AC 2010-1522: ASSESSING THE STANDARDS FOR ASSESSMENT: IS IT TIME TO UPDATE CRITERION 3?

Stephen Ressler, United States Military Academy

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Purpose

The ABET engineering accreditation criteria specify that engineering programs must implement continuous quality improvement processes to ensure that they remain relevant and effective over time. But how does ABET ensure that its *criteria* remain relevant and effective over time? In 2009, the Criteria Committee of the ABET Engineering Accreditation Commission (EAC) sought to answer this question by exploring the possibility of initiating a continuous quality improvement process for its accreditation criteria. Once implemented, this process is expected to include an assessment of the continued relevance of the EAC Criterion 3 outcomes—statements that define the minimum essential knowledge and skills that an engineer is expected to attain through baccalaureate-level education.

The purpose of this paper is to support the EAC Criteria Committee's initiative by providing a preliminary assessment of the Criterion 3 outcomes, in the context of the strategic direction of the engineering profession. The scope of the paper includes (1) background on the initial formulation of Criterion 3, (2) a review of recent strategic vision statements that suggest a need for changes to Criterion 3, (3) a discussion of potential barriers to change, and (4) recommendations for aligning Criterion 3 with an emerging consensus about the essential attributes of future engineering professionals.

ABET Engineering Criteria 2000

In 1992, in response to a growing perception that existing engineering accreditation criteria were inhibiting educational innovation, ABET established an Accreditation Process Review Committee (APRC) to advise on how to increase flexibility in accreditation criteria and processes. Based on the APRC's recommendations, ABET conducted a series of consensus-building workshops in May 1994. One of these, the Criteria Reform Workshop, produced seven recommendations, four of which are directly relevant to criteria development:[1]

- Engineering accreditation should be based on ongoing institutional processes for defining educational objectives, evaluating achievement of objectives, and improvement of educational effectiveness, with periodic external audits of the process by ABET.

- Criteria should specify a limited set of education objectives for any engineering program and a limited floor of curricular content. Complete objectives, curricula to achieve them, and processes to evaluate achievement would be defined by the institution.

- Program criteria could still be specified by the responsible professional societies but would be restricted to curricular issues (subject areas, but not credit hours) and faculty qualifications.

- Criteria should include a core, consisting of both knowledge and skills. This core should uniformly define what it takes to become an engineer and what constitutes the minimum content of an engineering curriculum. It should also ensure a broad education that emphasizes the basics, encourages lifelong learning, and inculcates desirable experiences and capabilities.

These recommendations served as the basis for the development of ABET Engineering Criteria 2000 (commonly abbreviated as EC2000). These criteria were formally adopted by ABET Board in 1996 and were published for a three-year phased implementation, beginning with the 1998-99 accreditation cycle.

The ABET Criteria Reform Workshop's recommendations for a "limited floor of curricular content" and a core that would "uniformly define what it takes to become an engineer" were manifested, to a large extent, in Criterion 3 of EC2000. This criterion defines eleven educational outcomes that graduates of accredited programs are expected to achieve. These outcomes, as published in the final year of EC2000 implementation (the 2000-01 accreditation cycle), are shown in the center column of Table 1.[2] The right-hand column of this table shows the equivalent educational outcomes in the most recently published EAC accreditation criteria (the 2010-11 accreditation cycle).[3] The differences between the two sets of outcomes are highlighted in bold type.

As Table 1 clearly illustrates, the Criterion 3 outcomes have remained remarkably stable over the past decade. Indeed, of the two modest changes that have been made, the additional specifications in Criterion 3(c) were actually just relocated from Criterion 4 (Curriculum); thus, they represent a change in emphasis, rather than a set of new requirements.

In the author's view, the long-term stability of the Criterion 3 outcomes has been entirely appropriate. Implementation of EC2000 and the associated outcomes-based assessment and improvement processes have been significant challenges for most educational institutions. Over the past decade, definitions of key terms, guidance on acceptable measurement methods, and standards of enforcement have all evolved significantly. During this period of flux, substantive changes to Criterion 3 would have caused considerable confusion and would probably have done more harm than good.

