process that will eventually lead to the development and acceptance by key stakeholders of a framework for a spectrum of activities appropriate to the engineering education enterprise and to the individual missions of engineering colleges.**

Within that objective, the task force developed a draft white paper which discussed:

- **The common agreement on the values of assessment**
- **Current assessment trends and practices**
- **Guidelines for designing an assessment framework for engineering education programs**
- **Examples of assessment measures available to the engineering education community**
- **Assessment ideals**

Various versions of the draft white paper were shared widely. The paper was distributed to the leadership of each organization represented on the task force, and discussed at several of those groups' committee meetings and conferences. The draft document was also posted electronically on the ASEE home page on the World Wide Web, and summarized in the May-June issue of ASEE PRISM magazine. The ASEE home page received more than 1,500 inquiries as of early June, 1996. As a result, the task force benefited from extensive comments by a broad constituency of the engineering community.

Based on this dialogue, the task force has assembled those sections of the white paper thought to be most useful to the reader, and extended its work to formulate a series of recommendations and policy positions aimed at best advancing engineering education assessment.

The Nature and Purposes of Assessment

One comprehensive view of the nature and purpose of assessment of higher education programs is given by Angelo in Reassessing (and Defining) Assessment, (American Association for Higher Education Bulletin, November, 1995, pp. 7-9) as follows:

- Assessment is an ongoing process aimed at understanding and improving student learning. It involves making our expectations explicit and public; setting appropriate criteria and high standards for learning quality; systematically gathering, analyzing, and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain, and improve performance. When it is embedded effectively within larger institutional systems, assessment can help us focus our collective attention, examine our assumptions, and create a shared academic culture dedicated to assuring and improving the quality of higher education.
- It is unnecessary to assess the performance of each student to know if engineering graduates from a particular program are generally developing the

attributes of an ideal engineering graduate. Stated another way, we should not confuse the ability of the engineering education community to articulate a vision for the ideal graduate as a mandate for every graduate of every engineering program to demonstrate competence and proficiency in every attribute. Each goal is a yardstick against which to measure program success, not an item on a check list to inventory failure. Nor does program assessment measure just the outcome of an education (so-called outcomes assessment). It also examines policies, programs and other factors that influence the achievement of those outcomes.
- Two education associations have developed sets of assessment principles that are both useful and complementary. One takes the institutional perspective, the other a more general philosophical view.

The National Association of State Universities and Land Grant Colleges' (NASULGC) 1988 Statement of Principles on Student Outcome Assessment contains seven principles for assessment by higher education institutions. Assessment should:

- focus primarily on the effectiveness of academic programs and the improvement of student learning and performance;
- be based on incentives rather than regulations or penalties;
- be developed in collaboration with the faculty;
- be appropriate to the particular mission and goals of the institution;
- use multiple methods of assessment;
- be fiscally conservative and not impose costly programs on institutions; and
- be linked to strategic planning and program review processes within the institution.

In a December 1992 document, the American Association for Higher Learning Assessment Forum articulated a more philosophic view in Principles of Good Practice for Assessing Student Learning:

- The assessment of student learning begins with educational values.
- Assessment is most effective when it reflects an understanding of learning as multidimensional, integrated, and revealed in performance over time.
- Assessment works best when the programs it seeks to improve have clear, explicitly-stated purposes.
- Assessment requires attention to outcomes but also and equally to the experiences that lead to these outcomes.
- Assessment works best when it is ongoing, not episodic.
- Assessment fosters wider improvement when representatives from across the educational community are involved.
- Assessment makes a difference when it begins with issues of use and illuminates questions that people really care about.
- Assessment is most likely to lead to improvement when it is part of a larger set of conditions that promote change.
- Through assessment, educators meet responsibilities to students and the public.

Attributes of an Engineer

In recent years there have been many thoughtful reports aimed at improving engineering education. Several are discussed briefly below.

