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Accreditation Insights and the Next Body of Knowledge

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Accreditation Insights and the Next Body of Knowledge

Abstract

The American Society of Civil Engineers (ASCE) organized the Civil Engineering Program Criteria Task Committee (CEPCTC) in October 2012. The CEPCTC charge was to determine if the current ABET Civil Engineering Program Criteria (CEPC) should be changed to reflect one or more of the 24 outcomes of the second edition of the *Civil Engineering Body of Knowledge*. After two years of work, a proposed CEPC was approved by the relevant ASCE committees and forwarded to ABET for approval and incorporation into accreditation criteria. Two previous papers have chronicled the work of this committee and were presented at the 2014 and 2015 ASEE Annual Conferences in Indianapolis and Seattle, respectively. The third edition of the Civil Engineering Body of Knowledge for the 21st Century (BOK3) is scheduled to be finalized by October 2018. This third and final paper shares the CEPCTC insights, lessons learned, suggestions and recommendations with the BOK3 task committee and the rest of the academic and professional community.

Introduction

The American Society of Civil Engineers (ASCE) published the second edition of the *Civil Engineering Body of Knowledge* (BOK2) in 2008 expanding the knowledge, skills and attitudes required of future civil engineers. There were major changes to the BOK2 as the number of expected outcomes increased from 15 to 24 and the cognitive level of attainment was more precisely defined. A major implementation and enforcement mechanism for the BOK is the ABET accreditation criteria which includes both General Criteria 3 and 5 and the discipline-specific program criteria. Of those, the program criteria are the most appropriate and easiest to change. Even though General Criteria 3 and 5 are currently undergoing revision, affecting change through this effort is more difficult because the BOK2 applies exclusively to civil engineers while the General Criteria applies to many other engineering disciplines.

In 2013, ASCE created the Civil Engineering Program Criteria Task Committee (CEPCTC) whose charge was to determine if the current CEPC should be changed to reflect an additional one or more of the 24 outcomes of BOK2. After two years of meetings, conference calls, draft criteria, constituency input, and associated revisions, a proposed change to the CEPC was approved by ASCE and submitted to ABET for approval. The CEPC was supplemented with an associated commentary. The proposed CEPC completed its two-year ABET approval process in October 2015 and will go into effect for the 2016-2017 accreditation cycle. The results of the committee's work were presented in papers at the 2014 and 2015 ASEE Annual Conferences in Indianapolis and Seattle, respectively.[1,2]

The Body of Knowledge is a living document that will continue to be updated and revised. ASCE has developed an eight year cycle of change that will make future iterations of the BOK and CEPC both systematic and predictable.[3] As such, a Body of Knowledge Task Committee

(BOKTC) is scheduled to be formed in October 2016. The BOKTC could recommend no revisions, minor revisions, or extensive revisions to BOK2. If substantive changes are recommended to BOK2, the master plan calls for the completion of the third edition of the *Civil Engineering Body of Knowledge for the 21st Century* (BOK3) by October 2018 with publication in March 2019.

Because the CEPC was created to be compatible with the BOK2 outcomes, the CEPCTC studied the BOK2 in depth. The BOK2 is an aspirational and visionary document that only partially accounts for the real-world constraints faced by engineering programs in terms of mandated maximum units in an undergraduate program and additional requirements imposed by a state government or a university. Conversely, the ABET accreditation criteria (general plus program) define the minimum requirements for a program to receive accreditation. There will naturally be a gap between those two standards.

For the cycle of change to be successful, the insights and lessons learned from the development of the CEPC should be communicated with the BOKTC and vice versa. This paper attempts to do that. The paper will define the gap between (1) the BOK2 and (2) EAC/ABET accreditation criteria (General Criteria plus proposed CEPC as well as newly revised General Criteria plus proposed CEPC) and make recommendations for closing the gap. During their work, the CEPCTC encountered issues with the BOK2 that suggest potential revisions for the BOK3. This paper is a mechanism for sharing CEPCTC insights, lessons learned, suggestions and recommendations with the rest of the academic and professional community.

Composition of the Committee

The CEPCTC was comprised of a mix of distinguished civil engineering practitioners and experienced academics with considerable experience in the accreditation process. The committee was rounded out with ASCE staff members who are knowledgeable about education and the accreditation change and approval process.

Task Committee Members:

• **Rich Anderson (Chair)**: Somat Engineering, Inc.; Past-President of ABET; past Chair of the BOK2 Committee.
• **George Blandford:** CE Department Chair at University of Kentucky, past Chair of the Department Head Coordinating Council (DHCC), and active in ASCE educational committees.
• **Phil Borrowman:** Retired from Hanson Professional Services Inc.; Past-President of ABET and retired consulting engineer.
• **Donald Carpenter:** Professor of Civil Engineering and Past Director of Assessment, Lawrence Technological University with extensive experience in preparing ABET Self Studies.
• **Allen Estes:** Architectural Engineering Department Chair at California Polytechnic State University; experienced ABET PEV and active in ASCE Committee on Education and DHCC.
• **Jeff Evans:** Immediate Past CE Chair at Bucknell University; active in ASCE “Raise the Bar” committees.