Nonetheless, it must be recognized that the current Criterion 3 outcomes reflect the professional environment of the mid-1990s, when they were formulated. The world has changed considerably since then—and there are increasing indications that the minimum essential knowledge and skills required for engineering practice have changed as well. Hence, the EAC Criteria Committee's decision to consider changes to Criterion 3 is both well-founded and timely.

Criterion	2000-01 Accreditation Cycle	2010-11 Accreditation Cycle
3(a)	An ability to apply knowledge of mathematics, science, and engineering	An ability to apply knowledge of mathematics, science, and engineering
3(b)	An ability to design and conduct experiments, as well as to analyze and interpret data	An ability to design and conduct experiments, as well as to analyze and interpret data
3(c)	An ability to design a system, component, or process to meet desired needs	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**
3(d)	An ability to function on multi-disciplinary teams	An ability to function on multi-disciplinary teams
3(e)	An ability to identify, formulate, and solve engineering problems	An ability to identify, formulate, and solve engineering problems
3(f)	An understanding of professional and ethical responsibility	An understanding of professional and ethical responsibility
3(g)	An ability to communicate effectively	An ability to communicate effectively
3(h)	The broad education necessary to understand the impact of engineering solutions in a global and societal context	the broad education necessary to understand the impact of engineering solutions in a global**, economic, environmental,** and societal context
3(i)	A recognition of the need for, and an ability to engage in life-long learning	A recognition of the need for, and an ability to engage in life-long learning
3(j)	A knowledge of contemporary issues	A knowledge of contemporary issues
3(k)	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 1. Comparison of Criterion 3 outcomes for the 2000-01 and 1010-11 accreditation cycles

Voices for Change

The emerging need to redefine the minimum essential knowledge and skills required for engineering practice can be seen in four recent sources:

- The National Academy of Engineering's strategic vision for the engineering profession
- Efforts by several professional societies to formally define their disciplinary bodies of knowledge
- These societies' adoption of Bloom's Taxonomy to improve clarity and to explicitly define levels of achievement in educational outcome statements
- A forthcoming National Society of Professional Engineers position statement regarding the need for revisions to Criterion 3

In 2003, the National Academy of Engineering (NAE) published a broad-based vision for the engineering profession—*The Engineer of 2020*.[4] As part of that vision, the NAE identified the following attributes of engineers in 2020:

- Strong analytical skills
- Practical ingenuity
- Communication skills
- Business and management
- Leadership
- High ethical standards
- Professionalism
- Dynamism, agility, resilience, and flexibility
- Lifelong learning

It is noteworthy that four of these nine attributes—practical ingenuity, business and management, leadership, and dynamism—are not addressed in the current EAC Criterion 3 outcomes.

The NAE report also identifies the Academy's aspirations to:

- "engineers…who will expand their vision of design through a solid grounding in the humanities, social sciences, and economics."

- "engineers who will assume leadership positions from which they can serve as positive influences in the making of public policy and in the administration of government and industry."

- "engineers [who] will continue to be leaders in the movement toward use of wise, informed, and economical sustainable development."

- "engineers [who] are prepared to adapt to changes in global forces…"

These areas of emphasis—humanities, social sciences, economics, public policy, public administration, sustainability, and globalization—are only addressed indirectly in Criterion 3. Their inclusion in the criterion is sufficiently peripheral that a program could easily avoid addressing these topics without any risk of noncompliance. For example, sustainability is addressed in Criterion 3(c) as one of eight possible design constraints; thus, a program can avoid addressing sustainability simply by including some of the other constraints in the design experience. Humanities might be included in a "broad education," as referenced in Criterion 3(h), but a program that included no humanities could easily achieve breadth by other means. Evidently, a substantial portion of the NAE's vision for the engineer of 2020 is not addressed, or not adequately addressed, in the current Criterion 3 outcomes.