The Accreditation Board for Engineering and Technology (ABET), whose periodic accreditation review is the most widely recognized form of undergraduate engineering program assessment, is now evaluating its proposed new ABET Engineering Criteria 2000, which include Criteria for Accrediting Programs in Engineering in the United States. The task force encourages engineering schools to use these criteria in their program assessments, in conjunction with others that are specific to individual school missions. The new criteria, as currently drafted, emphasize program outcomes. Graduates must demonstrate:

- an ability to apply knowledge of mathematics, science, and engineering;
- an ability to design and conduct experiments, as well as to analyze and interpret data;
- an ability to design a system, component, or process to meet desired needs;
- an ability to function on multidisciplinary teams;
- an ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global/societal context;
- a recognition of the need for and an ability to engage in lifelong learning;
- a knowledge of contemporary issues; and
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Two recent reports that are useful in assessment of engineering education are the ASEE Engineering Deans Council / Corporate Roundtable study, **Engineering Education for a Changing World** (ASEE, Washington, D.C., October, 1994), and the National Research Council study, Engineering Education, Designing an Adaptive System (National Academy Press, Washington, D.C., 1995). These two studies are helpful in identifying those attributes or characteristics that engineers should develop by the time they begin their practice of engineering. The task force encourages engineering faculty to consider these outcomes as additional program criteria. Among the attributes from these studies that go beyond those articulated by ABET are several that are commended by the task force as useful and important to assessment:

- leadership (an ability to develop and demonstrate it);
- an understanding and appreciation of diversity and pluralism;
- a commitment to quality, timeliness, and continuous improvement; and
- experience in undergraduate research and engineering practice.

These objectives suggest that multiple measures will be needed to assess the true effectiveness of an engineering education program. Such measures could include student portfolios, standard tests (such as the Fundamentals of Engineering examination, the Graduate Record Examination and other nationally normed exams), locally developed critical essay tests, major research papers, interviews with employers, exit interviews with students, and student individual and group performance in design. A single measure used alone would be of little value in assessing development of the desired characteristics of an engineer.

Since the attributes of the successful engineer are broad and diverse, engineering education assessment programs also should include input from practicing engineers. These individuals can provide important insights about the capabilities needed by engineering graduates as they begin and move through their careers in the profession.

Contexts for Program Assessment

Effective program assessment includes the evaluation of student inputs, student outcomes, and the educational environment within which change in the student occurs. Alexander W. Astin, (Assessment for Excellence: The Philosophy and Practice of Assessment and Evaluation in Higher Education, American Council on Education Series on Higher Education, Oryx Press, 1993, p. 18) defines these terms in a useful way:

"Outcomes," of course, refers to the talents we are trying to develop in our educational program; "inputs" refers to those personal qualities the student brings initially to the educational program (including the student's initial level of developed talent at the time of entry); and "the environment" refers to the student's actual experiences during the educational program. Environmental information is especially critical here, because the environment includes those things that the educator directly controls in order to develop the student's talent. A fundamental purpose of assessment and evaluation, it should be emphasized, is to learn as much as possible about how to structure educational environments so as to maximize talent development.

Effective program assessment must consider also a broader context. As stated in the ASEE report, **Engineering Education for a Changing World**, (p.11):

Engineering education must be RELEVANT, ATTRACTIVE and CONNECTED:

- RELEVANT to the lives and careers of students, preparing them for a broad range of careers as well as for lifelong learning involving both formal programs and hands-on experience;
- ATTRACTIVE so that the excitement and intellectual content of engineering will attract talented students with a wider variety of backgrounds and career interests--particularly women, underrepresented minorities and the disabled--and will empower them to succeed; and
- CONNECTED to the needs and issues of the broader community through integrated activities with other parts of the educational system, industry, and government.

Engineering education assessment, then, should be concerned with outcomes, inputs, and the educational environment, and it should be capable of measuring progress toward making programs relevant and attractive to students and connected to the broader community.

