AC 2008-611: THE NEW AND IMPROVED CIVIL ENGINEERING BODY OF KNOWLEDGE

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The New and Improved Civil Engineering Body of Knowledge

Abstract

In January 2004 the American Society of Civil Engineers (ASCE) published the Civil Engineering Body of Knowledge for the 21st Century report (BOK1)[1]. Based on the favorable reception of the BOK1 in the civil engineering community, ASCE embarked on a revision of the BOK to take advantage of the comments received and the lessons learned in early implementation of the BOK1. Late in 2005 ASCE initiated the Second Edition of the Body of Knowledge Committee (BOK2Cmte) under the auspices of the Committee on the Academic Prerequisites for Professional Practice (CAP^3). The BOK2Cmte committee started with what had been accomplished in implementation of the BOK1 but with no preconceived notions on what should be included or excluded from the civil engineering Body of Knowledge. The committee initiated the revision of the BOK by identifying over 30 topics as candidates for inclusion in the new BOK, including the 11 from the ABET/EAC. Through a rigorous process, the desired level of achievement of each of the topics, or outcomes, was determined according to Bloom's Taxonomy of the Cognitive Domain. The number of outcomes was eventually whittled down to a comprehensive, coordinated list of 24 outcomes divided into three outcome categories; Foundational, Technical and Professional. In addition, the level of achievement expected to be achieved prior to entry into the professional practice of civil engineering is identified for each outcome. Each of the Bloom's levels of achievement for each outcome is also assigned to a stage in the young engineer's career, from the baccalaureate degree program, to post-baccalaureate formal education, to pre-licensure working experience. Next, the BOK2 will be reviewed by a new committee, the BOK Educational Fulfillment committee, which will assemble best practices for use in fulfilling the BOK through formal education.

Introduction

In February 2008 the American Society of Civil Engineers (ASCE) published the Second Edition of the Civil Engineering Body of Knowledge (BOK2)[2]. The publication of this document is the culmination of over two years of research, study and hard work by the Second Edition of the Body of Knowledge Committee (BOK2Cmte). The Second Edition of the BOK document has built on the content and success of the First Edition and gone beyond in terms of content, clarity, and responsibilities.

For the purposes of this paper, the following terminology is used:

BOK = Civil Engineering Body of Knowledge
BOK1Cmte = The ASCE/CAP^3 committee charged with developing the first edition of the report on the BOK
BOK1= The report developed by the BOK1 committee, Reference 1
BOK2Cmte = The ASCE/CAP^3 committee charged with developing the second edition of the report on the BOK
BOK2= The report developed by the BOK2 committee, Reference 2

Improvements to the Second Edition relative to the First Edition include a better system of identifying the level of achievement (as opposed to the level of competence) expected of the engineering student and the young practicing engineer, a system of allocating responsibility and the timing of that responsibility for achievement of the respective outcomes, and more clarity in the comprehensive, coordinated list of 24 outcomes that will be required for entry into the professional practice of civil engineering in the 21st Century.

First Edition of the Civil Engineering Body of Knowledge

The First Edition of the Civil Engineering Body of Knowledge (BOK1)[1] report was published by ASCE in January 2004. The essence of the BOK1 was the 15 outcomes, the attainments of which were defined as prerequisites for entry into the professional practice of civil engineering in the 21st Century. This document leaned heavily on the ABET General Criteria as developed by the Engineering Accreditation Commission of ABET (ABET/EAC)[3]. Nominally, eleven of the fifteen outcomes identified in the BOK1 were directly related to the ABET/EAC General Criteria 3(a-k).

"In addition to the 11 ABET outcomes, which are included verbatim in the 15 BOK outcomes, four entirely new outcomes (Outcomes 12-15) address technical specialization, project management, construction, asset management, business and public policy and administration, and leadership." [1]

Upon embarking on the BOK1, ASCE was cognizant that this would be a long-term iterative learning process and subsequent work would be required. The BOK1 was successful in stimulating dialogue amongst civil engineers and within the engineering community at-large. ASCE promoted this dialogue by presenting or attending many forums in which the BOK1 was discussed, challenged, dissected, and critiqued. ASCE recorded and catalogued the content of these forums in full anticipation that some day a Second Edition would be required. Because of the richness of these conversations on the BOK1, that day came sooner than many expected. The BOK has evolved into a process to help achieve the ASCE aspirational vision that is strategic, future focused, and comprehensive. It is a dynamic document and not a static, backwards looking document.