Concurrent with the development of the NAE vision, several disciplinary professional societies that have been similarly engaged in attempting to define the strategic direction of the engineering profession. For over a decade, ASCE has been involved in an ambitious effort to better prepare civil engineering professionals to meet the technological, environmental, economic, social, and political challenges of the future.[5] This "Raise the Bar" initiative attained an important milestone in October 1998, when the ASCE Board of Direction formally adopted Policy Statement 465. The most recent version of this policy is as follows:

> The ASCE supports the attainment of a body of knowledge for entry into the practice of civil engineering at the professional level. This would be accomplished through the adoption of appropriate engineering education and experience requirements as a prerequisite for licensure.[6]

In conjunction with the implementation of Policy Statement 465, ASCE initiated a comprehensive project to formally define the profession's body of knowledge (BOK). In January 2004 this effort came to fruition with ASCE's publication of the first edition of the *Civil Engineering Body of Knowledge for the 21st Century*—a report describing the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level.[7]

This report describes the civil engineering BOK in terms of fifteen outcomes, the first eleven of which correspond nominally to the ABET Criterion 3 outcomes. BOK Outcome 12 describes a requirement for knowledge in a specialized area related to civil engineering; and Outcomes 13, 14, and 15 require understanding of professional practice topics—management, business, public policy, public administration, leadership, and attitudes. Given that these professional practice topics are not specific to the civil engineering discipline, the BOK indirectly suggests that the current Criterion 3 outcomes no longer reflect the full scope of knowledge, skills, and attitudes required for engineering practice today.

Having published its BOK, ASCE then determined that that changes to the EAC accreditation criteria constitute the only viable instrument for effecting the broad-based curriculum reform required for BOK implementation. Although outcomes associated with general professional practice topics would have been most appropriately included in Criterion 3, ASCE recognized that making changes to any of the General Criteria would be infeasible in the short term. Thus, ASCE's Committee on Academic Prerequisites for Professional Practice (CAP^3) chose instead to implement changes to the Civil Engineering Program Criteria, which ASCE can more readily influence.[8]

In conjunction with BOK implementation and the development of new Civil Engineering Program Criteria, CAP^3 and its subcommittees discovered that the wording of the current Criterion 3 outcomes (which had been adopted without modification as BOK Outcomes 1 through 11) was too ambiguous to clearly establish the expected level of achievement associated with each outcome. This distinction was particularly important to ASCE, because the civil engineering BOK differentiates the knowledge, skills, and attitudes gained through *education* from those gained through *experience*. Given that both education and experience contribute to the attainment of most outcomes, it was critical to be able to define the different level of achievement expected from each source.

CAP^3 addressed this problem by adopting Bloom's Taxonomy as the basis for defining levels of achievement—in revisions to accreditation criteria as well as future editions of the BOK.[9] Bloom's Taxonomy is a well-established framework for defining educational objectives in terms of the desired level of cognitive development.[10] Benjamin Bloom's six levels of cognitive development—knowledge, comprehension, application, analysis, synthesis, and evaluation—

describe a hierarchy of increasing complexity and sophistication in thought. Definitions of the six levels are provided in the center column of Table 2 below.

The fundamental premise of Bloom's Taxonomy is that an educational objective can be referenced to a specific level of cognitive development through the verb used in the objective statement. Some illustrative examples of verbs associated with Bloom's six levels are provided in the right-hand column of Table 2.

Level	Definition	Illustrative Verbs
1. Knowledge	The remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information.	define; describe; enumerate; identify; label; list; match; select; state.
2. Comprehension	The ability to grasp the meaning of material. This may be shown by translating material from one form to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects). These learning outcomes go one step beyond simple remembering and represent the lowest level of understanding.	classify; cite; convert; describe; discuss; explain; generalize; give examples; paraphrase; summarize.
3. Application	The ability to use learned material in new and concrete situations. This may include the application of rules, methods, concepts, principles, laws, and theories. Learning outcomes in this area require a higher level of understanding than those under comprehension.	apply; calculate; chart; compute; determine; demonstrate; implement; relate; report; solve; use.
4. Analysis	The ability to break down material into its component parts so that its organizational structure may be understood. This may include the identification of parts, analysis of the relationship between parts, and recognition of the organizational principles involved. Analysis represents a higher level than comprehension and application because it requires an understanding of both the content and the structural form of the material.	analyze; correlate; differentiate; discriminate; distinguish; formulate; illustrate; infer; organize, outline; prioritize; subdivide.
5. Synthesis	The ability to put parts together to form a new whole. This may involve the production of a unique communication, a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information). Learning outcomes in this area stress creative behaviors, with major emphasis on the formulation of new patterns or structure.	adapt; combine; compile; compose; create; design; develop; devise; generate; integrate; modify; plan; revise; structure.
6. Evaluation	The ability to judge the value of material for a given purpose, based on definite criteria. Learning outcomes in this area are highest in the hierarchy because they contain elements of all the other categories, plus conscious value judgments based on clearly defined criteria.	appraise; compare & contrast; conclude; criticize; critique; decide; defend; evaluate; judge; justify.