Guidelines for Designing a Framework for Engineering Education Assessment

With these views in mind, the task force recommends the following considerations in designing an assessment program for any degree-granting engineering unit:

Institution-Specific Mission and Goals.

An assessment program must be developed in the context of the distinctive mission of each engineering program. While focusing on ways to meet the educational goals of the academic unit, the program should also promote synergistically other valid purposes. For example, a research-active institution should integrate research activities into both the classroom and the work experience components of the undergraduate curriculum. Universities with a strong commitment to external service should design courses that relate the academic experience of the student to that service function. Engineering programs developed in the context of a strong liberal arts college have the opportunity to productively utilize that strength with high quality, broad-based humanities and social science offerings. In each of these cases, an assessment program should be capable of recognizing and reinforcing the distinctive individual mission of each school, thereby encouraging the diversity of educational goals. This diversity is one of the strengths of engineering education in the United States.

Institution-wide, Longitudinal Assessment Programs.

The assessment of engineering programs is best accomplished not as an isolated undertaking but in concert with a coordinated institution-wide effort aimed at program improvement. This allows the engineering program to be compared with other programs in the institution, and to judge its substance and depth in the light of the broader-based educational objectives of the school. As program improvement is the objective of assessment, schools are cautioned to assure that assessment results measure the consequences of a program characteristic that has operated long enough to have a causal relationship to the outcomes being measured. Program modifications over relatively short intervals are likely to make assessment ineffective.

ABET Accreditation.

The most widely recognized form of engineering program assessment in the United States is the periodic accreditation review conducted by the Accreditation Board for Engineering and Technology (ABET). The task force strongly encourages use of the ABET Engineering Criteria 2000 in developing criteria for engineering education program assessment. The entire engineering community will need to play a stronger role in relating outcomes measures to professional practice, career achievement, and civic contribution.

Beyond ABET: Broader Career Goals.

Engineering program assessment should recognize the pitfalls of overspecialization in the face of an increasing demand for graduates who can demonstrate adaptability to rapidly changing technologies and to increasingly complex multinational markets. Assessment measures should be sufficiently broad to encompass the educational benefits of an engineering program for students preparing for careers in medicine, finance, law, business entrepreneurship, and other areas. Specific measures of student performance should capture the preparation provided by an engineering program for a wide range of career opportunities.

Cost Factors.

The cost of any assessment program should be clearly outweighed by the benefits to the educational programs under review. Although administrative personnel who design an assessment program must receive adequate resources to allow its completion, the extent of expenditures should not have a negative effective on the educational program itself. In the interest of economy, it is vital that assessment and accreditation efforts be well-integrated. This assures efficiency in program evaluation and consistency in objectives defined to be common to all engineering programs. On a broader scale, it is economically advantageous to view engineering as a continuum that includes the educational process, assessment, accreditation, licensure, professional practice, and constructive citizenship. From this viewpoint, costs associated with an assessment program are more readily accepted.

II. Assessment Ideals

The task force encourages its represented organizations, the engineering professional societies, and the larger engineering education community to actively support development of an assessment framework that enables the engineering faculty of each school to improve learning. By the inclusion of proper measures, assessment can identify when goals considered valid by the engineering community are achieved. Such a framework should do the following:

Improve Student Learning and Development.

Each assessment measure should gauge a program's effectiveness in achieving specific learning objectives, development goals, and student competencies. Assessment results should provide educators with a scholarly basis for curricular innovation and educational development.

Focus on Undergraduate Education.

Undergraduate and graduate education should be separately evaluated. Educational program assessment should focus on the undergraduate educational mission, including the educational benefits to undergraduates of the school's research and service activities.

Recognize Educational Breadth.

Professional service and civic leadership transcend the profession of engineering, are broadly based, and require intellectual adaptability. Assessment systems should be capable of recognizing a program's balance of liberal and professional educational goals.

Reflect Relevance to Practice and Citizenship.