• **Ken Fridley:** CE Chair at the University of Alabama; active in ASCE educational committees, past Vice-Chair of the BOK2 Committee, and prepared five ABET self-studies.
• **Tom Lenox:** Member of ABET Board of Directors; ASCE Executive VP Emeritus -- retired from ASCE staff after supporting various educational/professional initiatives.
• **Carolyn Merry:** (deceased) CE Past-Chair at The Ohio State University; active in ASCE educational activities and lead on several ABET self-studies.
• **Paul Mlakar:** U.S. Army Corps of Engineers, experienced ABET PEV, and member of ABET/EAC.
• **Ellen Stevens:** Consulting engineer, ABET/EAC PEV, and active in ASCE educational committees.
• **Jim O'Brien:** Ex-officio, ASCE staff, Managing Director, Professional & Educational Activities.

Photo 1: The CEPCTC conducts their second face-to-face meeting as ASCE Headquarters in Reston, Virginia in May 2014. Pictured from left to right are Jim O'Brien, Phil Borrowman, Ellen Stevens, George Blandford, Al Estes, Don Carpenter, Carolyn Merry, Rich Anderson, Ken Fridley, Tom Lenox, and Jeff Evans. Tragically, Carolyn Merry was killed in an automobile accident shortly after this meeting. We will all miss her.

• **Corresponding members** of the CECPTC include Angela Bielefeldt, University of Colorado – Boulder; Joseph Hanus, United States Military Academy; Kenneth Lamb, California State

Polytechnic University – Pomona; Daniel Lynch, Dartmouth College; Dennis Truax, Mississippi State University; David Vaccari, Stevens Institute of Technology; and Ronald Welch, The Citadel.

Proposed Criteria

Having completed the second and final reading of the ABET approval process, the following Civil Engineering Program Criteria will take effect for the 2016-2017 accreditation cycle:

PROGRAM CRITERIA FOR CIVIL AND SIMILARLY
NAMED ENGINEERING PROGRAMS
Lead Society: American Society of Civil Engineers

These program criteria apply to engineering programs that include "civil" or similar modifiers in their titles.

1. Curriculum
The curriculum ~~program~~ must prepare graduates to apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science~~, consistent with the program educational objectives~~; apply probability and statistics to address uncertainty; ~~apply knowledge of~~ analyze and solve problems in at least four technical areas appropriate to civil engineering; conduct ~~civil engineering~~ experiments in at least two technical areas of civil engineering and analyze and interpret the resulting data; design a system, component, or process in at least two ~~more than one~~ civil engineering contexts; include principles of sustainability in design; explain basic concepts in project management, business, public policy, and leadership; analyze issues in professional ethics; and explain the importance of professional licensure.

2. Faculty
The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience. The program must demonstrate that it is not critically dependent on one individual.

Approval Process

The revised CE program criteria was approved without change by the ASCE Committee on Accreditation on May 22, 2014. It was supported by the Department Heads Coordinating Council and approved without change by the ASCE Committee on Education on May 26, 2014. The committee's work was presented at a special session of the Civil Engineering Division of the American Society for Engineering Education (ASEE) at the ASEE Annual Conference in Indianapolis in June 2014[1]. The CEPC was forwarded to ABET on June 3, 2014, approved upon

first reading by the ABET-EAC on July 9, 2014, and approved upon first reading by the ABET Board of Directors on November 1, 2014. The proposed changes to the CEPC were formally accepted by ABET's first reading formal public review process on June 15, 2015. The second readings were accepted by the ABET-EAC and the ABET Board of Delegates in mid-July 2015 and October 17, 2015, respectively. The newly revised CEPC will become effective for the 2016-2017 accreditation cycle and ASCE is currently conducting a communication and education effort with its constituents.

The Commentary

The CEPCTC has written and approved a Commentary[4] to accompany the CEPC. The Commentary helps faculty, program evaluators, and other constituents interpret the program criteria. The Commentary can be very helpful in (1) providing the rationale behind the criteria and (2) communicating expectations to avoid misunderstandings and provide consistency among visits.

The Commentary is broken into parts A through D. Part A describes the purpose of the Commentary. Parts B and C provide a description of the BOK2 and the applicable ABET criteria, respectively. The most essential part is Part D (Understanding the CE Program Criteria) which divides the CEPC into 10 sections and examines each element of the criteria individually. The Commentary is covered in much greater detail in two 2015 ASEE papers[2,5].

With the approval of the new CEPC and the companion Commentary, the CEPCTC's work is done. After assisting with the communication effort, such as participating in the ASCE CEPC webinar[6], the CEPCTC will be dissolved. The responsibility for maintaining the CEPC and the Commentary will reside with the ASCE Committee on Accreditation (COA) and its Committee on Accreditation Operations (COAO).

The Future

Because change is both healthy and inevitable for a dynamic Civil Engineering profession, there will be future editions of the Body of Knowledge and CEPC. It is important that change is managed in a systematic and responsible manner. To that effort, ASCE has established an eight year cycle of updating the Civil Engineering Body of Knowledge and a corresponding eight year cycle of reviewing and updating the CEPC[7,8] as shown in Table 1. If the current schedule holds, constituents can expect BOK3 to be published in 2019 and a committee to review the CEPC organized in 2020 with its implementation effective for the 2024-2025 accreditation cycle.

As the CEPCTC and the BOK committees alternate in accomplishing their duties, historical information and lessons learned need to be communicated between them. The CEPCTC's source

document was the BOK2. Hopefully, the BOK3 committee will consider suggestions from the CEPCTC as it starts its work. What follows are the CEPCTC insights, lessons learned, suggestions and recommendations to those who will participate in future steps in this systematic process of change.

