Assessment in Engineering Programs: Evolving Best Practices

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FOREWORD

This volume is the third in a series sponsored by the Association for Institutional Research (AIR) focused on assessment in the disciplines. The first year was dedicated to employing assessment in the teaching of business (Vol. 1 and 2), the second year (Vol. 3) to the teaching of mathematics and related fields. Future volumes will focus on assessment of teaching writing, chemistry, and other topics.

Engineering has been one of the most interesting subjects to observe as an assessment professional for a variety of reasons. The engineering accreditation body, known as ABET (formerly Accreditation Board for Engineering and Technology and now simply ABET, Inc.) is actually a federation of engineering societies which accredits engineering programs at the discipline level, although schools may choose to accredit programs simply as engineering. Most programs are accredited by discipline such as industrial engineering or electrical engineering. ABET has a very strong industry influence among its accrediting bodies and reviewers. This became clear when a momentous shift came about with EC2000, the engineering accreditation standard that shifted the criteria for engineering away from what had traditionally been seen as "bean counting" or the overemphasis on inputs and trivia and towards a much heavier emphasis on both outcomes and what many regard as the softer side of education (i.e., such matters as teamwork, whether or not an engineering solution will be effective in a certain culture, whether students are being prepared for life-long learning). It is fair to say, and most of the engineers whom I have met agree wholeheartedly, that without the strong influence of industry engineers on the accreditation process, EC2000 would never have come about in its current form. Engineering accreditation, as it is known today, would have had a quite different emphasis, more likely with heavier weight given to traditional, quantitative and physical science based knowledge and skills and much less emphasis on the "softer" side.

This volume offers the assessment professional as well as the classroom professor of engineering some practical suggestions for implementing procedures to assess what has become known as the "a through k" criteria of EC2000, while at the same time providing a national overview of the impact of those criteria in Chapters 2 and 11. It also shows those assessing and teaching in other fields how "soft" knowledge and skills can be taught and measured even in such a "hard" discipline as engineering. And in some cases, the students even have fun learning!

I would like to convey a special thanks to Bill Kelly, the volume editor, who worked so hard to pull these chapters together, to Amy Smyth at the Association for Institutional Research for her editorial assistance, to Randy Swing, our new Executive Director, for his continuing support and guidance, and to the AIR Publications Committee and its current chair, Gary Pike. Volumes of this type, and the series in assessment, are only possible because of the efforts of many people such as these.

We in institutional research continue to cherish our role as partners with faculty in improving higher education through assessment. This volume and series are tangible evidence of that continuing commitment.

John A. Muffo
Ohio Board of Regents

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CHAPTER 1

EVOLUTION OF ENGINEERING ASSESSMENT

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Introduction

The vision of the engineer of 2020 presented by the National Academy of Engineering (NAE) in their 2004 report goes well beyond the ABET outcomes, as it should. One of the keys, according to the authors of the NAE report, is life-long learning—one of the current ABET outcomes and one that has been particularly difficult to assess and evaluate. The NAE authors state that "...to be individually/personally successful, the engineer of 2020 will learn continuously throughout his or her career, not just about engineering but also about history, politics, business, and so forth."

Assessment is increasingly focusing on student learning, including the ability of students to assess their own learning. Ultimately, professionals must have the ability and the motivation to assess where there are gaps in their knowledge and skills and to develop, implement, and evaluate appropriate learning strategies to address those gaps.

An overall goal of accreditation is to assure minimum levels of quality in programs and to promote continuous quality improvement in programs. The preface to the current ABET Engineering Criteria (ABET, 2007) states that

> These criteria are intended to assure quality and to foster the systematic pursuit of improvement in the quality of engineering education that satisfies the needs of constituencies in a dynamic and competitive environment. (p. 1)

The current ABET criteria are not prescriptive as to what students should learn, but they do require a process of goal setting, evaluation of achievement of goals, assessment of outcomes, and quality improvement. As a minimum, each program must assess all of the outcomes listed in ABET Criterion 3 (a) through (k) or also known as 3(a–k) (ABET, 2007).

ABET recognizes that to realize its vision, it must be a leader in promoting assessment and continuous improvement. To this end, ABET recently completed a longitudinal study of the impact of EC2000 on engineering education and published *Engineering Change: A Study of the Impact of EC2000* that documents the positive impact that the new engineering criteria already are having on graduates (ABET, 2006).

The ABET longitudinal study also documents the broad support that the new criteria and the philosophy of assessment and improvement have in the engineering education community. The issue for the engineering education community now is how best to do assessment and how to do it effectively and efficiently.

ABET and others recognize that the processes for assessment and improvement must be sustainable for a range of educational institutions. Therefore, assessment must not be too burdensome for faculty and also must be perceived by faculty and administrators as adding value to their programs. It also is reasonable for faculty members to expect that good assessment practices will help them improve their teaching effectiveness and ultimately, to improve student learning.