Program assessment should measure the integration of engineering education with professional practice and constructive citizenship. Evaluative measures should include feedback from accomplished professional practitioners with experiences that represent the range of career opportunities of the program's graduates.

Use Validated Measures of Desired Outcomes. The EAC-ABET Engineering Criteria 2000, combined with programs' mission-specific criteria, should serve as a common articulation of desired outcomes for engineering education. The goal of engineering education should be its graduates' accomplishments, and measures used as proxies to these accomplishments should be validated as such.

Offer Comparisons to Other Programs.

Engineering education programs should be assessed in comparison to other educational programs as a means of judging their standards, substance, and depth.

Accommodate Future Needs.

Assessment should accommodate the changing professional requirements of graduates. For example, the increasingly important ability to share, access, and interpret information should be considered for measurement.

Prove Cost-Effective in Terms of Program Improvement.

The cost of assessment should be outweighed by the benefits to the educational program being assessed. Equally important, changes to educational programs resulting from assessment should only occur after sufficient longitudinal data are available to clearly relate programmatic change to learning results.

III. Examples of Program Assessment Measures

There is a diversity of both educational objectives and the means by which the attainment of these objectives is measured. Some of these objectives are more narrowly defined, such as the mastery of a particular skill or method, while others, such as understanding the impact of engineering solutions in a societal context or the ability to design, are more broadly construed. Clearly, no one assessment device will serve for all the educational objectives that we expect the modern engineering graduate to obtain from today's university education. This need for an array of devices prompted the task force to develop a matrix of measures from which to choose.

Reinforcing the need for a matrix of choices was Thomas Angelo's advice to the task force that one assessment device is generally insufficient to measure a desired outcome. Angelo suggested choosing as many as three different measuring devices. In this manner, using a phrase familiar to engineering measurement, a triangulation could be performed on a particular outcome.

Purposeful experimentation is necessary for validating a set of measures for assessing an engineering education program. Most, if not all, measures available are limited in their abilities to assess program quality. Measures of student outcomes in the absence of information about the students entering a program will not reflect the impact of the program on students as well as a system of evaluation measures that can account for students' development after entering the program. Also, validating the relationships of measures to actual professional performance will require yet-to-be-established longitudinal studies of significant scope. Until the results of such studies are available, measurements would be premature and ill-advised.

Several post-graduation devices that might relate to the stated objectives of a school's mission are included in the matrix as a set of possible corollaries available to validate program assessment measures over time. It is in the post-graduation performance of graduates that measures are most in need of articulation. The task force calls on the broader engineering education community to focus its attention on this need.

A matrix of possible program assessment measures is presented as a starting point to foster discussion among all constituents interested in engineering education. Where there is a likely intersection between educational objective and its measuring device, the task force has attempted to insert an estimate of correlation: 1) for those techniques perceived by the task force to be reasonably correlated, 2) for moderately correlated, and 3) for possibly correlated. The matrix is intended to convey the need for sufficient breadth to measure most attributes (objectives) with three or more measurement devices. This matrix recognizes the need to validate the relationship of a specific criterion--or desired educational outcome -- with both its measurement and its subsequent validation in the form of professional and personal accomplishments.

The rows of the matrix show attributes desired of a graduate. They fall into three broad categories:

1. Attributes of an engineer as defined in the ABET Engineering Criteria 2000
2. Special attributes particular to the objectives of the university
3. Nonengineering practice professional goals

MATRIX OF ENGINEERING EDUCATION ASSESSMENT MEASURES

Pre-Graduation - Criteria 2000

Desired Attribute	Transcript	FE Exam	MFAT	GRE	GMAT, LSAT, MCAT	Other	Portfolio	Video Presentation	Co-Curricular Resume	Self-analysis survey
Knowledge of Math, Sci., & Eng	**1**	**1**	**2**	**2**	**-**	**-**	**2**	**3**	**-**	**2**
Experimentation & data analysis	**2**	**-**	**-**	**-**	**-**	**-**	**2**	**2**	**-**	**3**
Design	**2**	**-**	**-**	**-**	**-**	**-**	**2**	**1**	**-**	**2**

