The Evolution of the Civil Engineering Body of Knowledge: From the First Edition to the Third Edition

Dr. Decker B. Hains, Western Michigan University

Dr. Decker B. Hains is a Master Faculty Specialist in the Department of Civil and Construction Engineering at Western Michigan University. He is a retired US Army Officer serving 22 years on active duty with the US Army Corps of Engineers and taught at the United States Military Academy at West Point (USMA). He earned a Bachelor of Science degree in Civil Engineering from USMA in 1994, Master of Science degrees from the University of Alaska Anchorage in Arctic Engineering in 1998 and Missouri University Science & Technology in Civil Engineering in 1999, and a PhD in Civil Engineering from Lehigh University in 2004. He is a registered Professional Engineer in Michigan.

Dr. Kenneth J. Fridley, University of Alabama

Kenneth J. Fridley is the Senior Associate Dean for the College of Engineering at The University of Alabama. Prior to his current appointment, Fridley served as Professor and Head of the Department of Civil, Construction and Environmental Engineering at the University of Alabama. Dr. Fridley has been recognized as a dedicated educator throughout his career and has received several awards for his teaching efforts, including the ExCEEd (Excellence in Civil Engineering Education) Leadership Award in 2010. At the University of Alabama, Fridley has led efforts to establish several new programs including new undergraduate degree programs in construction engineering, architectural engineering and environmental engineering, a departmental Scholars program allowing highly qualified students an accelerated program to earn their MSCE in addition to their BS degree, the interdisciplinary "Cube" promoting innovation in engineering, and the cross-disciplinary MSCE/MBA and MSCE/JD dual-degree programs.

Dr. Thomas A. Lenox Dist.M.ASCE, F.ASEE, American Society of Civil Engineers

Thomas A. Lenox, Ph.D., Dist.M.ASCE, F.ASEE is Executive Vice President (Emeritus) of the American Society of Civil Engineers (ASCE). He holds a Bachelor of Science degree from the United States Military Academy (USMA), Master of Science degree in Theoretical & Applied Mechanics from Cornell University, Master of Business Administration degree in Finance from Long Island University, and a Ph.D. degree in Civil Engineering from Lehigh University. Dr. Lenox served for over 28 years as a commissioned officer in the U.S Army Field Artillery in a variety of leadership positions in the U.S., Europe, and East Asia. He retired at the rank of Colonel. During his military career, Dr. Lenox spent 15 years on the engineering faculty of USMA including five years as the Director of the Civil Engineering Division. Upon his retirement from the U.S. Army in 1998, he joined the staff of the American Society of Civil Engineers (ASCE). In his position as educational staff leader of ASCE, he managed several new educational initiatives – collectively labeled as Project ExCEEd (Excellence in Civil Engineering Education). As ASCE's Executive Vice President, Dr. Lenox led several educational and professional career-development projects for the civil engineering profession – with the overall objective of properly preparing individuals for their futures as civil engineers. An example is his staff leadership of ASCE's initiative to "Raise the Bar" for entry into professional engineering practice. Dr. Lenox's awards include ASCE's ExCEEd Leadership Award, ASEE's George K. Wadlin Award, ASCE's William H. Wisely American Civil Engineer Award, and the CE News' "2010 Power List – 15 People Advancing the Civil Engineering Profession." He is a Distinguished Member of ASCE and a Fellow of ASEE. In January 2014, Dr. Lenox retired from his staff position with ASCE. He continues to serve the engineering profession as an active member of ABET's Board of Delegates, Engineering Area Delegation, Global Council, and Governance Committee; several of ASCE's educational and professional committees; and ASEE's Civil Engineering Division.

Ms. Leslie Nolen CAE, American Society of Civil Engineers

Leslie Nolen, CAE, serves as director, educational activities for the American Society of Civil Engineers. She brings over 20 years of association management experience to her work with ASCE's Committee on Education on issues of importance to the undergraduate and graduate level education of civil engineers.

Mr. James J. O'Brien Jr., American Society of Civil Engineers

JIM O'BRIEN

Jim O'Brien has over 44 years of experience as a leader, team builder, and manager in diverse professional and academic environments. During his 26-year military career in the US Army Corps of Engineers, he commanded combat engineer units and served 13 years on the teaching faculties of the United States Military Academy at West Point, the US Army's Command & General Staff College, and the University of Notre Dame.

Now retired from the US Army, Jim currently serves as the American Society of Civil Engineers' Managing Director of Leader Development. Here, he serves as the staff leader to increase the civil engineering formal education and experience prior to entry into the professional practice of civil engineering. Jim joins others in the sustainability community seeking to change the CE Profession to make all civil work sustainable. He continues other opportunities in teaching university teachers to be better teachers through ASCE's ExCEEd (Excellence in Civil Engineering Education) Teaching Workshop and in ABET accreditation of engineering programs. In addition to Leader Development, his portfolio also includes Educational Activities, Professional Activities, Raise the Bar, and Sustainability Departments.

Jim is also an adjunct faculty member at George Mason University where he teaches leadership and leading change in the Applied Information Technology MS graduate program.

Jim is a lifelong learner, seeking to continually improve and reinvent himself. His passions include leadership, mentoring, professionalism, personal responsibility, non-verbal communication, and teaching effectiveness. He strives to always "Be Intentional"–that is, to do everything for a reason.

The Evolution of the Civil Engineering Body of Knowledge:
From the First Edition to the Third Edition

The American Society of Civil Engineers (ASCE) Civil Engineering Body of Knowledge 3 Task Committee (CEBOK3TC) recently completed the Third Edition of the Civil Engineering Body of Knowledge (CEBOK3) with a scheduled publication in May 2019. Like its predecessors, the third edition defines the knowledge, skills, and attitudes for entry into the practice of civil engineering at the professional level and uses an outcomes-based approach with associated levels of achievement. However, the format, content, and the definition of the Civil Engineering Body of Knowledge (CEBOK) has evolved over the last fifteen years since the publication of the First Edition of the Body of Knowledge (CEBOK1).

This paper will provide a comprehensive history of the evolution of the CEBOK from its initial concept inception in the late 1990s through its present form as the third edition. The origins of the CEBOK will be discussed followed by a brief summary of CEBOK1 which was published in 2004. Based on a significant challenge associated with the levels of achievement in CEBOK1, a Levels of Achievement Subcommittee was formed shortly after the publication of CEBOK1. Following the subcommittee report, the Civil Engineering Body of Knowledge 2 Task Committee was formed in October 2005 to develop an updated CEBOK, the Second Edition of the Civil Engineering Body of Knowledge (CEBOK2), which was published in 2008. In the subsequent years, ASCE developed a plan for the long-term management of CEBOK on an eight-year cycle which led to the formation of the CEBOK3TC which began work in October 2016. This paper concludes with a discussion on the update from CEBOK2 to CEBOK3.