Table 2. Bloom's Taxonomy.

It should be noted that recent scholarship by Anderson and Krathwohl has produced a substantial revision to Bloom's model.[11] CAP[3] carefully considered this revision but ultimately decided to use Bloom's Taxonomy in its original form as the basis for defining levels of achievement. In Anderson and Krathwohl's model, "create" (the equivalent of Bloom's "synthesis") is placed at Level 6, and "evaluate" is relegated to Level 5. In engineering practice, design is the most common form of synthesis; and design work is generally evaluated and affirmed by a supervising engineer. Hence, from an engineering perspective, it makes more sense for evaluation to be placed above synthesis in the cognitive hierarchy, as is the case in Bloom's original model.

ASCE's adoption of Bloom's Taxonomy has won strong support from the society's accreditation community, in part because Bloom's model is well established and well respected, but also because the use of strong, action-oriented verbs has significantly improved the clarity, conciseness, and measurability of its new Civil Engineering Program Criteria. The success of this effort also highlights significant shortcomings in Criterion 3—the use of ambiguous, non-measurable verbs and the lack of any purposefully delineated levels of achievement in all eleven outcome statements.

ASCE's publication of the BOK generated a good deal of healthy discussion across the profession. In response to the extensive feedback it received, CAP[3] developed and published a revised edition of the civil engineering BOK in 2008.[12] This revised formulation increased the number of outcomes from 15 to 24. A portion of this increase resulted from subdividing and reorganizing the previous 15 outcomes to improve clarity and measurability. For example, the previous Outcome 1 (which corresponds to EAC Criterion 3(a), "an ability to apply knowledge of mathematics, science, and engineering") was reformulated as four separate outcomes in the second edition of the BOK:

- Outcome 1 – **Solve** problems in mathematics through differential equations and **apply** this knowledge to the solution of engineering problems. *(Level 3)*

- Outcome 2 – **Solve** problems in calculus-based physics, chemistry, and one additional area of natural science and **apply** this knowledge to the solution of engineering problems. *(Level 3)*

- Outcome 5 – Use knowledge of materials science to **solve** problems appropriate to civil engineering. *(Level 3)*

- Outcome 6 - **Analyze** and solve problems in solid and fluid mechanics. *(Level 4)*

Note that, in these revised outcomes, the verbs (highlighted in **bold** type) communicate the expected level of achievement (in *italics*), through the application of Bloom's Taxonomy. Note also the implication that the current EAC Criterion 3(a) requires considerable clarification.

In addition to reformulating and reorganizing existing outcomes, the second edition of the BOK defines new outcomes addressing humanities, social sciences, sustainability, history and heritage, risk and uncertainty. These new outcomes are not specific to civil engineering and, thus, are reasonably applicable to all engineering disciplines. ASCE has begun considering how these new outcomes might be addressed in an additional revision to the Civil Engineering Program Criteria;[13] however, the general character of these outcomes would make their inclusion in Criterion 3 of the EAC General Criteria more appropriate.

In 2009, the American Academy of Environmental Engineers defined and published the environmental engineering body of knowledge (ENVE BOK).[14] Of the 18 outcomes that define the ENVE BOK, topics that are not addressed in EAC Criterion 3 and are not specific to the environmental engineering discipline include risk, reliability, and uncertainty; problem formulation and conceptual analysis; sustainability; globalization; project management; business and public administration; and leadership. And like the civil engineering BOK, the ENVE BOK fully incorporates the use of Bloom's taxonomy as the basis for defining levels of achievement.