Event	BOK 2nd Edition	BOK 3rd Edition	BOK 4th Edition
BOK Committee of CAP[3] organized	Already accomplished	October 2016	October 2024
BOK finalized		September 2018	September 2026
BOK published		March 2019	March 2027
Accreditation Committee of CAP[3] organized		October 2020	October 2028
Draft CE Program Criteria published		March 2022	March 2030
CE Program Criteria approved by ABET EAC (1st reading)		July 2022	July 2030
CE Program Criteria approved by ABET Board of Directors (1st reading)		October 2022	October 2030
Public Review of CE Program Criteria initiated		November 2022	November 2030
CE Program Criteria approved by ABET EAC (2nd reading)		July 2023	July 2031
CE Program Criteria approved by ABET Board of Directors (2nd reading)		October 2023	October 2031
First Reviews Under New CE Program Criteria	September 2016	September 2024	September 2032

Table 1. ASCE schedule for continued eight-year cycle updates of the Body of Knowledge and the Civil Engineering Program Criteria

The Gap

The BOK2 is an aspirational and visionary document which may not account for all of the real-world constraints faced by engineering programs such as mandated maximum units in an undergraduate program and additional requirements imposed by a state government or a university. Conversely, the ABET program criteria define the minimum requirements for a program to receive accreditation. As such, there will naturally be a gap between those two standards. With the newest iteration of the CEPC completed, it is important to assess that gap between the requirements of the BOK2 at the undergraduate level and the newly revised CEPC.

The body of knowledge needed by the civil engineer of the future is constantly changing. While a few baccalaureate programs have revised their curriculum to include most or all of the BOK2

outcomes, mandating this change for all civil engineering programs over the next decade would be "too much, too fast." The CEPCTC changes to the CEPC reflect a perceived priority of value gained by the civil engineering profession, a continuation of spirit and intent of "raising the bar," and a recognition that further changes to the CEPC will still be necessary in the future – especially as the next versions of the body of knowledge are developed.

In order to assess whether the gap is reasonable, it must first be defined. Appendix A compares the baccalaureate degree recommendations for civil engineering as specified in BOK2 with the ABET accreditation criteria. This ABET accreditation criteria are a combination of the General Criteria specified in Criteria 3 (Student Outcomes) and 5 (Curriculum) and the newly revised CEPC.

As shown in the last column of the table in Appendix A, there is no gap between the BOK2 requirements and accreditation criteria for BOK2 Outcomes 1 (Mathematics), 2 (Natural Sciences), 4 (Social Sciences), 7 (Experiments), 8 (Problem Recognition and Solving), 9 (Design), 14 (Breadth in Civil Engineering Areas), 15 (Technical Specialization), 17 (Public Policy), 21 (Teamwork), and 23 (Lifelong Learning). The wording of the two standards is almost identical and those BOK2 outcomes should be fully met. There is a partial gap with respect to Outcomes 5 (Materials Science), 6 (Mechanics), 10 (Sustainability), 11 (Contemporary Issues and Historical Perspectives), 12 (Risk and Uncertainty), 13 (Project Management), 16 (Communication), 18 (Business and Public Administration), 19 (Globalization), 20 (Leadership), 22 (Attitudes), and 24 (Professional and Ethical Responsibility). A partial gap typically indicates that the accreditation criteria includes a portion of the outcome but not all of it or it requires a lower cognitive level than specified in BOK2. Finally, there is a total gap for Outcome 3 (Humanities) meaning that there is nothing in the accreditation criteria that assures attainment of any portion of this outcome.

This does not mean that the outcomes with a partial or total gap are currently missing from most civil engineering programs. Even with respect to Outcome 3 (Humanities), most programs include humanities in their general education requirements and many programs make an effort to relate those humanities to the practice of engineering. There is just nothing in the accreditation criteria that mandates this.

One might ask why there is not a total gap with respect to Outcomes 5 (Materials Science) and 6 (Mechanics). There is nothing in the proposed accreditation criteria that specifically mandates courses or course coverage in those areas. The rationale for a partial gap is that the CEPC requires problem solving in four areas of civil engineering and the committee argued that attainment would be impossible without a background knowledge of solid and fluid mechanics. By that rationale, one might question why the gap is partial rather than having no gap. It would be possible to have minimal coverage to solve some civil engineering problems at the

undergraduate level but have insufficient coverage to meet the intent of the BOK2 Outcome 6 (Mechanics). For example, one could solve problems in the areas of structures, geotechnical, transportation and construction without an extensive knowledge of fluid mechanics.

With respect to Outcome 5 (Materials Science), the BOK2 is not sufficiently clear. Because the BOK2 refers to "understanding of materials at the macroscopic and microscopic levels", this would indicate the need for a materials science course. Many CE programs have a course in Material Science, but admittedly many do not. If a course in Materials Science is required, any potential gap would be greatly reduced. BOK2 further states, "Construction materials with broad applications in civil engineering include such ceramics as Portland cement concrete and hot mix asphalt concrete, such metals as steel and aluminum, and polymers and fibers. Infrastructure often requires repair, rehabilitation, or replacement due to degradation of materials.[9]" Most, if not all, civil engineering curricula have some coverage of construction materials. The committee believed that it is impossible to solve problems in four areas of civil engineering and conduct experiments in two areas of civil engineering without significant coverage of materials as described in BOK2. Thus the gap is only partial.