Why is this historical review and summary important to the civil engineering profession? To maintain the momentum of the educational and professional reform activities initiated by ASCE in the mid-1990's (called the Raise the Bar Initiative), the successful processes of the past and the associated "lessons learned" must be clearly communicated to future leaders and proponents of this initiative. Much has been learned from the experiences of the past – and these hard-learned experiences should guide the preparation of future editions of the CEBOK. A relevant quotation (from Adlai E. Stevenson) comes to mind: "We can chart our future clearly and wisely only when we know the path which has led to the present."

As the CEBOK has evolved, numerous papers have been published discussing various aspects of its three different editions. A new paper titled "The Role of the Civil Engineering Body of Knowledge in ASCE's Raise the Bar Effort" is also being published and presented at the 2019 ASEE Annual Conference [1].

Planting the Seeds (1995-2001)

Although the origins of maintaining a current and relevant engineering education process can be traced back to the Mann Report in 1918 [2], the most recent efforts to truly elevate the civil engineering profession and to ensure it maintains it relevancy and professional status in society began in 1995 with the American Society of Civil Engineers (ASCE) Civil Engineering Education Conference (CEEC '95) in Denver [3]. It had long been recognized that education and experience were the key components required to practice engineering at the professional

level. Indeed, most, if not all, licensing boards have education and experience requirements to attain a professional engineering license.

However, a key finding from CEEC '95 was that "an additional period of study, recognized by a professional degree, is required before entering practice [4]." Essentially, the CEEC '95 recognized that the education component could no longer be satisfied by a baccalaureate degree in civil engineering alone and that additional education beyond the baccalaureate degree was required. Consequently, ASCE leaders organized the Task Committee on Civil Engineering Education Initiatives (TCCEEI) to recommend the next steps in implementing the findings of CEEC '95. The TCCEEI recommended an ASCE Policy statement which would state that in the future, education beyond the baccalaureate degree will be necessary for entry into the professional practice of civil engineering. In 1998, the ASCE Board of Direction passed the original ASCE Policy Statement 465–Academic Prerequisites for Licensure and Professional Practice, which in part stated [3]:

> *"ASCE supports the concept of the Master's degree as First Professional Degree for the practice of civil engineering at a professional level."*

To clearly articulate the rationale and plan for implementing the new policy, the Task Committee for the First Professional Degree (TCFPD) was formed in October 1999 and charged with developing a vision for the realization of the new ASCE Policy 465 and a strategy for achieving this vision. The TCFPD concluded that ASCE should move forward with the increased educational requirements for civil engineers and the "Raise the Bar" initiative. They also recommended [5] and the ASCE Board of Direction passed a refined ASCE Policy 465 in October 2001 which stated:

> *"ASCE supports the concept of the master's degree or equivalent as a prerequisite for Licensure and the practice of civil engineering at a professional level."*

The First Edition of the Civil Engineering Body of Knowledge (2001-2004)

In October 2001, the efforts of the TCFPD were transferred to a new committee – the Task Committee on the Academic Prerequisites for Professional Practice (TCAP^3). TCAP^3 was charged with developing, organizing, and executing a detailed plan for the full realization of ASCE Policy 465. In May 2002, as one step in carrying out that charge, TCAP^3 formed the Body of Knowledge Committee, which was charged to: [6]

- Define the body of knowledge (BOK) needed to enter the practice of civil engineering at the professional level (licensure)
- Address the role of experience in the licensure preparation process
- Design and/or identify bachelor's plus master's or 30 credits (B+M/30) programs plus experience that will implement the BOK in the early part of the 21st Century
- Describe the role of faculty, practitioners, and students in imparting the BOK by means of B+M/30 programs
- Seek input from and support for the preceding from forward-looking academics and practitioners

In February 2004, after nearly two years of intense work, the BOK Committee, which was now a constituent committee of the Committee on the Academic Prerequisites for Professional Practice (CAP^3), published the first-ever *Civil Engineering Body of Knowledge (CEBOK1)*. The committee defined the CEBOK as the knowledge, skills, and attitudes necessary to become a licensed professional engineer and listed 15 outcomes for the CEBOK [6]. The first 11 outcomes were identical to the ABET Criterion 3 student outcomes a – k at the time and were distinguished along three broad levels of competence: Level 1 (Recognition), Level 2 (Understanding), and Level 3 (Ability) [7].

Table 1 lists the 15 outcomes from BOK1, including the level of competency for each, and the corresponding ABET outcome if directly associated. The outcome names were added in a subsequent Levels of Achievement report [8].

Table 1. CEBOK1 Outcomes.

Outcome	Outcome Statement	Level	ABET
1. Technical Core	an ability to apply knowledge of mathematics, science, and engineering	Ability (3)	a
2. Experiment	an ability to design and conduct experiments, as well as analyze and interpret results	Ability (3)	b
3. Design	an ability to design a system, component, or process to mean desired needs	Ability (3)	c
4. Mult-disciplinary	an ability to function on multi-disciplinary teams	Ability (3)	d
5. Engineering Problems	an ability to identify, formulate, and solve engineering problems	Ability (3)	e
6. Professional/ Ethical	an understanding of professional and ethical responsibility	Understanding (2)	f
7. Communication	an ability to communicate effectively	Ability (3)	g
8. Engineering Impact	the broad education necessary to understand the impact of engineering solutions in a global and societal context	Understanding (2)	h
9. Life-long Learning	a recognition of the need for, and an ability to engage in life-long learning	Ability (3)	i
10. Contemporary Issues	a knowledge of contemporary issues	Recognition (1)	j
11. Engineering Tools	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Ability (3)	k
12. Specialized Area	an ability to apply knowledge in a specialized area related to civil engineering	Ability (3)	N/A
13. Project Management, Construction, and Asset Management	an understanding of the elements of project management, construction, and asset management	Understanding (2)	N/A

14. Business and Public Administration	an understanding of business and public policy and administration fundamentals	Understanding (2)	N/A
15. Leadership	an understanding of the role of the leader and leadership principles and attitudes	Understanding (2)	N/A

Although the committee's focus was on the "what", i.e. the BOK, they also made recommendations in the BOK1 on how the BOK should be taught and learned and who should teach and learn it. Also, in October 2004, the concept of the body of knowledge first appeared in ASCE Policy 465 when the ASCE BOD refined it to read [9]:

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

The Second Edition of the Civil Engineering Body of Knowledge (2005-2008)

Soon after the publication of CEBOK1, two significant issues became apparent that would lead to the formation of the Second Edition of the Body of Knowledge Committee Task Committee (CEBOK2TC) in October 2005. First, several strategic vision documents were published or were going to be published that called for future engineers to develop certain knowledge, skills, and attitudes that had not been included in CEBOK 1. These included the National Academy of Engineering's two seminal reports, *The Engineer of 2020: Visions of Engineering in the New Century* in 2004 [10] and *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* in 2005 [11]. Also, ASCE planned and conducted a Vision 2025 Summit in June 2006 that resulted in the publication of *The Vision for Civil Engineering in 2025* in 2007.