Also in 2009, the National Society of Professional Engineers (NSPE) initiated its own internal evaluation of the continued relevance and adequacy of EAC Criterion 3, from the perspective of engineering licensure. This effort is expected to yield a formal NSPE Position Statement within the next six months. Although this evaluation is still ongoing, its product is expected to include a call to expand the scope of Criterion 3—to include new outcomes associated with risk and uncertainty, sustainability, project management, business, public administration, public policy, and leadership.

These recent initiatives by NAE, NSPE, ASCE, and AAEE demonstrate a remarkable degree of consistency with respect to their emphasis on topics beyond the scope of the current Criterion 3 outcomes. These areas of emphasis are summarized in Table 3 below. Of the 15 areas, eight are emphasized in at least three of the four sources, and two more are emphasized in two sources. The level of agreement is even higher if one considers the NAE's "dynamism, agility, resilience, and flexibility" to be a subset of ASCE's "attitudes," and economics to be a subset of the social sciences. A number of influential engineering educators and practitioners have called for greater emphasis on many of these same subjects as well.[15,16] It is evident that, if Criterion 3 is to be updated, the most broadly endorsed of these subjects should receive first priority.

Outcome	NAE Engineer of 2020	ASCE CE BOK 2nd Ed.	AAEE ENVE BOK	NSPE Position
Attitudes		√		
Business	√	√	√	√
Dynamism, Agility, Resilience, Flexibility	√			
History and Heritage		√		
Economics	√			
Globalization	√	√	√	
Humanities	√	√		
Leadership	√	√	√	√
Management or Project Management	√	√	√	√
Practical Ingenuity	√			
Public Policy	√	√		√
Public Administration	√	√	√	√
Risk and Uncertainty		√	√	√
Social Sciences	√	√		
Sustainability	√	√	√	√

Table 3. Areas of emphasis beyond EAC Criterion 3 in various strategic vision documents.

Potential Barriers to Change

There are four substantial barriers that are likely to impede the EAC Criteria Committee's efforts to consider changes to EAC Criterion 3:

- Programs' desire for stability in accreditation criteria

- Programs' resistance to further increases in non-engineering content in the baccalaureate-level curriculum

- ABET's ongoing effort to achieve harmonization of criteria across its four commissions

- A general belief that changes to accreditation criteria are not effective in facilitating curricular reform or are not necessary to motivate curricular reform

Engineering programs' desire for long-term stability in accreditation criteria is well-founded. Substantive changes to accreditation criteria typically trigger major curriculum changes within programs. At most institutions, large-scale curricular change may take one or two full years to design, approve, and publish. Furthermore, major curriculum change often requires a phased implementation period of up to four years, because the courses available to incoming freshmen are typically treated as a contract between the institution and the students. Thus the time lag between the inception of a major curriculum change and the assessment of outcomes associated with graduates who have experienced the revised curriculum can easily reach six years. If additional accreditation criteria changes occur within this six-year period, the program is in the unenviable position of initiating new curriculum changes even before the previous round of changes has been fully implemented or assessed. This so-called "moving target problem" is real, and it must be taken into consideration in any decision to make major accreditation criteria changes.

The "moving target problem" notwithstanding, the current Criterion 3 outcomes were first published in 1996 and could not feasibly be changed before 2013 (assuming, optimistically, that changes could be formulated by 2011, approved for public comment by 2012, and approved for implementation in the 2013-14 accreditation cycle). If a criteria change cycle of less than six years is demonstrably too short, then a change cycle of seventeen years is clearly too long—particularly in an era of profound and accelerating change in the world around us.