In addition, parallel to, but completely independent of, the ASCE BOK efforts, other engineering groups were also evaluating the changes needed in engineering education and practice for the 21st Century. These evaluations included the seminal studies from the National Academy of Engineering (NAE), "The Engineer of 2020"[4] and "Educating the Engineer of 2020[5]. A broader constituency was energized with the NAE national call to action "Rising Above the Gathering Storm" [6]. This document presented a roadmap for engineering and science for what the nation needs to do to maintain our eminence in these fields. The publication of these studies by the NAE opened the discussion to a much wider audience with a broader agenda. And, coincidentally, they lent credibility and urgency to the ASCE efforts to reform civil engineering education in preparation for the changing requirements of the new century.

ASCE Vision

In June 2006, a diverse group of civil engineering and other leaders, including international participants, gathered to articulate an aspirational 2025 global vision for the future of civil engineering. Participants in this Summit on the Future of Civil Engineering saw a very different world for civil engineers in 2025. An ever-increasing global population that is shifting even more to urban areas will require widespread adoption of sustainability. Demands for energy, transportation, drinking water, clean air, and safe waste disposal will drive environmental protection and infrastructure development. Society will face threats from natural events, accidents, and perhaps other causes such as terrorism.[7]

Informed by the preceding, an aspirational global vision was developed that sees civil engineers entrusted by society to lead in the creation of a sustainable world and enhancing the global quality of life. The report resulting from this vision setting gathering, "The Vision for Civil Engineering in 2025"[7], provided further input for the revision of the BOK1. In fact there was significant potential synergism between the Vision and the BOK efforts.

Second Edition of the Civil Engineering Body of Knowledge

Based on the groundswell of opinions and the plethora of reports and studies that indicated the time for engineering education reform has come, ASCE elected in 2005 to revise the BOK1 to reflect the consensus that had developed since the development of the BOK1. Thus, in late 2005 the Second Edition of the Civil Engineering Body of Knowledge Committee (BOK2Cmte) was formed for the specific purpose of revising the BOK1 to reflect all that had happened in this arena in the intervening years.

BOK2Cmte was formed as a constituent committee of the Committee on the Academic Prerequisites for Professional Practice (CAP^3), the Board level committee charged with the implementation of ASCE Policy Statement 465. An open call for potential committee members was made, and as a result, appointment to the 14 funded positions on the BOK2Cmte was very competitive. The result was that the diversity inherent in the ASCE membership was maintained so that all sectors of the ASCE membership had a voice. In addition, because there were far more applicants than funded positions available, other interested people were invited to be corresponding members. A total of about 50 people ultimately signed on to become corresponding members, with approximately 10 of those from outside of the United States. These 50 people were primarily civil engineers, but some represented other engineering disciplines, and some were not even engineers, such as training and professional development staff people from large engineering organizations. Both the funded committee members and the corresponding members had representatives from academia, industry and governmental sectors.

The agenda for the BOK2Cmte was large and intimidating. Most of the work of the BOK2Cmte was conducted via 65 telephone conference calls for the main committee, and probably an equal number of conference calls for the various task committees. The task committees were formed as needed to research and prepare position or background papers on specific topics that helped to define the potential outcomes. In addition, four face-to-face meetings were held. The corresponding members served on the task committees and participated in e-mail discussions as well as some of the telephone conference calls. Over 15 drafts of the BOK2 were eventually developed and circulated.

The BOK2Cmte started out by performing a thorough review of the BOK1, the NAE reports, ABET requirements, bodies of knowledge from other professions, and the comments received from ASCE members and others in and outside of the general engineering community. From review of this information, it was evident to the BOK2Cmte that there was room for improvement in the BOK1, but there was also the realization that the BOK2 could not be all things to all people.

Outcomes and the Organization of BOK2

After the BOK2Cmte had thoroughly reviewed the available information, the committee identified over 30 topics that were initially considered to be suitable for inclusion as outcomes. Although both the ABET criteria and the BOK1 and the BOK2 use the term outcome, there is a difference between the ABET use of the word and the BOK use of the word. ABET defines an outcome as: "*…program outcomes are statements that describe what students are expected to know and be able to do by the time of graduation.*".[3] The ASCE BOK definition of an outcome is: "*Statements that describe what individuals are expected to know and be able to do by the time of entry into the practice of civil engineering at the professional level in the 21st Century. Outcomes define the knowledge, skills, and attitudes that individuals acquire through appropriate formal education and pre-licensure experience.* ".[2] There is significant overlap in the ABET outcomes and the BOK2 outcomes, which is to be expected because 11 of the 15 outcomes in the BOK1 came directly from ABET/EAC General Criteria 3 (a-k)[3].