Second, as ASCE developed and submitted proposed new CEBOK1 compliant accreditation criteria to the Engineering Accreditation Commission of ABET in June 2006, it found that many of the outcomes of CEBOK1 did not lend themselves to effective measurement, specifically with regard to the three levels of competency used in CEBOK1. To address this issue, ASCE formed a Levels of Achievement (LOA) Subcommittee of CAP^3 which recommended helpful changes to the definitions of the different levels use to define the CEBOK and possible modifications to the CEBOK profile that integrated outcome levels of achievement, formal education, and pre-licensure experience. Specific recommendations from the Levels of Achievement Subcommittee applicable to the CEBOK2TC [8]:

- Substituting achievement for competency in all future references to levels of demonstrated learning
- Using Bloom's Taxonomy or a refinement of Bloom's Taxonomy as the framework for defining levels of achievement in the BOK because the Bloom's levels of the cognitive domain are widely known and understood across the education community and the use of measurable, action-oriented verbs facilitates more consistent curricula design and assessment
- Presenting the outcomes in a rubric

- More explicitly addressing the role of critical thinking in the BOK

The CEBOK2TC worked from the recommendations of the LOA, examined critical issues, and published *The Civil Engineering Body of Knowledge for the 21st Century*, *Second Edition* in 2008 (CEBOK2) [12].

The CEBOK2 differed from CEBOK1 in several important ways and incorporated substantive changes including:

- Increasing the number of outcomes and categorizing the outcomes
- Using Bloom's Taxonomy for levels of achievement
- Establishing paths to fulfillment for the outcomes
- Including a full rubric beyond the level of achievement required for the CEBOK
- Including extensive appendices describing the outcomes and various other aspects of the CEBOK

The number of outcomes expanded from 15 to 24 and were divided into three categories, Foundational, Technical, and Professional. To some extent, the increase in outcomes reflected the committee's attempt to enhance clarity and specificity, rather than to increase the scope of the CEBOK. However, the CEBOK2 outcomes did place increased emphasis on such topics as the natural sciences, the humanities, sustainability, globalization, risk and uncertainty, and public policy. The categorization helped to show relationships among the outcomes and to some extent, a progression, especially from Foundational to Technical. CEBOK2 included an appendix, Appendix H, dedicated to presenting the relationship between the ABET, CEBOK1, and CEBOK2 outcomes.

The CEBOK2 used Bloom's Taxonomy as the basis for defining the levels of achievement. The fundamental premise of Bloom's Taxonomy is that an educational objective can be referenced to a specific level of cognitive development through the verb used in the objective statement. The use of measurable, action-oriented verbs linked to levels of achievement is beneficial because the resulting outcome statements can be assessed more effectively and consistently. The six levels of achievement used in CEBOK2 are listed in Table 2 and Table 3 presents the CEBOK2 outcomes with their levels of achievement.

Table 2. Bloom's Taxonomy for CEBOK2.

Level of the Cognitive Domain	**Definition [13]**
1. Knowledge	Knowledge is defined as the remembering of previously learned material.
2. Comprehension	Comprehension is defined as the ability to grasp the meaning of material.
3. Application	Application refers to the ability to use learned material in new and concrete situations.
4. Analysis	Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood.

5. Synthesis	Synthesis refers to the ability to put parts together to form a new whole.
6. Evaluation	Evaluation is concerned with the ability to judge the value of material for a given purpose.

Table 3. CEBOK2 Outcomes and Levels of Achievement.

Outcome	Outcome Statement	Level
	Foundational	
1. Mathematics	**Solve** problems in mathematics through differential equations and **apply** this knowledge to the solution of engineering problems.	Application (3)
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.	Application (3)
3. Humanities	**Demonstrate** the importance of the humanities in the professional practice of engineering.	Application (3)
4. Social Sciences	**Demonstrate** the incorporation of social sciences knowledge into the professional practice of engineering.	Application (3)
	Technical	
5. Materials Science	**Use** knowledge of materials science to **solve** problems appropriate to civil engineering.	Application (3)
6. Mechanics	**Analyze** and **solve** problems in solid and fluid mechanics.	Analysis (4)
7. Experiments	**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.	Synthesis (5)
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.	Analysis (4)
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	Evaluation (6)
10. Sustainability	**Analyze** systems of engineered works, whether traditional or emergent, for sustainable performance.	Analysis (4)
11. Contemporary Issues & Historical Perspectives	**Analyze** the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and **analyze** the impact of engineering solutions on the economy, environment, political landscape, and society.	Analysis (4)
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 nonperformance) for a specified failure mode.	Analysis (4)

13. Project Management	**Formulate** documents to be incorporated into the project plan.	Analysis (4)
14. Breadth in a Civil Engineering Area	**Analyze** and **solve** well-defined engineering problems in at least four technical areas appropriate to civil engineering.	Analysis (4)
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.	Evaluation (6)
Professional		
16. Communication	**Plan**, **compose**, and **integrate** the verbal, written, virtual, and graphical communication of a project to technical and nontechnical audiences.	Synthesis (5)
17. Public Policy	**Apply** public policy process techniques to simple public policy problems related to civil engineering works.	Application (3)
18. Business and Public Administration	**Apply** business and public administration concepts and processes.	Application (3)
19. Globalization	**Analyze** engineering works and services in order to function at a basic level in a global context.	Analysis (4)
20. Leadership	**Organize** and **direct** the efforts of a group.	Analysis (4)
21. Teamwork	**Function** effectively as a member of a multidisciplinary team.	Analysis (4)
22. Attitudes	**Demonstrate** attitudes supportive of the professional practice of civil engineering.	Application (3)
23. Lifelong Learning	**Plan** and **execute** the acquisition of required expertise appropriate for professional practice.	Synthesis (5)
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.	Evaluation (6)

The CEBOK2 also established paths to fulfillment for the outcomes and applied the B+M/30&E model from CEBOK1. These three components were defined as follows:

> *Bachelor's Degree (B)* – a baccalaureate degree in civil engineering.
> *Master's Degree or Equivalent (M/30)* – a master's degree, or approximately 30 coordinated graduate or upper-level undergraduate semester credits or the equivalent agency/organization/professional society courses providing equal quality and rigor.
>
> *Experience (E)* – appropriate experience based upon broad technical and professional practice guidelines that provide sufficient flexibility for a wide range of roles in engineering practice.