Programs' resistance to increasing content in the baccalaureate-level curriculum is well-founded as well. Even as the engineering BOK continues to expand, many programs are facing institutional or governmental pressure to reduce credit-hour requirements in their baccalaureate degree programs.[17] Logically, however, *ignoring the expanding BOK cannot be an acceptable answer to this problem.* If the *demand* for additional knowledge and skills is increasing, then the profession's logical response must be to increase the *supply* of education. Given the practical limitations on curricular content in a four-year baccalaureate program, and the historical fact that five-year baccalaureate programs have generally not been successful, establishment of the master's degree as the academic prerequisite for professional engineering practice is, arguably, essential. Fortunately, the National Council of Examiners for Engineering and Surveying (NCEES) has already paved the way for this solution by modifying its Model Law requirements for engineering licensure.[18] The revised Model Law states that admission to the engineering licensing exam will require a bachelor's degree plus a master's degree or an additional 30 credits of acceptable upper-level undergraduate or graduate-level coursework from approved course providers. In 2008, the effective date for the new Model Law was set at January 2020.

ABET's recent harmonization project is intended "to promote clear, consistent, and compatible communications among its many constituents and commissions" by achieving greater consistency in criteria and terminology across the four ABET commissions—the Engineering Accreditation Commission (EAC), the Computing Accreditation Commission (CAC), and Technology Accreditation Commission (TAC), and the Applied Science Accreditation Commission (ASAC).[19] Proposed harmonized criteria are currently published for public comment and are intended for implementation during the 2011-12 accreditation cycle.[20] Within the harmonized criteria, Criterion 3 is now titled "Student Outcomes" for all four commissions, and the student outcomes defined therein are highly consistent, as shown in Appendix A. Having invested considerable time and effort in achieving this level of consistency, ABET may resist large-scale changes to Criterion 3 for a single commission.

The author suggests, however, that the worthy goal of harmonization cannot supersede the requirement that accreditation criteria define the minimum essential knowledge and skills required for engineering practice. Without question, the formalized process for assessing the validity of Criterion 3 should occur in all four commissions, and in cases where new outcomes (e.g., project management) are found to be applicable across commissions, consistency should be maintained. But in cases where consensus across commissions cannot be achieved, it must be acknowledged that the explicit linkage between engineering education and licensure (and, therefore, the linkage between engineering accreditation and public safety) is a compelling reason for some degree of uniqueness in the EAC criteria.

A final potential barrier to change lies in the common and closely related beliefs that changes to accreditation criteria *are not effective* in facilitating curricular reform or *are not necessary* to motivate curricular reform. Both beliefs are inconsistent with the available evidence.

In 2006, the Center for the Study of Higher Education at Pennsylvania State University published the results of a comprehensive and rigorous study of the impact of EC2000.[21] The study demonstrated unequivocally that engineering programs changed their curricula, teaching methods, and internal continuous improvement processes substantially in response to EC2000. Over the period of EC2000 implementation, student learning outcomes also improved, at a statistically significant level, in all areas associated with the Criterion 3 outcomes. In light of these results, the claim that accreditation criteria do not make a difference is not supportable.

Could these benefits have been achieved without the element of compulsion implied in the use of accreditation criteria? Some contend that the publication of a compelling vision, such as the NAE's *Engineer of 2020*, should be an adequate motivator for broad-based curriculum reform. According to this line of reasoning, programs should change on their own initiative, rather than in response to the dictates of accreditation criteria. And while self-directed change is certainly desirable, ASCE's experience with the implementation of Policy Statement 465 suggests that it is likely to occur in only a minority of programs. Studies performed by the CAP[3] Curriculum Committee following the publication of the BOK 1st Edition and by the CAP[3] Educational Fulfillment Committee following the publication of the BOK 2nd Edition show a consistent pattern: despite the promulgation of a compelling vision for curricular reform, a majority of programs do not implement curricular change until the vision is translated into accreditation criteria.[22]

Conclusions and Recommendations

The evidence presented above leads to three important conclusions:

(1) Recently published visions for the engineering profession are highly consistent in their call for more broadly educated engineers. Most of the specific knowledge, skills, and attitudes identified in these sources would be most appropriately addressed in Criterion 3 of the EAC accreditation criteria.

(2) These sources agree that greater breadth should be attained at the baccalaureate level, with technical specialization achieved through master's-level study.