Over the BOK2Cmte's term of service, the number of outcomes was whittled down from 30+ to 24 by combining some and eliminating others. The number itself is not nearly as important as the content, the clarity, and the impact of the individual outcomes. There are relatively few "new" outcomes in the list of 24 relative to the BOK1. Appendix A of this paper contains a chart that shows the genealogy of the 24 outcomes of BOK2 starting with the ABET/EAC 11. In fact, many of the ABET/EAC 11 were derived from a document from the early 90's titled "Desired Attributes of an Engineer"[8] , as developed by the Boeing Corporation. Boeing was very active in engineering education, and along with several other large industrial employers of engineers, was instrumental in focusing attention on the need to reform the ABET accreditation process and criteria, resulting in the outcomes based assessment system now used by ABET.

The 24 outcomes have been arranged in three categories: Foundational, Technical, and Professional. The outcome titles in each are as follows:

Foundational

1. Mathematics
2. Natural Sciences
3. Humanities
4. Social Sciences

Technical

5. Materials Science
6. Mechanics

7. Experiments
8. Problem Recognition and Solving
9. Design
10. Sustainability
11. Contemporary Issues & Historical Perspectives
12. Risk and Uncertainty
13. Project Management
14. Breadth in Civil Engineering Areas
15. Technical Specialization

Professional

16. Communication
17. Public Policy
18. Business and Public Administration
19. Globalization
20. Leadership
21. Teamwork
22. Attitudes
23. Life-Long Learning
24. Professional and Ethical Responsibility

The importance of an outcome in a typical civil engineering curriculum cannot be inferred by its stand-alone presence or order in the table. Substantially more time will by spent by the students in Problem Recognition and Solving, or Design, than on Globalization or Public Policy, but they are all separate outcomes with varying levels of achievements expected of the students and/or young practitioners.

Several of the outcomes resulted from disaggregation of broader outcomes in either the ABET/EAC 11, or the BOK1. This was done primarily for the sake of clarity and recognition that the combined outcomes need to be disaggregated in order to properly highlight the distinctiveness of the individual outcomes and the role they will play in the education of the civil engineer of the future.

For instance, ABET/EAC General Criteria outcome 3(a) states: "*Engineering programs must demonstrate that their students attain: (a) an ability to apply knowledge of mathematics, science, and engineering*"[3]. There are actually several topics wrapped up in this one outcome, and they all must be addressed in an ABET/EAC Self Study document, and they are all subject to the same level of expected achievement – "*an ability to apply knowledge of...*". This one ABET outcome is represented by BOK2 outcomes 1-Mathematics, 2-Natural Sciences, 5-Materials Science, and 6-Mechanics. This one ABET/EAC outcome expanded into four BOK2 outcomes for the sake of clarity and distinctiveness. The last topic in the ABET/EAC 3(a) is *engineering*, which is a nebulous term that lacks a clear-cut definition in this context, but is probably inherent in many of the other outcomes.

For reasons demonstrated by outcome 3(a) as noted above, one of the objectives of the BOK2Cmte was to clarify and coordinate the 15 outcomes of the BOK1 so that all users of the

document would have the same understanding of what the civil engineering BOK really means. How this was accomplished is described in the following sections.

Identification of Outcomes

The first step for the BOK2Cmte was to identify topics that could be potential stand-alone outcomes. For this, the committee relied on potential topics from the BOK1, the NAE documents, comments from users of the BOK1, and the BOK's from other professions. In addition, members of BOK2Cmte had their own ideas of what should be included in the civil engineering BOK. The list of potential outcomes was in excess of 30 at the beginning. These include the disaggregation of the 15 outcomes from the BOK1. The 15 outcomes turned into about 25 potential new outcomes, although a precise number is not possible because of the redefinition of some of the outcomes.

"The committee focused on outcomes without consideration of courses, semesters, faculty expectations, co- and extra-curricular activities, access and delivery systems, and other administrative and logistical aspects of teaching and learning the outcomes. For example, topics listed in the outcomes could appear in more than one course, one course could contain many of the outcomes, and conceivably, one outcome could encompass an entire course."[2]

When the list of potential outcomes was condensed to 28 candidates, members of the committee, and some corresponding members, were subdivided into task committees to prepare, helpful, but not prescriptive, explanations for what the outcomes meant. For this, the committee solicited subject matter experts, as necessary, from the ranks of the corresponding members for some of the topics, such as History and Heritage, Risk and Uncertainty, Attitudes, and Sustainability. All of the explanations were limited to one page of text; the committee's thought being that if the candidate outcome was really worthy of being a stand-alone outcome, then one page of text should be sufficient to describe the meaning of an outcome to a reader of the document. These one page explanations kept the committee focused on the meaning of the outcome and became the "touchstone" when people wandered away from the true meaning of the outcome.

An example of an explanation is attached as Appendix B to this paper. The top section of the explanation presents an overview of the outcome. The bottom sections describe the levels of achievement appropriate for that particular outcome.