Table 3 shows the CEBOK2 outcomes integrated with the levels of achievement and paths to fulfillment.

Table 3. CEBOK2 Outcomes, Levels of Achievement and Paths to Fulfillment. [12]

Outcome Number and Title	*Level of Achievement*					
	1	*2*	*3*	*4*	*5*	*6*
	Knowledge	*Compre-hension*	*Application*	*Analysis*	*Synthesis*	*Evaluation*
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 & hist. 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. Lifelong learning	B	B	B	E	E	
24. Professional and ethical responsibility	B	B	B	B	E	E

In addition to defining the level of achievement for the outcomes required to enter the practice of civil engineering at the professional level, Appendix I of CEBOK2 included a complete rubric for all six levels of Bloom's Taxonomy. These were included for completeness.

Appendix J of CEBOK2 featured extensive appendices describing the outcomes in more detail. Appendices F and G of CEBOK2 provided additional discussion on the application of Bloom's Taxonomy both in the cognitive domain (Appendix F) and in the affective domain (Appendix G). The report also included several appendices on specific topics, some of which featured additional discussion on the outcomes.

These included:

- Humanities and Social Sciences (Appendix K)
- Sustainability (Appendix L)
- Globalization (Appendix M)
- Public Policy (Appendix N)
- Attitudes (Appendix O)

The Sociology of Professions and the Long-Term Management of the Civil Engineering Body of Knowledge (2008-2016)

Following the publication of CEBOK2, CAP^3 formed two committees to study and formulate guidelines for the fulfillment of the CEBOK, one focused on education and one on experiences.

The BOK Educational Fulfillment Committee (BOKEdFC) was formed in early 2008 and they investigated the incorporation of the 24 CEBOK2 outcomes into civil engineering curricula. Specifically, they were charged with (1) fostering the creation of a learning community of scholars interested in engineering educational reform, (2) reviewing the work products of the Body of Knowledge Committee and providing feedback, and (3) documenting how programs can incorporate the Body of Knowledge into their curriculum [14].

The BOK Experiential Fulfillment Committee (BOKExFC) was formed in spring 2009 to address the CEBOK2 outcomes requiring pre-licensure experience. They were charged with developing a stand-alone "Guidelines Document" using the 15 outcomes in the CEBOK2 with experiential expectations as a basis to be used by civil engineering interns and their mentor/supervisors during the pre-licensure part of the intern's career. The goal was to provide a resource document that interns would find both useful and user-friendly in documenting, validating, and reporting their pre-licensure experience activities [15].

As Ressler notes in his seminal article, "Sociology of Professions: Application to the Civil Engineering "Raise the Bar" Initiative", despite steady and substantial progress since 1998 to raise the bar and require education beyond a traditional four-year baccalaureate degree to practice at the professional level, the process has and still is contentious [16]. Indeed, ASCE's experience with the development and refinement of the CEBOK features near-constant change much of which was associated with the implementation of ASCE Policy 465. Civil engineering, through ASCE, was the first engineering profession to articulate a body of knowledge, so like most design projects, iterations involving trial and error were inevitable. Moreover, each of the iterations and supporting efforts were conducted by committees, each of which brought varying perspectives to the process.

Moreover, as Ressler suggests, sociological theory supports the idea that continuous change is an inherent characteristic in any professional BOK and that the CEBOK must continue to evolve. As Abbot in *The System of Professions* explains, a strong profession must be able to adapt its body of knowledge in response to emerging needs, opportunities, and threats. Ressler and Lynch specifically cite the following as influences that will lead to the continuous evolution of the CEBOK [17]:

- "new engineering challenges (e.g., climate change, emphasis on sustainability, energy
- shortages, terrorism, increase in the frequency and severity of natural disasters);
- new technologies (e.g., building information management, high-performance materials, smart buildings and sensing technologies);
- changes in the international business environment (e.g., limited financial capital, low-cost engineering services delivered via the internet, increased market consolidation);
- changes in law and the regulatory environment (e.g., licensure laws, environmental regulation);
- changes in relationships between and within engineering disciplines (e.g., evolving role of paraprofessionals); and
- engineering failures (e.g., Hurricane Katrina, the Gulf oil spill, the Minneapolis I-35 bridge collapse)."

Based largely on the examination of the sociology of professions and the simple fact that we live in an ever-changing world, ASCE committed to a fixed eight-year cycle for the CEBOK and the associated subsequent influences on accreditation criteria. The first CEBOK under this cycle is the Third Edition of the Body of Knowledge whose task committee (CEBOK3TC) officially formed in October 2016 and will publish CEBOK3 in spring 2019.

The Third Edition of the Body of Knowledge (2016-2019)

The Third Edition of the Civil Engineering Body of Knowledge (CEBOK3) is focused on preparing the future civil engineer for entry into the practice of civil engineering at the professional level.

Following a discussion of the committee charge, this section will summarize the significant revisions and updates from CEBOK2 to CEBOK3 which include:

- Revising the definition of the CEBOK
- Reducing the number of outcomes from 24 to 21 and adding an outcome category
- Confirming the use of Bloom's Taxonomy for levels of achievement and reducing the number of action verbs used
- Incorporating the use of Bloom's Taxonomy in the Affective Domain for 7 of the 21 outcomes
- Revising the typical paths to fulfillment
- Changing the format
- Recommending the development of companion materials to communicate important aspects of the CEBOK to various stakeholder groups

Committee Charge

The charge to the CEBOK3TC was to:

1) Critically review published literature regarding the future of engineering, other disciplines, and civil engineering practice;
2) Proactively solicit constituent input;
3) Evaluate the CEBOK2;
4) Determine if a Third Edition of the Civil Engineering Body of Knowledge (CEBOK3) report was warranted;
5) If warranted, develop the CEBOK3 report.