(3) The professional societies that have formally articulated their disciplinary bodies of knowledge have found that the wording of the existing EAC Criterion 3 can be greatly clarified through the application of Bloom's Taxonomy.

In response to these conclusions, the author recommends the following:

(1) The EAC Criteria Committee's ongoing project to develop a continuous quality improvement process for its accreditation criteria should be strongly supported by ABET and its member societies. If the process is applied across all four commissions, ABET should not feel constrained to preserve full consistency across all four sets of Criterion 3 outcomes. The continuous improvement process should give a high priority to formalized strategic visions and policy positions published by the NAE, NSPE, and the disciplinary professional societies. Once implemented, this process should be applied to the Criterion 3 outcomes.

(2) In order to address the "moving target problem," the process of systematically assessing and updating criteria should be implemented at regular six-year intervals. This six-year interval would correspond to *both* the normal accreditation cycle and the worst-case time period required for a program to design, approve, publish, implement, and assess major curricular change. Thus, constraining major ABET criteria changes to a predictable six-year schedule would allow programs to integrate accreditation criteria changes into their own internal assessment, curriculum change, and accreditation preparation processes. And no one would be caught off guard by unanticipated criteria changes.

(3) The scope of EAC Criterion 3 (and, to the greatest extent possible, the scope of Criterion 3 for the CAC, TAC, and ASAC criteria) should be expanded to include student

outcomes requiring knowledge of business, globalization, leadership, project management, public policy and administration, risk and uncertainty, and sustainability. As a second priority, outcomes associated with the humanities and social sciences should be considered as well. These could be substituted for the current outcomes associated with "broad education" and "contemporary issues," but the references to humanities and social sciences should be explicit, such that the criteria requirements cannot be bypassed.

(4) All of the Criterion 3 outcomes should be rewritten to incorporate Bloom's taxonomy. The wording of each outcome should reflect a purposefully defined level of achievement.

(5) In conjunction with the implementation of revised Criterion 3 outcomes, current Program Criteria that include provisions related to the new outcomes can, and should, be simplified through the elimination of redundancies. Program Criteria for Civil Engineering, Ceramic Engineering, Construction Engineering, Electrical Engineering, Engineering Management, Environmental Engineering, Ocean Engineering, Petroleum Engineering, and Software Engineering are most likely to be affected.

To illustrate the author's intent in (3) and (4) above, a recommended set of revised Criterion 3 outcomes is provided in Appendix B. For each outcome, the implied level of Bloom's Taxonomy is also provided.

Implementation of these recommendations would, no doubt, entail an immense investment in time and effort—within ABET and across the engineering profession. In the author's view, this level of investment is necessary if the NAE's aspirational vision for the engineer of 2020 is to be achieved. The vision is sufficiently compelling to make this effort worthwhile.

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Appendix A – Comparison of Criterion 3 Outcomes across ABET Commissions

EAC	ASAC	CAC	TAC
(a) an ability to apply knowledge of mathematics, science, and engineering	(l) an ability to apply knowledge of mathematics, science, and applied sciences	(a) An ability to apply knowledge of computing and mathematics appropriate to the discipline	b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	(m)an ability to design and conduct experiments, as well as to analyze and interpret data		c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes
(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	(n) an ability to formulate or design a system, process, or program to meet desired needs	(c) An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs	d. an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives
(d) an ability to function on multidisciplinary teams	(o) an ability to function on multidisciplinary teams	(d) An ability to function effectively on teams to accomplish a common goal	e. an ability to function effectively as a member or leader on a technical team
(e) an ability to identify, formulate, and solve engineering problems	(p) an ability to identify and solve applied science problems	(b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution	f. an ability to identify, analyze, and solve broadly-defined engineering technology problems
(f) an understanding of professional and ethical responsibility	(q) an understanding of professional and ethical responsibility	(e) An understanding of professional, ethical, legal, security and social issues and responsibilities	i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity
(g) an ability to communicate effectively	(r) an ability to communicate effectively	(f) An ability to communicate effectively with a range of audiences	g. an ability to communicate effectively regarding broadly-defined engineering technology activities
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	(s) the broad education necessary to understand the impact of solutions in a global and societal context	(g) An ability to analyze the local and global impact of computing on individuals, organizations, and society	j. a knowledge of the impact of engineering technology solutions in a societal and global context
(i) a recognition of the need for, and	(t) a recognition of the need	(h) Recognition of the need for and	h. an understanding of the need for and an