The explanations for all 24 outcomes are presented in Appendix J of Reference 2 and can be found at www.asce.org/raisethebar.

These explanations are an improvement over the discussion presented in the BOK1 because they are very carefully worded definitions of what is included, and not included, in any specific outcome. It was the committee's belief that these explanations will remove a substantial portion of the ambiguity inherent in the ABET/EAC outcomes and those of the BOK1.

Bloom's Taxonomy

In the General and Program Criteria of the four commissions of ABET (Engineering Accreditation Commission, Applied Science Accreditation Commission, Technology Accreditation Commission, and Computing Accreditation Commission) there are numerous terms used to represent the level of achievement expected to be achieved for the various outcomes, with no common definition for any of the terms that are used. Some of the terms used are: *an ability to apply knowledge of, an ability to function on, an understanding of, a recognition of, an ability to use, proficiency in, the capability to apply, an ability to conduct, etc.*[3]

As a result of the lack of definition and uniformity, it is difficult for the faculty in a specific department, or within the college, or for the members of a visiting ABET team, to understand or agree on what is expected of the students. This defect in nomenclature was recognized by the BOK1Cmte, and somewhat rectified for civil engineering in the BOK1.

Three levels of competence were recognized in the BOK1: Level 1 (Recognition), Level 2 (Understanding), and Level 3 (Ability). The use of these terms helped to clarify the problem, but trying to use them certainly pointed out the deficiencies in trying to adopt these terms as standardized terms. There was still too much ambiguity.

"Accordingly, the ASCE Levels of Achievement Subcommittee[9], which completed it work in September 2005, undertook a review of the educational psychology literature to find potential frameworks that might be applicable to the BOK. Specifically, the Subcommittee wanted a relatively simple framework, informed by educational research, which could link BOK outcomes to actual learning and achievement. The taxonomy that met simplicity and relevancy needs was Bloom's Taxonomy of the Cognitive Domain…"[10]. In addition, the chosen system would also have to be compatible with the ABET evaluation process, which means that assessability also was considered.

Based on this research and the recommendation from the Subcommittee, the BOK2Cmte decided to adopt Bloom's Taxonomy for the Cognitive Domain as the standard nomenclature for the BOK2. Appendix F in Reference 2 provides a succinct description of Bloom's Taxonomy of the Cognitive Domain. Appendix G of the same reference contains a companion article on the Affective Domain of Bloom's Taxonomy. The Affective Domain was not explicitly used in the BOK2, although there are outcomes where it may have some applicability, such as the Attitudes outcome.

By adopting Bloom's six levels of achievement, and the corresponding Bloom's verbs that are applicable to the respective levels of achievement, it became immediately possible to communicate within the BOK2Cmte and with users of the document, what was expected of the learner in terms of expected levels of achievement. The terms that were adopted to represent the six levels are as follows: Level 1-Knowledge, Level 2-Comprehension, Level 3-Application, Level 4-Analysis, Level 5-Synthesis, and Level 6-Evaluation.

For each outcome, a rubric was developed that contained a short statement for each of the six levels of achievement, with each of the six statements incorporating an appropriate Bloom's verb.

For instance, for the Sustainability outcome, the six statements are as follows: (condensed with the Bloom's verb bolded)

Level 1: **Define** key aspects of sustainability…
Level 2: **Explain** key properties of sustainability…
Level 3: **Apply** the principles of sustainability…
Level 4: **Analyze** systems of engineered works…for sustainable performance
Level 5: **Design** a complex system, process or project to perform sustainably. **Develop** new, more sustainable technology. **Create** new knowledge…
Level 6: **Evaluate** the sustainability…

As can be seen, the progression from Level 1 through Level 6 provides for increasing complexity and increasing knowledge of the subject. Also the combination of the Levels and the usage of the Bloom's verbs is intuitively easy to grasp and readily adaptable to all 24 of the BOK2 outcomes.

The rubrics for each of the 24 outcomes are presented in Appendix I of Reference 2. A tabular listing of all 24 outcomes is presented in Appendix D of this report.

The BOK2Cmte is convinced that application of this system would improve the ABET General and Program Criteria. It would improve communication and understanding between faculty members teaching sequential classes, or service classes, between departments within a college, and amongst and between the ABET visiting team members and the faculty of the program being reviewed. This shift to a standard nomenclature would entail some additional work for the member societies of ABET to rewrite their program criteria. ASCE has already done exactly that and the time and effort required to accomplish this was relatively minor, considering the tremendous difference between the "old" text and the "new" text. In addition, the ABET/EAC General Criteria were restated using Bloom's Taxonomy as an exercise by an ASCE member, and the resulting Criteria were much more readable and easier to understand.