The CEBOK3TC completed a comprehensive and critical review of published papers, reports, and other documents. Significant publications included:

- Two internationally recognized engineering competency models – the U. S. Department of Labor's *Engineering Competency Model* [18] and the International Engineering Alliance's *Graduate Attributes and Professional Competencies* profiles [19].
- The American Society for Engineering Education's *Transforming Undergraduate Education in Engineering* [20].
- Body of knowledge documents published by other organizations, including:
    - The National Society of Professional Engineers' *Engineering Body of Knowledge* [21]
    - The American Society of Mechanical Engineers' *Vision 2030* [22],
    - The American Institute of Chemical Engineers' *Body of Knowledge for Chemical Engineers* [23]
    - The American Academy of Environmental Engineers' *Environmental Engineering Body of Knowledge* [24].
- Scholarly works published in venues such as ASCE's *Journal of Professional Issues in Engineering Education and Practice* [16, 25] and the American Society for Engineering Education's annual conference proceedings [3], [14-15], [17] [26-34].
- Other reference materials such as:
    - The United Nations Educational, Scientific and Cultural Organization's *Youth and Skills: Putting Education to Work* report [35],
    - The National Leadership Council for Liberal Education and America's Promise's *College Learning for the New Global Century* report [36]
    - The National Academy of Engineering's *Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning* [37].

In addition to the CEBOK2, the CEBOK3TC reviewed more than 50 separate publications, of which those having the most influence were listed above, during its evaluation of available literature and conducted the first of three constituent surveys to determine if a third edition was warranted. The CEBOK3TC concluded that a third edition should be developed [38] and proceeded with developing it. [39]

Another key source which helped guide the CEBOK3TC on the process on developing the CEBOK was "The Raise the Bar Effort: Charting the Future by Understanding the Path to Present – The BOK and Lessons Learned" written by Stuart Walesh, who chaired the CEBOK1 committee and served as the editor for the CEBOK2. The CEBOK3TC applied the nine lessons learned cited in that paper [40]:

- conduct scholarly studies
- start with vision
- expect and deal with setbacks
- apply a change model
- test-drive terminology
- function transparently and inclusively
- persevere and practice principled compromise
- recognize and leverage serendipity, and
- stand respectfully and thankfully on the shoulders of others

The committee also proactively solicited constituent input. This process and results are fully addressed in a companion paper titled, "Constituent Input in the Process of Developing the Third Edition of the Civil Engineering Body of Knowledge (CEBOK3)" which is also being published and presented at the 2019 ASEE Annual Conference [41].

Revising the definition of the CEBOK

The definition of the CEBOK evolved since the CEBOK1 was published in 2004. In both the first and second editions, the CEBOK defined the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level, where "entry into the practice of civil engineering at the professional level" was defined as becoming licensed as a professional engineer (PE). Although the CEBOK3 supports licensure and recognizes licensure as an important aspect of the civil engineering profession, the CEBOK is separate and distinct from licensure, which is a legal status governed by licensing boards. As such, the CEBOK3 removes the direct link to licensure and recognizes that the CEBOK applies to all civil engineers regardless of career path or area of practice.

Reducing the number of outcomes from 24 to 21and adding an outcome category

The Third Edition of the Civil Engineering Body of Knowledge (CEBOK3) includes 21 outcomes in four categories as shown in Table 4. In addition to the three categories – foundational, technical, and professional – used in the CEBOK2, the CEBOK3 introduced a new, fourth category – engineering fundamentals. The foundational outcomes provide the knowledge on which all other outcomes are built both for civil engineers and those in most other learned professions. The engineering fundamentals outcomes form a bridge between the foundational and technical outcomes for all civil engineers, and notably for many other disciplines of engineering as well. The technical outcomes specify knowledge more specific to civil engineering, and the professional outcomes focus on interpersonal and professional skills needed for success in the practice of civil engineering at the professional level.

Table 4. CEBOK3 Outcomes.

Foundational	**Engineering Fundamentals**
Mathematics	Materials Science
Natural Sciences	Engineering Mechanics
Social Sciences	Experiment Methods & Data Analysis
Humanities	Critical Thinking & Problem Solving
Technical	**Professional**
Project Management	Communication
Engineering Economics	Teamwork & Leadership
Risk & Uncertainty	Lifelong Learning
Breadth in Civil Engineering Areas	Professional Attitudes
Design	Professional Responsibilities
Technical Depth	Ethical Responsibilities
Sustainability	

Overall the number of outcomes was reduced from 24 to 21; however, the scope of the CEBOK did not decrease. Also, the numbering system for the outcomes was removed to clarify that there is no specific order of importance among the outcomes. All of the outcomes were revised in some manner, two were combined, two were separated, four were removed as separate outcomes but incorporated into others, and one new outcome was added.

The two separate Teamwork and Leadership outcomes in CEBOK2 were combined to form the Teamwork and Leadership outcome in CEBOK3. The Professional and Ethical Responsibility outcome in the CEBOK2 was split into two separate outcomes, the Professional Responsibilities outcome and the Ethical Responsibilities outcome, in the CEBOK3.

Four outcomes, Contemporary and Historical Perspectives, Public Policy, Globalization, and Business and Public Administration, were removed as separate outcomes in CEBOK3. However, Contemporary and Historical Perspectives, Public Policy, and Globalization are related to the Professional Responsibilities outcome and are included as topics important to the profession. Also, many of the critical concepts in the Business and Public Administration outcome are incorporated into the Engineering Economics, Teamwork and Leadership, and Professional Responsibilities outcomes. The Engineering Economics outcome was added and it addresses many business fundamentals topics in CEBOK2.

There were two other significant revisions to the outcomes. Critical thinking is now explicitly included with problem solving in the Critical Thinking and Problem Solving outcome and data analysis is fully included with conducting experiments in the Experimental Methods and Data Analysis outcome.

Confirming the use of Bloom's Taxonomy for levels of achievement and reducing the number of action verbs used

The CEBOK3TC reviewed the literature for possible alternative taxonomies and to determine if the use of Bloom's Taxonomy for both the cognitive and affective domain could be appropriate as the framework for CEBOK3. Although other taxonomies were considered by the CEBOK3, they noted that the others were either too complex, not well-informed, or lacked the structural coherency of Bloom's Taxonomy. The committee then considered several variations of Bloom's Taxonomy for the cognitive domain including:

- Bloom's original taxonomy
- Bloom's original taxonomy with subcategories
- Bloom's original taxonomy with a knowledge dimension
- The revised Bloom's taxonomy
- The revised Bloom's taxonomy with a knowledge dimension

Although for some pedagogical applications there are benefits of the revised taxonomy, the CEBOK3TC agreed with the CEBOK2TC and adopted an amended form of the original Bloom's Taxonomy [42] hierarchy and not Anderson and Krathwohl's revisions [43] to the hierarchy. The main driving force in adopting the original Bloom's Taxonomy is the belief that in the field of engineering creation and design logically come before evaluation. Thus, *evaluate* remained at the top of the hierarchal pyramid. The CEBOK3TC also felt that the addition of the dimension of cognitive processes would add unnecessary complexity to determining a level of attainment for each outcome of the CEBOK3.