The BOK2 outcome at the undergraduate level requires graduates to organize and deliver effective verbal, written, virtual, and graphical communications. The BOK2 defines virtual communication as communication created, simulated, or carried on by means of a computer or other network. The BOK2 rightly asserts that "within the scope of their practice civil engineers prepare and/or use calculations, spreadsheets, equations, computer models, graphics, and drawings—all of which are integral to a typically complex analysis and design process" and thus need to be able to communicate effectively in these areas[9]. The CEPC has no specific provision for communication and the current ABET General Criterion 3(g) requires graduates attain an ability to communicate effectively. ABET Criterion 3(g) is often interpreted to encompass written and spoken communication. To ensure inclusion of virtual and graphical communication, it would need to be explicitly included in the CEPC, thus creating a partial gap.

There are three BOK2 outcomes where partial gaps were created as a result of constituent feedback: Outcomes 10 (Sustainability), 12 (Risk and Uncertainty), and 13 (Project Management). The initial draft of the CEPC was completely compliant with the BOK2 in these areas. The cognitive levels of these outcomes were lowered in response to constituent feedback, especially from the civil engineering department heads. The details of the feedback to include a CE department head survey and rationale for these changes are described in a previous paper[2].

The partial gap that exists with respect to Outcomes 11 (Contemporary Issues and Historic Perspectives), 18 (Business and Public Administration), 19 (Globalization), 20 (Leadership), and 24 (Professional and Ethical Responsibility) are described in Appendix A and the previous paper[1]. The CEPCTC included a number of veteran CE department heads who helped strike a

balance between BOK2 compliance and the realities facing civil engineering programs today. The committee prioritized the outcomes to ensure the most important ones were adopted.

Outcome 22 (Attitudes) was a bit difficult. While there is an overlap with professional and ethical responsibility, the attitudes suggested in BOK2 Outcome 22 (Attitudes) include "commitment, confidence, consideration of others, curiosity, entrepreneurship, fairness, high expectations, honesty, integrity, intuition, judgment, optimism, persistence, positiveness, respect, self-esteem, sensitivity, thoughtfulness, thoroughness, and tolerance". Those attitudes are built over a lifetime and are a function of role models, mentors and experiences that are largely outside the curriculum. They are very difficult to incorporate into a CEPC that is restricted to curricular issues. Still, it could be argued that this topic is embedded in several existing requirements in both the General Criteria and the newly revised CEPC. By the time students have functioned on a multidisciplinary team, demonstrated an understanding of professional and ethical responsibility, recognized the need for life-long learning, explained basic concepts in leadership, analyzed issues in professional ethics, and explained the importance of professional licensure, they have met much of this outcome. Nevertheless, a partial gap will probably always be present in this area.

Effect of Newly Proposed ABET General Criteria

ASCE and the CEPCTC used the CEPC as the mechanism for integrating the BOK2 requirements into the accreditation process. The ABET General Criteria have been in effect for a decade and a half and changing them is cumbersome and includes a large constituency outside of the civil engineering community. The CEPCTC operated under the logical assumption that the ABET General Criteria would not change for several more years. As it turns out, significant changes to the General Criteria were being considered by the EAC.

The ABET EAC Criteria Committee appointed a Criterion 3 task force in 2009 to propose changes to that portion of the ABET General Criteria. The Criterion 3 task force identified and engaged stakeholders, created surveys, studied the issues, developed draft criteria and presented their findings to EAC Criteria Committee and full EAC in July 2013. The EAC Criteria Committee continued the effort and sought comment on the proposed criteria. After receiving more than 100 comments, the committee made changes, and submitted the proposed General Criteria to EAC for adoption in the summer of 2015. In July 2015, substantially revised Criteria 3 and 5 were approved by the EAC; and in October 2015, the EAC presented the proposed General Criteria to the Engineering Area Delegation (EAD) of the ABET Board of Delegates for approval. The EAD approved the proposed General Criteria on first reading, albeit with considerable discussion and some dissent. The proposed General Criteria are currently undergoing public review, with the public comment period ending on June 30, 2016.[10] They could be considered for final approval by the EAC and the EAD in July 2016 and October 2016,

respectively. If approved by both the EAC and EAD, these proposed General Criteria could go into effect as early as the 2017-2018 accreditation cycle.

"The Proposed Revisions To Criteria for Accrediting Engineering Programs, Definitions, General Criterion 3 Student Outcomes and General Criterion 5 Curriculum"[11] do not offer many substantive changes. Some of the current Criterion 3(a-k) outcomes have been combined to create the proposed Criterion 3(1-7) outcomes. According to some EAC leaders, these changes could serve to align ABET criteria more closely with Washington Accord graduate attributes.[12] The seven proposed Criterion 3(1-7) outcome categories are: 1. Engineering problem solving, 2. Engineering design, 3. Measurement, testing, and quality assurance, 4. Communication skills, 5. Professional responsibility, 6. Professional growth, and 7. Teamwork and project management. The seventh outcome was added in response to constituent input. Some of the current Criterion 3(a-k) outcomes have been moved to criterion 5 in the new proposal. Some key definitions or explanations have been placed in a list of definitions[13].