After the statements for each of the Bloom's levels were accepted for each of the 24 outcomes, then it was time to decide what level of achievement was the lower bound for entry into the professional practice of civil engineering for each outcome.

Setting Levels of Achievement

Not every outcome of the BOK2 requires the same level of achievement as all of the others. For instance, most practicing civil engineers can get by quite nicely with Level 3-Application for the Mathematics outcome. However, for Design, which may be considered the heart and soul of civil engineering, greater capabilities are needed and expected. Hence, the Level 6-Evaluation for the Design outcome.

The chart in Appendix B of this paper lists the 24 outcomes and their respective levels of achievement. Each of these levels of achievement for each of the outcomes was thoroughly deliberated within the overall committee, including the corresponding members. Completion of the respective levels of achievement for each outcome will be required for the civil engineer of

the future to enter the professional practice of civil engineering. These go beyond graduation requirements from a baccalaureate or master's program, in that fulfillment of almost two-thirds of the outcomes rely, in part, on prelicensure experience.

In the Appendix B chart, it can be seen that no outcome has a level of achievement less than Level 3-Application. Similarly, only three outcomes have their levels of achievement set at Level 6-Evaluation. These are No. 9-Design, No. 15-Technical Specialization, and No. 24-Professional and Ethical Responsibility.

Much of our deliberation on the levels of achievement revolved around what do we expect out of our baccalaureate students now, and what should be expected in the future for entry into the profession. Although use of the six levels of achievement and the Bloom's terminology was new to most committee members, the system is so intuitive that, for the most part, consensus on setting the respective levels of achievement was readily achieved.

There have certainly differences of opinion during the discussions on how and when the specified levels of achievement should be achieved. It is clear that it is practically impossible to push more content into the 120 to 128 semester hour baccalaureate program. If something is added to the curriculum, then something else must get pushed out. This conundrum was the focus of the next step for the BOK2Cmte .

When are the Levels of Achievement Achieved?

In the chart in Appendix B, each of the cells under the levels of achievement is filled with either a "B", an "M/30", or an "E". The furthest cell to the right for each outcome is the level of achievement that is required for the civil engineer of the future to enter the professional practice of civil engineering. But when is this to be achieved other than prior to professional licensure? The letters in the cells tell the user of the chart when this is to be achieved and the responsibility for ensuring the achievement. Actually, the fledgling engineer is the person responsible for ensuring achievement, but there are many entities that will be assisting the engineer in achieving these outcomes.

The process the BOK2Cmte used to set the various levels of achievement was as follows:

1. The committee first determined what level of achievement was necessary in each outcome for the civil engineer of the future to enter the professional practice of civil engineering. There was much give and take in these deliberations. Because over 50 experienced civil engineers participated in these deliberations, consensus was achieved without ever having to resort to a vote of the participants.

2. After this "professional practice" line was set, the committee then determined what level of achievement was proper at the time of graduation from an undergraduate civil engineering program. Again, consensus was reached without having to vote, largely as a result of the preparatory work done by the committee in developing the explanations and the rubrics.

3. Next, the division of responsibility between the post-baccalaureate education (M/30) and the pre-licensure professional experience was decided upon. Through the committee's discussions, it became apparent that some levels of achievement in some of the outcomes were better achieved in a structured educational format than while working as a not-yet licensed engineer. And vice-versa. Again, with a clear understanding of what was to be achieved based on the rubrics and the explanations, the allocation of the remaining cells between M/30 and E was decided upon in a collegial manner without having to resort to a formal vote.

A "B" in a cell indicates that *"Portion of the BOK fulfilled through the bachelor's degree"*[2]. It is apparent that most of the cells are filled with B's. At first glance, this would seem to indicate that a tremendous percentage of the total BOK must be acquired in the undergraduate program. This is true, and not much different from today's situation. The BSCE has been treated as a defacto terminal degree for practice for over 100 years. However, there are no B's under Level 6, and only one in Level 5, that being Design. All of the other outcomes have their highest B's in either Level 2, Level 3, or Level 4. The BOK2Cmte realized that not much more content, if any, could be squeezed into the bachelor's degree programs. Therefore, the distribution of B's reflects very closely the curriculum content of the typical undergraduate civil engineering program of today, with some enrichment with new or clarified content.

Assuming this is all true, then where is the "Raise the Bar" content that PS-465 is built upon?

That is where the other letters in the cells come in. An "M/30" in a cell indicates that *"Portion of the BOK fulfilled through the master's degree or equivalent (approximately 30 semester credit hours of acceptable graduate-level or upper-level undergraduate courses in a specialized technical area and/or professional practice area related to civil engineering)"*[2]. An "E" in a cell indicates that *"Portion of the BOK fulfilled through the prelicensure experience"*[2].