However, the CEBOK3TC adopted an amended form of the Bloom's Taxonomy hierarchy for the cognitive domain. The amended taxonomy shown in Table 5 is a modification of the original 1956 Bloom's Taxonomy for the Cognitive Domain with selected naming conventions from the revision by Anderson and Krathwohl. The CEBOK3TC adopted the verb form for the names of the levels and as noted above, levels 5 and 6 align with the original Bloom's Taxonomy hierarchy in that synthesize comes before evaluate. Also, the name for level 2 became "comprehend" from the original "comprehension" in the 1956 Bloom's Taxonomy instead of "understand" from the revised taxonomy, mainly because "understanding" was used as one of the three levels in CEBOK1. However, level 1 was renamed "remember" as used in the revised taxonomy from "knowledge" used in CEBOK2 and the original taxonomy. The CEBOK3TC concluded that these modifications to the framework most effectively communicated the outcomes in the CEBOK. The CEBOK3 Outcomes and the Level of Achievement in the Cognitive Domain necessary for entry into the practice of civil engineering at the professional level are presented in Table 6.

Table 5. Defining the Levels of Bloom's Taxonomy for the Cognitive Domain (Adapted from Anderson et.al., [31]) [39]

Bloom's Level	*Examples and Key Words*
(1) Remember: Recall or retrieve previously learned information	*Examples:* Recite safety rules. List the steps in the engineering design process. *Key Words*: define, describe, identify, label, list, match, recall, recite, recognize reproduce
(2) Comprehend: Restating a problem in one's own words, or interpreting content or instructions. Note: Anderson called this category Understanding	*Examples*: Explain how to conduct an experiment. Translate an equation into a spreadsheet. *Key Words:* convert, distinguish, explain, extend, paraphrase, rewrite, summarize.
(3) Apply: Apply what was learned to solve a problem, or use a concept in a new situation	*Examples:* Calculate stress in a in a beam. Construct a free body diagram. *Key Words*: Calculate, compute, construct, determine, predict, produce, solve, use.
(4) Analyze: Break concepts or problems into their component parts so that their structure can be understood	*Examples:* Select the appropriate technique(s) to interpret data. Identify the largest bending moment in structure. *Key Words:* Breakdown, compare, contrast, differentiate, identify, illustrate, infer, relate, select, separate.
(5) Synthesize: Combining disparate knowledge to create a new whole. Build a pattern or matrix from diverse elements	*Examples:* Design a structure to carry specified loads. Create construction specifications for a project. *Key Words:* Categorize, compile, create, design, devise, plan, revise, summarize
(6) Evaluate: Making judgements about the value of ideas, work products or processes.	*Examples:* Critique a proposed design. Justify a novel design or construction technique. *Key Words:* Assess, conclude critique, judge, justify, validate.

Table 6. CEBOK3 Outcomes and Levels of Achievement in the Cognitive Domain.

Outcome	Outcome Statement	Level
Foundational Outcomes		
Mathematics	**Apply** concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering problems.	Apply (3)
Natural Sciences	**Apply** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences, to solve civil engineering problems.	Apply (3)
Humanities	**Apply** aspects of the humanities to the solution of civil engineering problems.	Apply (3)
Social Sciences	**Apply** concepts and principles of social sciences relevant to civil engineering.	Apply (3)
Engineering Fundamentals Outcomes		
Materials Science	**Apply** concepts and principles of materials science to solve civil engineering problems.	Apply (3)
Engineering Mechanics	**Apply** concepts and principles of solid and fluid mechanics to solve civil engineering problems.	Apply (3)
Experimental Methods & Data Analysis	**Select** appropriate experiments, and **analyze** the results in the solution of civil engineering problems.	Analyze (4)
Critical Thinking & Problem Solving	**Develop** a set of appropriate solutions to a complex problem, question, or issue relevant to civil engineering.	Synthesize (5)
Technical Outcomes		
Project Management	**Apply** concepts and principles of project management in the practice of civil engineering.	Apply (3)
Engineering Economics	**Apply** concepts and principles of engineering economics in the practice of civil engineering.	Apply (3)
Risk & Uncertainty	**Select** appropriate concepts and principles of probability and statistics to analyze risk in a complex civil engineering problem.	Analyze (4)
Breadth in a Civil Engineering Area	**Analyze** complex problems that cross multiple specialty areas appropriate to the practice of civil engineering.	Analyze (4)
Design	**Develop** an appropriate design alternative for a complex civil engineering project that considers realistic requirements and constraints.	Synthesize (5)
Depth in a Civil Engineering Area	**Integrate** advanced concepts and principles into the solutions of complex problems in a specialty area appropriate to the practice of civil engineering.	Synthesize (5)
Sustainability	**Analyze** the sustainable performance of complex civil engineering projects from a systems perspective.	Analyze (4)
Professional Outcomes		
Communication	**Integrate** different forms of effective and persuasive communication to technical and non-technical audiences.	Synthesize (5)

Teamwork & Leadership	**Integrate** concepts and principles of effective teamwork and leadership, including diversity and inclusion, into the solutions of civil engineering problems.	Synthesize (5)
Lifelong Learning	**Integrate** new knowledge, skills, and attitudes acquired through self-directed learning into the practice of civil engineering.	Synthesize (5)
Professional Attitudes	**Illustrate** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Analyze (4)
Professional Responsibilities	**Integrate** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	Synthesize (5)
Ethical Responsibilities	**Develop** courses of action to ethical dilemmas in complex situations.	Synthesize (5)

Another significant revision in CEBOK3 involved the reduction of the number of verbs used in cognitive domain and the prohibition from using a verb at different levels [44]. As shown in Table 7, CEBOK3 used 16 different verbs compared to 40 verbs which accounts for five verbs that were used at two levels and one verb used at three. At the time and as explained in the Bloom's Taxonomy appendix of CEBOK2, from a scholarly perspective, the reasoning for using verbs at more than one level, through the use of different definitions of the verbs, was logical, in practice this proved too complicated and added much confusion. The logical reasoning, as noted in the CEBOK2 appendix, was that some verbs were used at levels for which they were not originally intended for the purposes of conveying appropriate educational objective progression. Although done with good intentions, the CEBOK3TC concluded that the use of verbs at multiple levels was too problematic and sought to clarify communication of the outcomes by reducing the number of verbs and prohibiting their use at multiple levels. Table 7 provides a comparison between the action-oriented verbs used in CEBOK2 and CEBOK3. The names of the levels correspond to the levels adopted for CEBOK3.