The obvious issue for the CEPCTC is the effect of these proposed General Criteria changes on the CEPC and the current gaps between accreditation criteria and the BOK2. While the effect is not major, the proposed General Criteria create some new partial gaps and remove some existing gaps as shown in Appendix A. The proposed General Criteria are included in Appendix A and the italicized print describes the effect of these changed criteria on the extent of the gap. The effect of the new General Criteria on the gap are as follows:

- BOK2 Outcome 9 (Design) states that the baccalaureate degree should prepare students to "design a system or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability." Compliance is attained from the current General Criterion 3 which provides a similar list of constraints to be included in the design. The proposed General Criterion 3(2) only requires "an ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs" which is far less specific and creates a gap with the BOK2. The list of EAC definitions in the proposed General Criteria however define engineering design as "the process of devising a system, component, or process to meet desired needs, specifications, codes, and standards within constraints such as health and safety, cost, ethics, policy, sustainability, constructability, and manufacturability." Without these constraints being explicitly stated in the General Criteria, it is difficult to tell the level of compliance and enforcement that will come from the definition. Said another way, it is unclear whether the implied requirement to consider constraints as part of the design process is enforceable. If not, this change would represent a significant new gap between the proposed EAC Criteria and BOK2.
- A wider gap is created with respect to BOK2 Outcome 11 (Contemporary Issues and Historic Perspectives) where the ABET General Criteria currently ensure partial

attainment of the outcome. The proposed General Criteria are silent on "explaining the impact of historical and contemporary issues". A knowledge of contemporary issues is contained in Criterion 3(j) of the current criteria but is absent from the proposed criteria. The knowledge of historic perspectives is absent from both the current and proposed General Criteria.

- The current gap in BOK Outcome 12 (Risk and Uncertainty) is caused by a lowering of the cognitive level from analysis to comprehension with regard to quantifying uncertainty. The proposed General Criteria reduces or potentially eliminates the gap in Criterion 3(7) by specifically requiring "analysis of risk and uncertainty". This is a new provision to the ABET General Criteria and degree to which risk and uncertainty will be analyzed versus merely explained is yet to be determined. The EAC Criteria Committee did not use Bloom's Taxonomy[14] to quantify the cognitive level of attainment precisely, so the meaning of analysis is less certain than its meaning in the CEPC.
- A new gap results in BOK2 outcome 21 (Teamwork) where students must function effectively as members of an intra-disciplinary team. The BOK2 defines intra-disciplinary team as one consisting of members from the different civil engineering sub-disciplines and multidisciplinary is composed of members from different professions.[9] Current general Criterion 3(d), an ability to function on multidisciplinary teams, is a higher standard than required in the BOK2 and thus there was no gap. The proposed General Criteria addresses teams in Criterion 3(7) and in the definition of teams. Neither require any mixture of different disciplines or sub-disciplines on the teams.
- The current gap in BOK2 Outcome 24 (Professional and Ethical Responsibility) is removed in the proposed General Criteria. The gap was created when the CEPC required analysis level attainment for ethics but only comprehension level attainment for professional responsibility.[1,2]. Criterion 3(5) of the proposed General Criteria requires "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments" which implies analysis level thought in both areas.

In summary, the changes in the gap with the proposed EAC General Criteria are minor which is not surprising. The proposed General Criteria offers very few changes from the current General Criteria. The words are mostly the same; they have simply been combined and reordered so the effect on the CEPC is negligible.

Advice for the BOK3 Committee

Hopefully, the BOK3 committee will consider suggestions from the CEPCTC as it starts its work. Some of the CEPCTC recommendations include:

- **Basic versus Natural Science.** The BOK2 states that undergraduates should be able to solve problems in chemistry, physics and one additional area of the natural sciences. The

BOK2 infers that natural science includes physics, chemistry and "natural science disciplines such as biology, ecology, geology/geomorphology, et cetera." The ABET definition of basic sciences from current General Criterion 5a is "biological, chemical and physical sciences". The definition of basic science in the proposed General Criteria is "chemistry and physics, and other biological, chemical, and physical sciences, including astronomy, biology, climatology, ecology, geology, meteorology, and oceanography". The committee debated this topic at length and in the first draft version of the proposed CEPC used the term natural science because it was believed to be more precise. Ultimately, the CEPCTC could not think of a single example where an area of science would count for one definition but not the other. To avoid confusion and to maintain consistency with the current General Criteria definition, the newly revised CEPC uses the term basic sciences. The CEPCTC recommends that the BOK3 consider adopting the term basic science.

- **Mechanics and Natural Science mismatch.** The discussion of this issue revealed a potential mismatch in standards between BOK2 Outcome 2 (Natural Sciences) which is fairly prescriptive in the amount of natural science required at the undergraduate level and BOK Outcome 6 (Mechanics) which simply requires undergraduates to solve problems in solid and fluid mechanics. For a constrained CE program that is trying to make tough decisions on what to eliminate from its curriculum, the BOK2 seems to allow flexibility to cut electrical circuits, rigid body dynamics and thermodynamics but offers no flexibility on the additional area of science. Whether this distinction was intentional or not should be addressed by the committee that creates the BOK3.
- **Risk and Uncertainty.** The baccalaureate BOK2 Outcome 12 (Risk and Uncertainty) is, "apply principles of probability and statistics to solve problems containing uncertainty." After input from constituents, the CEPCTC changed the newly revised CEPC to read, "apply principles of probability and statistics to address uncertainty." The change was intended to reduce the emphasis on solving problems and focus more on addressing uncertainty in a qualitative manner, which reduced the mandate for a separate course in probability and statistics. Furthermore, taking a course in probability and statistics without addressing any of the uncertainty associated with civil engineering would not meet the intent of the criteria. After much discussion, the CEPCTC concluded that risk and uncertainty should go together and both should be included in the outcome. Adding risk to the CEPC would be exceeding the requirements stated in the BOK2 and the CEPCTC was not willing to do that. Finally, one astute constituent made the comment that one could take a course in probability and statistics and solve problems containing uncertainty and yet never address a civil engineering problem. The BOK2 explanation is clear that "a basic understanding of risk and uncertainty must be incorporated into the civil engineering department courses"[9] but that is not explicitly stated in the outcome. The CEPCTC recommends that the BOK3 baccalaureate outcome be changed to read,

"apply principles of probability and statistics to address risk and uncertainty in civil engineering problems."