These E and M/30 cells indicate achievement of outcomes that generally cannot and generally should not be part of the undergraduate curriculum. These constitute the major portion of the "Raise the Bar" effort. The M/30 is easy to understand. These knowledge, skills and attitudes associated with the individual outcomes will be achieved in either a formal education, post-baccalaureate degree program, such as an MSCE or an MEng program, or a carefully selected collection of coordinated classes in a specialized field that do not necessarily culminate in a degree granted by a university or a college. Large consulting, industrial, and construction firms, as well as the armed services, have in-house educational service providers that may be able to provide the necessary coursework to fulfill these requirements.

The third letter, the "E", is revolutionary in that the employers of the pre-licensure engineers are being put on notice that they have a responsibility to the young engineers in their charge to help them get ready for licensure. Many employers of young engineers already take this for granted, and they do an admirable job of preparing their young engineers. But the BOK2 makes this responsibility explicit. This division of responsibility is perhaps best illustrated by outcome No. 15-Technical Specialization.

The first level of achievement (Knowledge) for this outcome is designated as a "B". This indicates that the faculty will introduce technical specialization to the students at some time in the undergraduate program. As outcome No. 14 shows, in the undergraduate program the students are being exposed to the breadth of civil engineering sub-disciplines, but at some point, the faculty would let the students know that they can specialize in any of the sub-disciplines. Also, they may want to specialize in a field related to civil engineering, such as Structural Health Monitoring of the Infrastructure, which would require coursework outside of civil engineering, probably in electrical engineering. But that is as far as this outcome would go at the undergraduate level.

Achievement levels 2, 3, 4 and 5 are designated as "M/30". This is easiest to visualize in a traditional MSCE program. As the graduate student makes his/her way through the master's program, they become more proficient in their chosen technical specialization. However, when they receive their MSCE, they still have a lot to learn. This is where the employer comes in, the "E". Until the young engineer has actually worked in a design firm, or for a contractor, or a governmental agency in their selected field, they have really not achieved the Level 6-Evaluation status. This is reflected in the licensing laws and regulations of the states and territories of the United States. All of the jurisdictions require a period of work experience before the candidate can become a licensed professional engineer.

In a similar manner for the other outcomes that have an "E" in their furthest right cell, the employer has a responsibility for the educational development of the young engineer.

There is a lot of information and guidance in the chart in Appendix B. This chart is the roadmap for successful achievement of the BOK2.

The Coordinated Final Document

When all of the rubrics and explanation sheets were completed, the BOK2Cmte stood back and asked – "Does all of this make sense?" "Are there duplications, redundancies, or extraneous material that is not needed?" "Can some of the outcomes be combined and still not lose content or distinctiveness?"

Based on this introspective evaluation, 28 outcomes turned into 24 for the final document. Early on in the life of the committee, assignments were made where committee members were assigned to be "champions" for each of the topics (potential outcomes). As a result, these champions fought very hard for their outcomes and the designation as a stand-alone outcome throughout the life of the committee. However, in the end, a consensus was reached based on the documentation that these 24 outcomes sufficiently defined the Body of Knowledge for Civil Engineering.

Conclusions

The Second Edition of the Body of Knowledge for Civil Engineering is a comprehensive document that is expected to set the educational stage for achievement of the Vision for Civil Engineering in 2025. The BOK2 has many improvements over the BOK1, including:

- The use of Bloom's Taxonomy for the Cognitive Domain in defining the levels of achievement for the 24 outcomes,
- An explanation document for each outcome that defines what is included in that outcome,
- A rubric for each outcome that defines each level of achievement,
- A system that designates when in the pre-licensure educational and work experience of a young engineer, each level of achievement for each outcome is attained, and
- The specification of an employer's responsibility in the development of the young engineer.

It is the belief of the BOK2Cmte that the BOK2 will be an enduring document, but that it will become outdated in time due to the changing nature of our profession. However, it is also the strong belief of the committee that the outcome rubrics and explanation sheets are the heart and soul of the BOK2 and implementation of the contents of the report will help "Raise the Bar" and position civil engineers to be technological leaders in developing a sustainable world.