Table 7. Action-Oriented Verbs Used in the Cognitive Domain for CEBOK2 and CEBOK3.

Level of the Cognitive Domain	**CEBOK2 Verbs**	**CEBOK3 Verbs**
1. Remember	Define, Describe, Identify, List, Recognize (5)	Define, Identify, Recognize (3)
2. Comprehend	Describe, Discuss, Distinguish, Explain (4)	Explain (1)
3. Apply	Apply, Conduct, Demonstrate, Develop, Explain, Formulate, Function, Organize, Report, Solve Use (11)	Acquire, Apply, Conduct, Formulate, Report (5)
4. Analyze	Analyze, Deliver, Direct, Formulate, Function, Identify, Illustrate, Organize, Select (9)	Analyze, Illustrate, Select (3)

5. Synthesize	Adapt, Compose, Create, Design, Develop, Execute, Explain, Integrate, Organize, Plan, Specify, Synthesize (12)	Develop, Integrate (2)
6. Evaluate	Appraise, Assess, Compare, Evaluate, Justify, Self-assess (6)	Assess, Evaluate (2)

Additional details on the application of Bloom's Taxonomy in CEBOK3 can be found in Appendix E.

Incorporating the use of Bloom's Taxonomy in the Affective Domain for 7 of the 21 outcomes

In addition to using Bloom's Taxonomy for the Cognitive Domain, CEBOK3 also formally introduces the application of Bloom's Taxonomy for the Affective Domain [45] for 7 of the 21 outcomes, including sustainability and all of the professional outcomes. The affective domain, describes changes in interests, attitudes, and values [45]. The classification scheme for the affective domain developed by Krathwohl and his colleagues is summarized in Table 8 with a collection of affective activities that represent an internalization continuum where level one, *receiving*, is the lowest level of internalization and level five, *characterization by a value complex* is the highest. Also illustrated in Table 8 is a set of affective behaviors that are associated with the continuum of activities [46].

Table 8. Levels of Internalization in the Affective Domain (Adapted from Krathwohl, et.al.,[45])

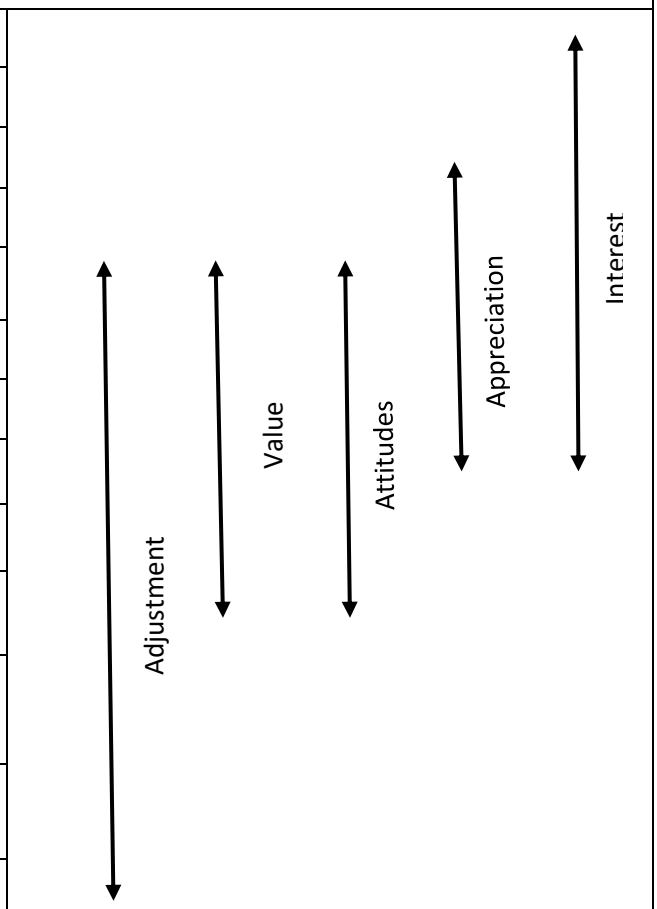
	Level of Internalization	
1 Receive	1.1 Awareness	
	1.2 Willingness to receive	
	1.3 Selected Attention	
2 Respond	2.1 Acquiescence in Responding	
	2.2 Willingness to Respond	
	2.3 Satisfaction in Responding	
3 Value	3.1 Acceptance	
	3.2 Preference for a Value	
	3.3 Commitment	
4 Organize	4.1 Conceptualization of a Value	
	4.2 Organization of a Value System	
5 Characterize	5.1 Generalized Set	
	5.2 Characterization	

Table 9 lists simplified definitions for the five major levels and possible examples of actions that would signify attainment of a particular level on the continuum relative to the topic of ethics [46].

Table 9. Definitions and Example of Actions Demonstrating Affective Attainment (Adapted from Krathwohl, et.al., [45])

Level	Definition and Examples
Receive	*Definition*: Being aware of or attending to something in the environment. *Example*: Individual reads a book passage and recognizes the relationship to ethical behavior.
Respond	*Definition*: Exhibit some new behaviors as a result of experience. *Example*: Individual participates in a discussion about the book, reads another book by the same author or another book about ethical behavior, etc.
Value	*Definition*: Display some definite involvement or commitment. *Example*: The individual demonstrates this by voluntarily attending a lecture on ethical behavior.
Organize	*Definition*: Integrate a new value into one's general set of values, giving it some ranking among one's general priorities. *Example*: The individual organizes a study session for other students on topics related to ethical behavior.
Characterize	*Definition*: Act consistently with the new value. *Example*: The individual is firmly committed to the value, perhaps becoming a public advocate of a revised or new code of ethics for his profession.

The CEBOK1 Task Committee recognized that a civil engineer's attitude, that is, the manner in which he or she approaches and values his or her work, determines how effectively he or she uses knowledge and skills and they concluded that attitude was an essential part of the CEBOK [6]. However, the aspect of attitude was not incorporated into an outcome and was addressed in its own section immediately following the outcomes [6].