- **Material science** – The committee struggled to determine whether or not a material science course was needed to satisfy the undergraduate requirements of BOK2 Outcome 5 (Materials Science) to "use knowledge of materials science to solve problems appropriate to civil engineering". The BOK3 Committee is encouraged to revise the narrative to make it clearer as to whether a materials science course is needed. The CEPCTC recommendation is that most undergraduate materials problems can be solved without a mandated material science course.
- **Additional area of science.** There remains the potential for significant confusion and misunderstanding for what constitutes an additional area of basic science. Despite the opposition from a vocal minority, the CEPCTC supported the requirement for additional science as written in the BOK2 and incorporated it into the newly revised CEPC. It has been well established that computer science, materials science and thermodynamics do not qualify as additional areas of basic (natural) science. The requirement that the additional area of science be disconnected from physics and chemistry is more problematic and open to different interpretations. Wikipedia[15] (not the most scholarly resource, but the one where evaluators might initially go) states that major sub-disciplines of atmospheric sciences are meteorology, climatology, atmospheric chemistry and atmospheric physics. Two of these would meet the requirement for additional science and two would not. Geophysics and geodesy investigate the shape of the earth, its reaction to forces and its magnetic and gravity fields. Geodesy would meet the requirement for extra science while geophysics would not. Seismology, which seems like a safe additional area of science, is considered by some to be a sub-discipline of geophysics. There is lots of room for misinterpretation and splitting of hairs.

  Furthermore, there are advanced areas of physics and chemistry that would meet the intent of an additional area of science and raising the bar. Some civil engineering students might benefit more from a course in organic chemistry than a course in ecology. Many programs offer a third semester of modern physics which includes sub-atomic particles, relativity, and basic nuclear theory. It is sufficiently different from Newtonian physics to constitute an additional area of science, especially for a student interested in nuclear energy and design. The CEPCTC recommends that the BOK Outcome 2 narrative be more flexible in this area or be more complete to mitigate different interpretations.
- **Remove "well-defined" from types of problems to be solved.** BOK2 Outcome 8 (Problem Solving and Recognition) requires baccalaureate engineers to "develop problem statements and solve well-defined fundamental civil engineering problems by applying appropriate techniques and tools." The initial proposed CEPC (as of December 2013) stated, "analyze and solve well-defined problems in at least four technical areas appropriate to civil engineering." The term "well-defined" caused confusion and produced so many comments from reviewers that it was eliminated in the later version.

Comments included that engineers solve open-ended problems, "well-defined" did not soften the increase in cognitive level as intended, and the term "well-defined" had a more derogatory meaning in other educational literature. It is important to note that subsequent to BOK2 being published, the International Engineering Alliance (IEA) developed outcome definitions[12] for engineers, engineering technologists, and engineering technicians. Future authors of BOK3 and future changes to the CEPC will need to consider those definitions to assure graduates from civil engineering programs accredited by ABET can remain internationally recognized as engineers. The CEPCTC changed the proposed CEPC to eliminate the words "well-defined". The CEPCTC recommends that the words "well-defined" be removed from this outcome in the BOK3.

- **Lower threshold on sustainability.** The BOK2 level of attainment for sustainability is Bloom's Level 3 – application. The sustainability outcome was rated as being very important by the CEPCTC. ASCE is a recognized leader in this advancing area. The first draft version of the proposed CEPC required students to "apply principles of sustainability in design." Upon further reflection and comments from constituents, this standard may be too difficult to attain without creating a separate course in sustainability which was not the committee's intent. The proposed CEPC was changed to "include principles of sustainability in design" which allows a more qualitative approach and lowers the cognitive level required. The BOK2 states that "mastery of scientific understanding of natural resources and the environment is implied" and this mastery "must rest on a wide educational base."[9] It is easy to assume that such mastery would require, as a minimum, an entire course in this area. The CEPCTC recommends that the BOK3 Committee consciously consider whether an entire course in sustainability is required. If so, the outcome and its explanation should remain unchanged. If not, the BOK3 Committee should consider softening the outcome and its explanation at the baccalaureate level.
- **Technical specialization**. The BOK2 lists the baccalaureate degree level of cognitive achievement for Outcome 15 (Technical Specialization) as Bloom's level 1 which is specified as "Define key aspects of advanced technical specialization appropriate to civil engineering." In reality, the baccalaureate degree accomplishes Bloom's level 3: "Apply specialized tools, technology, or technologies to solve simple problems in a traditional or emerging specialized technical area of civil engineering". This is currently listed as an "M/30" (masters or equivalent) accomplishment. Admittedly, no basic level of achievement in technical specialization is explicitly required in the newly revised civil engineering accreditation criteria. Nevertheless, one could convincingly argue that after an undergraduate student has *analyzed and solved problems in at least four technical areas appropriate to civil engineering, conducted civil engineering experiments in at least two technical areas of civil engineering and designed a system, component, or process in at least two civil engineering contexts*, that student has attained Bloom's Level

3 for Outcome 15 (Technical Specialization). The BOK3 could potentially be updated to recognize and reflect this.