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Appendix A: Relationship of ABET, BOK1 and BOK2 Outcomes

(Note: General relationships are presented, not one-to-one mapping)

ABET Outcome Titles[a]	BOK1 Outcome Titles[b]	BOK2 Outcome Titles[c]
(a) Mathematics, science, engineering	1. Technical core	1. Mathematics 2. Natural sciences 5. Materials science 6. Mechanics
(b) Experiments	2. Experiments	7. Experiments
(c) Design	3. Design	9. Design 10. Sustainability
	3. Design	12. Risk/uncertainty
(d) Multidisciplinary teams	4. Multi-disciplinary teams	21. Teamwork
(e) Engineering problems	5. Engineering problems	8. Problem recognition and solving
(f) Professional and ethical responsibility	6. Professional and ethical responsibility	24. Professional and ethical responsibility
(g) Communication	7. Communication	16. Communication
(h) Impact of engineering	8. Impact of engineering	11. Contemporary issues and historical perspectives
(i) Life-long learning	9. Life-long learning	23. Life-long learning
(j) Contemporary issues	10. Contemporary issues	11. Contemporary issues and historical perspectives 19. Globalization
(k) Engineering tools	11. Engineering tools	8. Problem recognition and solving
	12. Specialized area related to civil engineering	15. Technical specialization
Civil engineering EAC Program Criteria	13. Project management, construction, and asset management	13. Project management
	14. Business and public policy	17. Public policy 18. Business and public administration
Civil engineering EAC Program Criteria	15. Leadership	20. Leadership 22. Attitudes
ABET/EAC Criterion 4[d]	ABET/EAC Criterion 4[d]	3. Humanities 4. Social sciences
Civil engineering EAC Program Criteria	Civil engineering EAC Program Criteria	14. Breadth in civil engineering areas

a) Short names
b) Short names of outcomes appearing in the BOK1 report,[1] pp. 24-29
c) Short names from BOK2 report, Table 1, page 16
d) General education component

Appendix B: Example of an Outcome Explanation

Outcome 15: Technical Specialization

Overview: Advanced technical knowledge and skills beyond that included in the traditional four-year bachelor's degree are essential to attaining the BOK necessary for entry into the professional practice of civil engineering. Advanced technical specialization includes all traditionally defined areas of civil engineering practice, but also includes coherent combinations of these traditional areas—that is, advanced knowledge and skills in the area of general civil engineering are appropriate within the context of advanced specialization. Civil engineering specializations in nontraditional, boundary, or such emerging fields as ecological engineering and nanotechnology are suitable and encouraged.

Many non-engineering degrees and courses have content that would be beneficial to the professional practice of civil engineering. These topics/courses may be combined with other appropriate coursework to fulfill the technical specialization and/or other outcomes through the M/30. However, such non-engineering degrees as the M.B.A., J.D., and M.D. would most likely not, by themselves, fulfill the technical specialization of the BOK.

B: ***Define*** **key aspects of advanced technical specialization appropriate to civil engineering. (L1)** Before one can specialize one must have a basic level of knowledge about advanced technical specialization—that is, an individual must know what is expected of civil engineers that specialize in a particular area. This level of knowledge may be attained through traditional courses as well as through guest lectures by practitioners who practice in the area of interest.

M/30: ***Design*** **a complex system or process or** ***create*** **new knowledge or technologies in a traditional or emerging advanced specialized technical area appropriate to civil engineering. (L5)** In recognition of the ever-advancing profession of civil engineering, advanced technical specialization areas appropriate to civil engineering are, by necessity, open and encompassing of the future needs of our profession. Additionally, discovery and creation of new technologies and knowledge are equally important to the profession's future. Regardless of the specific path towards attainment of technical specialization, tangible relation to the professional practice of civil engineering is required. Individuals are expected to, within their technical area of specialization, synthesize a design, research and develop new methods or tools, and/or discover or create new knowledge or technologies.

E: ***Evaluate*** **the design of a complex system or process, or** ***evaluate*** **the validity of newly created knowledge or technologies in a traditional or emerging advanced specialized technical area appropriate to civil engineering. (L6)** The prelicensure experience should include opportunities to practice—under appropriate guidance and mentorship—civil engineering within the technical area of specialization. The role of practitioner mentorship and review is critical in terms of validating the individual's ability to evaluate, compare and contrast, and validate multiple options within the specific advanced technical area of specialization.

Appendix C: The 24 Outcome Titles and Their Respective Levels of Achievement

Outcome number and Title	Level of achievement					
	1 Know-ledge	2 Compre-hension	3 Appli-cation	4 Analy-sis	5 Synthe-sis	6 Evalu-ation
Foundational						
1. Mathematics	B	B	B			
2. Natural Sciences	B	B	B			
3. Humanities	B	B	B			
4. Social Sciences	B	B	B			
Technical						
5. Materials Science	B	B	B			
6. Mechanics	B	B	B	B		
7. Experiments	B	B	B	B	M/30	
8. Problem Recognition and Solving	B	B	B	M/30		
9. Design	B	B	B	B	B	E
10. Sustainability	B	B	B	E		
11. Contemp. Issues & Historical Perspectives	B	B	B	E		
12. Risk and Uncertainty	B	B	B	E		
13. Project Management	B	B	B	E		
14. Breadth in Civil Engineering Areas	B	B	B	B		
15. Technical Specialization	B	M/30	M/30	M/30	M/30	E
Professional						
16. Communication	B	B	B	B	E	
17. Public Policy	B	B	E			
18. Business and Public Administration	B	B	E			
19. Globalization	B	B	B	E		
20. Leadership	B	B	B	E		
21. Teamwork	B	B	B	E		
22. Attitudes	B	B	E			
23. Life-Long Learning	B	B	B	E	E	
24. Professional and Ethical Responsibility	B	B	B	B	E	E