ABET provides the criteria, but it is less able to define what constitutes good practice for assessment and improvement. It does, however, provide guidance through activities such as workshops for faculty on engineering assessment practice (ABET, 2008a). It also provides guidance on assessment planning through a section on the ABET web site maintained by Gloria Rogers.

Prados, Peterson, and Lattuca (2005) provide an overview of the initial impact of EC2000 as well as a comprehensive discussion of the factors that led to the changes in the accreditation criteria and accreditation processes. They also outline some of the challenges that ABET has experienced in transitioning to EC2000 and sustaining the change. ABET accredits programs; this process provides assurance to customers—students, parents, and employers—that graduates of each program have achieved the minimum competencies in the specified program field.

There were a number of drivers to change engineering accreditation that converged in the late 1980s, including industry concerns that graduates' competencies might not be preparing them for the new global economy. Employers expressed doubts that the strong technical skills that were the norm as a result of changes made to engineering curricula in the 1950s were still sufficient, if they had ever been. There needed to be more attention in engineering programs to the "soft skills" such as communications and team work. There were also strong feelings, notably among engineering deans, that the ABET processes had become too burdensome and could even be a barrier to needed innovation in engineering education.

ABET responded with both new, simplified criteria and a new performance or outcomes-based approach to accreditation. Instead of providing the recipe for engineering education, the approach is to focus on outcomes with ABET providing a minimum set in the Criteria. ABET also accepted the challenge to change its own processes, including training an entire new cadre of program evaluators and team chairs, and, finally, assessing the impact of EC2000 on engineering education.

There have been numerous sessions and papers at American Society for Engineering Education (ASEE) regional and national meetings dealing with assessment. ASEE started early with its white paper on assessment (American Society for Engineering Education, 1996). A search of the ASEE 2007 annual conference web site using *assessment* as the key word turned up over 125 papers with the word *assessment* in the paper title. This compares with nine papers in 1996, the earliest year for which papers are available on the ASEE web site. At the 2007 annual conference, there were also nine sessions with the word *outcomes* in the session title.

In 2005, Olds, Moskall, and Miller published a review of the state of assessment in engineering education as reflected in articles published in the ASEE *Journal of Engineering Education* (JEE). Assessment was reviewed in its role supporting engineering education research rather than as it is commonly applied by engineering faculty to assess achievement of the ABET Criterion 3(a–k) outcomes. Although most programs are primarily interested in processes to assess student achievement of outcomes, some are also interested in assessing the impact of program changes on student learning and also on outcomes such as student retention. Assessment design is divided into descriptive and experimental approaches, and examples from recent JEE articles are given and briefly discussed and summarized in two tables. Even programs only interested in assessing the ABET outcomes should find this paper a useful summary of where we are. Longer term, when programs look at evaluating achievement of program objectives, including the assessment of program changes on achievement of objectives, they will find their perspective on assessment to be more aligned with assessment for research.

So far, there is has been much less published on program quality assurance and improvement. There has been some experimentation by the International Organization for Standardization (ISO) with ISO 9001 and with Malcolm Baldridge in higher education, but there appear to have been few or no recent attempts to apply either to engineering programs in the U.S. On her "Assessment Planning" web site, Gloria Rogers notes that for industry and for education, it is difficult to separate assessment and quality assurance and, ultimately, quality improvement (Rogers, 2008).

At the ASEE annual meeting in 2007, there were only six papers with *quality* in the title that appeared to deal with program quality improvement. The paper by Prados et al. previously mentioned is one of the few recent JEE articles that discusses quality improvement. This is likely to change as the new general criteria now have a specific criterion dealing with quality improvement.

One of the issues that engineering programs must deal with is workload; thus, faculty members and program administrators want assessment methods that are both effective and efficient and, of course, acceptable to ABET. There is also the issue of data collection and processing, and this is where institutional-wide support services such as institutional research offices can and are helping. Universities have a need for, and an interest in, defining and managing assessment and improvement processes that will serve a wide variety of accrediting agencies and institutional needs.

In 2004, ABET looked at some of the potential barriers to full implementation of EC2000. One of the conclusions was that

> Workload, documentation, and assessment tools continue to provide frustration for constituents. Sustaining the change relies on sustaining the level of commitment and enthusiasm—the level of momentum—both on campus and at ABET. We understand this and are working to continually improve it.

Standards and assessment are a fact of life for elementary and middle school teachers and increasingly for high school teachers as states set and enforce learning standards. One purpose of standards is to document and promote best practice. The Joint Committee on Standards for Educational Evaluation (JCSEE) has published *The Student Evaluation Standards* (2003). Also, the ISO published a working agreement on applying ISO 9001 to higher education that could be useful to programs in organizing their improvement processes (Kelly, 2007). At this point, there are no international standards for assessment in higher education.