EAC	ASAC	CAC	TAC
an ability to engage in life-long learning	for and an ability to engage in life-long learning	an ability to engage in continuing professional development	ability to engage in self-directed continuing professional development
(j) a knowledge of contemporary issues	(u) a knowledge of contemporary issues		
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	(v) an ability to use the techniques, skills, and modern scientific and technical tools necessary for professional practice.	(i) An ability to use current techniques, skills, and tools necessary for computing practice.	a. an ability to select and apply the knowledge, techniques, skills, and modern tools of their disciplines to broadly-defined engineering technology activities
			k. a commitment to quality, timeliness, and continuous improvement.

Appendix B – Recommended Revised Criterion 3 Outcomes

Current Criterion 3 Outcomes	Recommended Criterion 3 Outcomes	Level of Bloom's Taxonomy
Engineering programs must demonstrate that their students attain the following outcomes:	**Engineering programs must demonstrate that their students can:**	
(a) an ability to apply knowledge of mathematics, science, and engineering	**Solve** problems in mathematics and science, and **apply** mathematics and science to the solution of engineering problems.	Level 3 Application
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	**Design** and **conduct** experiments, and **analyze** and **interpret** experimental data.	Level 5[a] Synthesis
(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	**Design** a system, component, or process to meet desired needs, accounting for economic, environmental, social, political, ethical, health and safety, manufacturability (or constructability), and sustainability constraints.	Level 5 Synthesis
(d) an ability to function on multidisciplinary teams	**Function** as a member of a multi-disciplinary team.	Level 3 Application
(e) an ability to identify, formulate, and solve engineering problems	**Identify**, **formulate**, and **solve** engineering problems.	Level 4[b] Analysis
(f) an understanding of professional and ethical responsibility	**Analyze** a situation involving conflicting professional and ethical interests to determine an appropriate course of action.	Level 4 Analysis
(g) an ability to communicate effectively	**Organize** and **deliver** effective verbal, written, and graphical communications.	Level 4[c] Analysis
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	*(Replaced by outcomes associated with humanities and social sciences below)*	
(i) a recognition of the need for, and an ability to engage in life-long learning	**Explain** the need for life-long learning, and **demonstrate** the capacity for self-directed learning.	Level 3[d] Application
(j) a knowledge of contemporary issues	*(Replaced by outcomes associated with humanities and social sciences below)*	
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	**Use** modern engineering tools to solve engineering problems.	Level 3 Application
	Solve project management problems.	Level 3 Application
	Apply principles of sustainability in engineering problem-solving.	Level 3 Application
	Apply an understanding of globalization in engineering problem-solving.	Level 3

Current Criterion 3 Outcomes	Recommended Criterion 3 Outcomes	Level of Bloom's Taxonomy
		Application
	Apply the principles of probability and statistics to account for risk and uncertainty in engineering problem-solving.	Level 3 Application
	Explain key concepts and processes used in business.	Level 2 Comprehension
	Explain leadership principles and the role of the leader in engineering problem-solving.	Level 2 Comprehension
	Explain how public policy is formulated and administered.	Level 2 Comprehension
	Draw upon knowledge of the humanities (which may include languages, literature, law, history, philosophy, religion, or the arts) to account for the human dimension of engineering problem-solving.	Level 3 Application
	Draw upon knowledge of the social sciences (which may include anthropology, archaeology, cultural studies, economics, international relations, political science, psychology, or sociology) to account for the social, political, and economic dimensions of engineering problem-solving.	Level 3 Application

[a] Level 5 is based on the verb **design**.
[b] Level 4 is based on the very **formulate**.
[c] Level 4 is based on the very **organize**.
[d] Level 3 is based on the verb **demonstrate**.