Key:

B	Portion of the BOK fulfilled through the bachelor's degree
M/30	Portion of the BOK fulfilled through the master's degree or equivalent (approximately 30 semester credits of acceptable graduate-level or upper- level undergraduate courses in a specialized technical area and/or professional practice area related to civil engineering)
E	Portion of the BOK fulfilled through the pre-licensure experience

Appendix D: The 24 Outcomes

Entry into the practice of civil engineering at the professional level requires fulfilling 24 outcomes to the various levels of achievement.

Key: L1 through **L6** refers to these levels of achievement:

Level 1 **(L1)** - Knowledge
Level 2 **(L2)** - Comprehension
Level 3 **(L3)** - Application
Level 4 **(L4)** - Analysis
Level 5 **(L5)** - Synthesis
Level 6 **(L6)** - Evaluation

Outcome number and title	To enter the practice of civil engineering at the professional level, an individual must be able to demonstrate this level of achievement
Foundational Outcomes	
1 Mathematics	***Solve*** problems in mathematics through differential equations and ***apply*** this knowledge to the solution of engineering problems. **(L3)**
2 Natural Sciences	***Solve*** problems in calculus-based physics, chemistry, and one additional area of natural science and ***apply*** this knowledge to the solution of engineering problems. **(L3)**
3 Humanities	***Demonstrate*** the importance of the humanities in the professional practice of engineering **(L3)**
4 Social Sciences	***Demonstrate*** the incorporation of social sciences knowledge into the professional practice of engineering. **(L3)**
Technical Outcomes	
5 Materials Science	**Use** knowledge of materials science to ***solve*** problems appropriate to civil engineering. **(L3)**
6 Mechanics	**Analyze** and solve problems in solid and fluid mechanics. **(L4)**
7 Experiments	***Specify*** an experiment to meet a need, conduct the experiment, and analyze and ***explain*** the resulting data. **(L5)**
8 Problem Recognition and Solving	***Formulate*** and solve an ill-defined engineering problem appropriate to civil engineering by ***selecting*** and applying appropriate techniques and tools. **(L4)**
9 Design	***Evaluate*** the design of a complex system, component, or process and ***assess*** compliance with customary standards of practice, user's and project's needs, and relevant constraints. **(L6)**
10 Sustainability	***Analyze*** systems of engineered works, whether traditional or emergent, for sustainable performance. **(L4)**

11 Contemporary Issues and Historical Perspectives	***Analyze*****,** ***compare,*** and ***contrast*** the economic, environmental, political, and societal impacts of engineering. **(L4)**
12 Risk and Uncertainty	***Analyze*** the loading and capacity, and the effects of their respective uncertainties, for a well-defined design and ***illustrate*** the underlying probability of failure (or non-performance) for a specified failure mode. **(L4)**
13 Project Management	***Formulate*** documents to be incorporated into the project management plan. **(L4)**
14 Breadth in Civil Engineering Areas	***Analyze*** and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering. **(L4)**
15 Technical Specialization	***Evaluate*** the design of a complex system or process, or ***evaluate*** the validity of newly-created knowledge or technologies in a traditional or emerging advanced specialized technical area appropriate to civil engineering. **(L6)**
Professional Outcomes	
16 Communication	***Plan, compose,*** and ***integrate*** the verbal, written, virtual, and graphical communication of a project to technical and non-technical audiences. **(L5)**
17 Public Policy	***Apply*** public policy process techniques to simple public policy problems related to civil engineering works. **(L3)**
18 Business and Public Administration	***Apply*** business and public administration concepts and processes. **(L3)**
19 Globalization	***Analyze*** engineering works and services delivered in a global context. **(L4)**
20 Leadership	***Organize*** and ***direct*** the efforts of a group. **(L4)**
21 Teamwork	***Function*** effectively as a member of a multi-disciplinary team. **(L4)**
22 Attitudes	***Demonstrate*** attitudes supportive of the professional practice of civil engineering. **(L3)**
23 Life-Long Learning	***Plan*** and ***execute*** the acquisition of required expertise appropriate for professional practice. **(L5)**
24 Professional and Ethical Responsibility	***Justify*** a solution to an engineering problem based on professional and ethical standards and ***assess*** personal professional and ethical development. **(L6)**