In the remainder of this chapter, I will outline some of what has been reported about assessment and improvement in the Association for Institutional Research (AIR) business and mathematics volumes and then provide an overview of this volume.

Previous Association for Institutional Research (AIR) volumes

AIR is the professional development organization that supports institutional research efforts in postsecondary education. Campus institutional research offices collect and manage data, which are used for a variety of campus planning and management activities. Increasingly, institutional research offices provide support, particularly for data collection and management, for campus-wide and program-level assessment activities. AIR instituted the series "Assessment in the Disciplines" specifically to support institutional researchers and faculty in campus assessment activities (Association for Institutional Research, 2008).

AIR has published three volumes on assessment practice thus far. The first two volumes focus on assessment in business schools, and the third volume deals with assessment in mathematics. This engineering volume is the fourth in the series.

Business schools are accredited at the school or college level in contrast to engineering programs, which are accredited at the program level. However, accreditation of general engineering programs at schools where there are multiple tracks in engineering probably comes close to business schools accreditation.

In 2003, the Association to Advance Collegiate Schools of Business (AACSB) approved and began to implement new standards for accrediting business schools (Association to Advance Collegiate Schools of Business, 2008). These standards require business schools to provide direct evidence of student progress in meeting learning goals (Trapnell, 2005). The operative words here are "direct evidence."

Martell and Calderon (2005) present what is intended to be a primer on assessment for business schools. In their introduction to the first AIR business volume, they provide a summary of what business schools are doing with assessment today. Some of their comments should resonate with engineering faculty and administrators. For example, they advise business deans to focus on direct assessment methods for assessing student learning; they note that surveys have their place in academic planning and management but not as evidence of student learning. They also advise deans to keep things simple. They point out that good program assessment does not have to meet the standards of academic rigor expected for peer-reviewed publication, but it does have to be effective—the judges of effectiveness ultimately being the users and the accrediting team.

Since the AACSB standards are relatively new, it is to be expected that business schools would be and are struggling with how to do direct assessment and provide appropriate evidence, a situation not too different from what engineering programs are dealing with. Martell and Calderon note that requirements for assessment data for business schools are consistent with those of regional and other professional accreditation bodies (e.g., ABET) and some state legislatures. There are many good examples in the two business volumes that should be useful to engineering faculty members and administrators charged with organizing assessment and improvement processes at the school and college level in engineering.

Anyone familiar with the evolution of engineering accreditation over the last ten years or so would find the discussion in business familiar. Martell and Calderon's comment that the AACSB requirements for assessment data are consistent with regional and other professional accrediting bodies and some state legislatures suggests, as noted earlier, that universities will increasingly define best assessment practices to demonstrate student learning for multiple audiences.

Mathematics knowledge and skills are extremely important in engineering. The ABET curricula requirement for mathematics and science is 32 credits, and a number of the program criteria imply a high level of mathematical performance for graduates. Assessment of mathematics readiness—related to performance—is also increasingly recognized for its importance in advising students studying, and potentially interested in studying, engineering. According to Adelman (1998), "the highest level of mathematics studied in secondary school is strongly correlated with bachelor's completion in any field." This is particularly true with respect to persistence and success in engineering.

Mathematics and the AIR mathematics volume are different from business and engineering in that mathematics programs themselves are not separately accredited. However, mathematics is an important part of all engineering programs, and thus there would be expected to be common assessment issues. Several of the papers in the mathematics volume are directly applicable to engineering. Also, the Mathematical Association of America (MAA) is actively supporting assessment with its "Supporting Assessment in Undergraduate Mathematics" (SAUM) program and has case histories available online (Mathematical Association of America, 2006). A relevant case history is one describing assessment of the core mathematics program at West Point. All cadets take the same four-course sequence in mathematics where the first course is in discrete dynamical systems with an introduction to calculus (Heidenberg & Huber, 2006).

Assessment in Engineering

ABET is a good source of assessment materials and a resource to check frequently is the ABET web page (Rogers, 2008). For programs undergoing a review there is no substitute for participation in the ABET annual meetings. The fall ABET meeting is now largely devoted to assisting programs in preparing self-study reports and the summer EAC meeting for deans provides the latest information on practices in place for the current visit cycle (e.g., what are the latest issues, how evaluators are looking at materials, how to present materials).

There is no substitute for experience, and all engineering administrators should consider volunteering as an ABET evaluator (ABET, 2008c). One of the keys to ABET's past and future success is having a cadre of dedicated and effective evaluators. ABET is focusing its current improvement efforts on improving the performance of program evaluators (ABET, 2008d). ABET's strategy has been not only to change the criteria, now essentially common for all of the commissions, but to improve the accreditation process