- **Revised Bloom's**. Recent literature has recommended a revision to Bloom's taxonomy[16] where the top two cognitive levels of synthesis (design) and evaluation are reversed. The BOK2 uses the original version of Bloom's taxonomy[14] and the CEPCTC consciously made the decision to use the original version in the CEPC and associated commentary. The BOK3 committee should examine the literature and make a separate analysis and decision on the subject.
- **Evaluate the gap.** The BOK3 committee should study the work of the CEPCTC and the resulting program criteria that was adopted. The rationale behind the decisions to create this gap are covered extensively in previous papers[1,2]. Perhaps the gap between the BOK3 and the newly revised CEPC can be reduced by lowering the requirement at the baccalaureate level in the BOK3 in certain areas. Perhaps the gap is inevitable and appropriate and as such, the aspirational vision of the undergraduate education should not be compromised to reduce that gap. The gap should at least be acknowledged and discussed by the BOK3 committee.

Conclusion

The work of the CEPCTC is complete, the new CEPC will go into effect for the 2016-2017 accreditation cycle. ASCE will continue to define the knowledge, skills and attitudes required of a civil engineer at the baccalaureate, masters, and pre-licensure experience levels through the Body of Knowledge. The accreditation criteria are the most effective means of "operationalizing" the Body of Knowledge at the university level. The CEPC is the most effective means of changing the accreditation criteria and there is a systematic continuous plan for that change in effect. The ABET General Criteria gets revised far less frequently or predictably. The first major revision in fifteen years is currently underway. As articulated in this paper, the substantive changes are minor.

The next major event is the formation of the BOKTC to revise the body of knowledge and create the BOK3. Hopefully this paper offers some insights and lessons learned when they start their work. As new editions of the BOK are published, a committee of practitioners and academic representatives should continue to revise the accreditation criteria that promote BOK-compliance at a level that is reasonable and sustainable given the constraints faced by civil engineering programs. It is a delicate balance that attracts a multitude of input from a variety of constituents. As long as the committee continues to seek constituent input, listens to the feedback, and communicates the rationale for the decisions, the process will be much better received by the community at large.

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Appendix A: Defining the Gap Between the BOK2 Baccalaureate-Level Standard and the Proposed ABET Accreditation Criteria

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard*	Current General Criteria	Proposed General Criteria	Civil Engineering Program Criteria	Existing Gap
1 Mathematics	B3: Solve problems in mathematics through differential equations and apply this knowledge to the solution of engineering problems.	Criterion 3 (a): an ability to apply knowledge of mathematics, science, and engineering Criterion 5 (a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences.	Criterion 3 (1): an ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics Criterion 5 (a) one academic year of a combination of college-level mathematics and basic sciences (some with experimental experience) appropriate to the program.	apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science.	No gap
2 Natural Sciences	B3: Solve problems in calculus-based physics, chemistry, and one additional area of natural science and apply this knowledge to the solution of engineering problems.	Criterion 5 (a): one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences.	Criterion 5 (a) one academic year of a combination of college-level mathematics and basic sciences (some with experimental experience) appropriate to the program. Basic sciences consist of chemistry and physics, and other biological, chemical, and physical sciences, including astronomy, biology, climatology, ecology, geology, meteorology, and oceanography.	apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science.	No gap

*Note: the designations B1 through B5 used in the second column of this table indicate the BOK2 goal for baccalaureate-level education using the cognitive levels of Bloom's Taxonomy. The six possible cognitive levels of Bloom's Taxonomy are (1) Knowledge, (2) Comprehension, (3) Application, (4) Analysis, (5) Synthesis, and (6) Evaluation[14]

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard	Current General Criteria	Proposed General Criteria	Civil Engineering Program Criteria	Existing Gap
3 Humanities	B3: Demonstrate the importance of the humanities in the professional practice of engineering.	Criterion 5(c): a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.	Criterion 5(c) a broad education component that includes humanities and social sciences, complements the technical content of the curriculum, and is consistent with the program educational objectives.		Total gap: the General Criterion is too nebulous to prescribe anything and CEPC is silent
4 Social Sciences	B3: Demonstrate the incorporation of social sciences knowledge into the professional practice of engineering.	Criterion 3(h): the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Criterion 3(5). An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.		No gap
5 Materials Science	B3: Use knowledge of materials science to solve problems appropriate to civil engineering.	Criterion 5(b): one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study.	Criterion 5(b): one and one-half academic years of engineering topics, consisting of engineering sciences and engineering design appropriate to the program and utilizing modern engineering tools.	analyze and solve problems in at least four technical areas appropriate to civil engineering	Partial gap: Nothing to ensure material science is taught

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard	Current General Criteria	Proposed General Criteria	Civil Engineering Program Criteria	Existing Gap
6 Mechanics	B4: Analyze and solve problems in solid and fluid mechanics.	Criterion 5(b): one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study.	Criterion 5(b): one and one-half academic years of engineering topics, consisting of engineering sciences and engineering design appropriate to the program and utilizing modern engineering tools.	analyze and solve problems in at least four technical areas appropriate to civil engineering	Partial gap: Nothing to ensure solid and fluid mechanics are taught
7 Experiments	B4: Analyze the results of experiments and evaluate the accuracy of the results within the known boundaries of the tests and materials in or across more than one of the technical areas of civil engineering	Criterion 3(b): an ability to design and conduct experiments, as well as to analyze and interpret data	Criterion 3(3): an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	conduct experiments in at least two technical areas of civil engineering and analyze and interpret the resulting data	No gap
8 Problem Recognition and Solving	B3: Develop problem statements and solve well-defined fundamental civil engineering problems by applying appropriate techniques and tools.	Criteria 3(e): an ability to identify, formulate, and solve engineering problems and Criterion 3 (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Criteria 3(1): an ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics. Criterion 5(b): ...utilizing modern engineering tools.	analyze and solve problems in at least four technical areas appropriate to civil engineering	No gap