Multi-Disiplinary Teamwork	-	-	-	-	-	-	1	2	2	2
Problem Solving	2	2	2	2	-	-	3	3	-	2
Professionalism, Ethics	-	-	-	-	-	-	2	-	3	2
Communication	2	-	-	-	-	-	1	1	-	2
Broad Education	1	-	-	-	-	-	-	-	1	2
Lifelong Learning	3	-	-	3	-	-	-	-	3	2
Contemporary Practice & Issues	2	2	2	-	-	-	2	2	1	1
Other	-	-	-	-	-	-	-	-	-	-

Campus and Departmental Goals

Integrated Liberal Arts	1	1	-	-	3	2	-	1	2	1
Leadership & Global Awareness	2	-	2	-	-	-	2	-	1	2
Community Service	-	-	2	-	-	-	2	-	1	1
Other	-	-	-	-	-	-	-	-	-	-

Beyond Initial Practice

Professional School Admission	-	-	-	3	1	-	-	-	-	2
Research & Graduate Study	-	-	-	1	-	-	-	-	-	2
Entrepreneurship	-	-	-	-	-	-	3	2	2	1
Non Engineering Management	-	-	-	-	-	-	-	-	1	2
Other	-	-	-	-	-	-	-	-	-	-

Post-Graduation - Criteria 2000

Desired Attribute	Admission to Prof. or Grad	Job offers per student	Average start salary	Five- and ten -year career survey	Post-grad satisfaction survey	Other
Knowledge of Math, Sci., & Eng.	3	-	-	3	1	-

Experimentation & Data Analysis	-	-	-	-	2	-
Design	-	-	-	1	2	-
Teamwork	-	-	-	3	2	-
Problem Solving	-	-	-	3	2	-
Ethics	-	-	-	-	2	-
Communication	-	-	-	3	2	-
Broad Education	3	-	-	3	2	-
Lifelong Learning	-	-	-	1	1	-
Contemporary Issues	-	-	-	3	1	-
Practice-Oriented Education	-	2	2	-	-	-
Other	-	-	-	-	-	-

Campus and Departmental Goals

Integrated Liberal Arts	3	-	-	-	2	-
Leadership & Global Awareness	-	-	-	1	2	-
Community Service	-	-	-	1	1	-
Other	-	-	-	-	-	-

Beyond Initial Practice

Professional School Admission	1	-	-	1	1	-
Research & Graduate Study	1	-	-	3	1	-
Entrepreneurship	-	2	2	1	2	-
Non Engineering Management	-	1	1	1	1	-
Other	-	-	-	-	-	-

Note. Numbers indicate levels of correlation between the measurement device and the desired attribute:
1 = Reasonable, 2 = Moderate, 3 = Possible.

The first set of attributes in the matrix is the ABET Engineering Criteria 2000. The second set incorporates specific campus and departmental goals. These goals include civic and organizational leadership skills that are developed within specific school missions such as those of the military academies (leadership), colleges with religious affiliations (community service), schools that emphasize integrated liberal arts knowledge, or those with other manifestations of the inner logic (Ashby, Eric, Adapting Universities to a Technological Society, Jossey-Bass, San Francisco, 1974) of that campus or department. The third set represents the broad abilities obtained by an engineering student and can include admission into professional schools of other disciplines such as law and medicine, entry into advanced engineering education, or even embarking on industrial and managerial careers of a nonengineering nature.

The columns of the matrix include candidate assessment devices to which others can be added. They are loosely grouped by measurement of pregraduation and postgraduation indicators. The first includes transcript data, such as courses attempted and grades achieved as well as levels of attainment on a major field assessment test (MFAT), such as the FE. Pregraduation indicators can also include grades on the Graduate Record Examination (GRE) and on the following professional school entrance examinations: Graduate Management Admissions Test (GMAT), Law School Admissions

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