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard	Current General Criteria	Proposed General Criteria	Civil Engineering Program Criteria	Existing Gap
9 Design	B5: Design a system or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.	Criterion 3 (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	Criterion 3 (2): an ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs.	design a system, component, or process in at least two civil engineering contexts;	No gap *Partial gap potentially results in proposed General Criteria; desired needs not as well defined although specifics included in design definition*
10 Sustainability	B3: Apply the principles of sustainability to the design of traditional and emergent engineering systems.			include principles of sustainability in design	Partial gap: CEPC only requires comprehension level 2 (B2) attainment
11 Contemporary Issues and Historic Perspectives	B3: Drawing upon a broad education, explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and explain the impact of engineering solutions on the economy, environment, political landscape, and society.	Criterion 3 (h): the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context and Criterion 3 (j): a knowledge of contemporary issues	Criterion 3(5). An ability to … make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.		Partial gap: Contemporary issues are adequately covered but no requirement to include historical perspectives *Gap increases in proposed General Criteria; contemporary issues not included*

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard	Current General Criteria	Proposed General Criteria	Civil Engineering Program Criteria	Existing Gap
12 Risk and Uncertainty	B3: Apply the principles of probability and statistics to solve problems containing uncertainties.		Criterion 3(7): an ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.	apply probability and statistics to address uncertainty	Partial gap: CEPC only requires comprehension level 2 attainment with respect to uncertainty *Proposed General Criteria reduces the gap with specific analysis of risk and uncertainty*
13 Project Management	B3: Develop solutions to well-defined project management problems.		Criterion 3(7): an ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.	explain basic concepts in project management, business, public policy, and leadership	Partial gap: CEPC only requires comprehension level 2 attainment with respect to project management
14 Breadth in Civil Engineering Areas	B4: Analyze and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering.			analyze and solve problems in at least four technical areas appropriate to civil engineering	No gap

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard	Current General Criteria	Proposed General Criteria	Civil Engineering Program Criteria	Existing Gap
15 Technical Specialization	B1: Define key aspects of advanced technical specialization appropriate to civil engineering.	Criterion 3(k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Criterion 5(b): one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study.	Criterion 5(b): one and one-half academic years of engineering topics, consisting of engineering sciences and engineering design appropriate to the program and utilizing modern engineering tools.	analyze and solve problems in at least four technical areas appropriate to civil engineering	No gap
16 Communication	B4: Organize and deliver effective verbal, written, virtual, and graphical communications.	Criterion 3 (g): an ability to communicate effectively	Criterion 3 (4): an ability to communicate effectively with a range of audiences.		Partial gap: no requirement for graphical or virtual com-munications
17 Public Policy	B2: Discuss and explain key concepts and processes involved in public policy.			explain basic concepts in project management, business, public policy, and leadership	No gap
18 Business and Public Administration	B2: Explain key concepts and processes used in business and public administration.			explain basic concepts in project management, business, public policy, and leadership	Partial gap: No requirement for public administration

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard	Current General Criteria	Proposed General Criteria	Civil Engineering Program Criteria	Existing Gap
19 Globalization	B3: Organize, formulate, and solve an engineering problem in a global context.	Criterion 3 (h): the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Criterion 3 (5): an ability to … make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.		Partial gap: General Criteria implies level 2 (B2) attainment while BOK2 requires level 3 (B3)
20 Leadership	B3: Apply leadership principles to direct the efforts of a small, homogenous group.			explain basic concepts in project management, business, public policy, and leadership	Partial gap: CEPC only requires comprehension level 2 attainment with respect to leadership
21 Teamwork	B3: Function effectively as a member of an intra-disciplinary team	Criterion 3(d): an ability to function on multidisciplinary teams	Criterion 3(7): an ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.		No gap *Partial gap results in proposed General Criteria; no requirement for intra-disciplinary teams*

Civil Engineering BOK2		ABET Accreditation Criteria			
Outcome	BOK Baccalaureate Standard	General Criteria	General Criteria	Civil Engineering Program Criteria	Existing Gap
22 Attitudes	B2: Explain attitudes supportive of the professional practice of civil engineering.	Criterion 3 (f): an understanding of professional and ethical responsibility	Criterion 3 (5): an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments …		Partial gap: General Criteria only touches on elements of this outcome.
23 Life-long Learning	B3: Demonstrate the ability for self-directed learning.	Criterion 3 (i): a recognition of the need for, and an ability to engage in life-long learning	Criterion 3 (6): an ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately.		No gap
24 Professional and Ethical Responsibility	B4: Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action.	Criterion 3 (f): an understanding of professional and ethical responsibility	Criterion 3 (5): an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	analyze issues in professional ethics; and explain the importance of professional licensure.	Partial gap: CEPC covers level 4 attainment (B4) with respect to ethics but is silent on professional responsibility. General Criteria only hits level 2.(B2) *Proposed General Criteria eliminates the gap with requirement to make informed judgments based on real world considerations.*