Although the CEBOK2TC addressed a methodology to address attitudes through the affective domain and even established an attainment matrix for the Communication and Professional and Ethical Responsibility outcomes in Appendix G of CEBOK2, they did not include the affective domain in the formal part of the CEBOK. Instead, the CEBOK2TC created a separate, stand-alone Attitudes outcome with levels of achievement described entirely in the cognitive domain. In reviewing the literature since the publication of CEBOK2, the CEBOK3TC noted a growing trend in engineering education for the need to supplement cognitive learning with the attainment of affective outcomes to promote deeper learning [47-48]. The CEBOK3TC also noted Ressler's discussion on the sociology of profession [16] and that according to Freidson, one of the five components of an ideal-type profession is "an ideology that serves one or more transcendent

values and claims greater commitment to doing good work than to economic reward" [49]. The role of values in a profession further supported the inclusion of the affective domain in the CEBOK.

Although the CEBOK3TC initially considered formulating an affective domain achievement matrix for all 21 outcomes of the CEBOK3, they concluded that the most effective use of the affective domain was to present 7 of the 21 outcomes, including the Sustainability outcome, due to its relationship to ethical behavior, and all of the professional outcomes, in the affective domain. Table 10 presents the CEBOK3 outcomes and the outcome statements in the affective domain.

Table 10. CEBOK3 Outcomes and Levels of Achievement in the Affective Domain.

Outcome	Outcome Statement	Level
Technical Outcomes		
Sustainability	**Integrate** a commitment to sustainability principles into the practice of civil engineering.	Organize (4)
Professional Outcomes		
Communication	**Display** effective and persuasive communication to technical and non-technical audiences.	Organize (4)
Teamwork & Leadership	**Display** effective teamwork and leadership, including support of diversity and inclusion.	Organize (4)
Lifelong Learning	**Establish** a lifelong learning plan to support one's own professional development.	Organize (4)
Professional Attitudes	**Establish** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Organize (4)
Professional Responsibilities	**Form judgements** about professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.	Organize (4)
Ethical Responsibilities	**Advocate for** ethical behavior in the practice of civil engineering.	Characterize (5)

Additional details on the application of Bloom's Taxonomy in the Affective Domain in CEBOK3 can be found in Appendix E of the third edition. Moreover, a companion paper, titled "Achieving the Civil Engineering Body of Knowledge in the Affective Domain" is also being published and presented at the 2019 ASEE Annual Conference [50]. This paper discusses more details on the application of the affective domain in the CEBOK3 and describes potential mechanisms by which one could demonstrate achievement at various levels in the affective domain.

Revising the typical paths to fulfillment

As with CEBOK2, CEBOK3 provides a pathway to fulfillment for attaining the levels of achievement for each of the outcomes. CEBOK2 named these "paths to fulfillment". Recognizing that the pathway may vary, CEBOK3TC revised this to "typical pathway for fulfillment of the outcome" to explicitly convey that the pathway is by no means the only pathway to fulfillment but rather, as the name implies, a typical pathway to fulfillment.

The Bachelor's Degree (B) pathway in CEBOK2 was redefined as Undergraduate Education (UG) and the Master's Degree or Equivalent (M/30) was redefined as Postgraduate Education (PG). Although the experience pathways are similar, the CEBOK3TC revised the experience (E) pathway from CEBOK2 to mentored experience (ME), placing further emphasis on the role of more experienced civil engineers developing early-career civil engineers.

With the addition of the affective domain, the CEBOK recognizes the need for civil engineers to internalize and have a value system which supports practice at the professional level. Consequently, the CEBOK3TC recognized that individual civil engineers are also responsible for their own development and established self-development as a new pathway component to fulfilling the CEBOK. Therefore, the CEBOK3 defines the typical pathway for fulfilling the levels of achievement using four components: undergraduate education, postgraduate education, mentored experience, and self-development as defined below [39]

> *Undergraduate Education (UG)* – undergraduate education leading to a bachelor's degree in civil engineering or a closely related engineering discipline, generally from a four-year ABET/EAC-accredited program.
>
> *Postgraduate Education (PG)* – postgraduate education equivalent to or leading to a master's degree in civil engineering or a closely related engineering discipline, generally equivalent to one year of full time study.
>
> *Mentored Experience (ME)* – early-career experience under the mentorship of a civil engineer practicing at the professional level, which progresses in both complexity and level of responsibility.
>
> *Self-Developed (SD)* – individual self-development through formal or informal activities and personal observation and reflection.

Table 11 presents the typical pathway to achievement for the CEBOK3 outcomes in the cognitive domain and Table 12 presents the typical pathway to achievement for the CEBOK3 outcomes in the affective domain.

Table 11. CEBOK3 Cognitive Domain Typical Pathway to Achievement [39]

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Foundational Outcomes						
Mathematics	UG	UG	UG			
Natural Sciences	UG	UG	UG			
Social Sciences	UG	UG	UG			
Humanities	UG	UG	UG			
Engineering Fundamentals Outcomes						
Materials Science	UG	UG	UG			
Engineering Mechanics	UG	UG	UG			
Experimental Methods & Data Analysis	UG	UG	UG	PG		
Critical Thinking & Problem Solving	UG	UG	UG	ME	ME	
Technical Outcomes						
Project Management	UG	UG	ME			
Engineering Economics	UG	UG	ME			
Risk & Uncertainty	UG	UG	UG	ME		
Breadth in Civil Engineering Areas	UG	UG	UG	ME		
Design	UG	UG	UG	ME	ME	
Depth in a Civil Engineering Area	UG	UG	PG	PG	ME	
Sustainability	UG	UG	UG	ME		

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Professional Outcomes						
Communication	UG	UG	UG	ME	ME	
Teamwork & Leadership	UG	UG	UG	ME	ME	
Lifelong Learning	UG	UG	UG	ME	ME	
Professional Attitudes	UG	UG	ME	ME		
Professional Responsibilities	UG	UG	ME	ME	ME	
Ethical Responsibilities	UG	UG	ME	ME	ME	

Table 12. CEBOK3 Affective Domain Typical Pathway to Achievement [39]

Outcome	Affective Domain Level of Achievement				
	Level 1 Receive	Level 2 Respond	Level 3 Value	Level 4 Organize	Level 5 Characterize
Technical Outcome					
Sustainability	UG	UG	ME	SD	
Professional Outcomes					
Communication	UG	UG	ME	SD	
Teamwork & Leadership	UG	UG	ME	SD	
Lifelong Learning	UG	UG	ME	SD	
Professional Attitudes	UG	UG	ME	SD	
Professional Responsibilities	UG	UG	ME	SD	
Ethical Responsibilities	UG	UG	ME	ME	SD

Another significant change from CEBOK2 to CEBOK3 is the increased focus on mentored experience. Although a direct comparison between the number of experience components is not possible because the outcomes changed from CEBOK2 to CEBOK3, the percentage of experience or mentored experience component can be compared. Of the 97 outcome statements in the full rubric required for entry into the practice of civil engineering at the professional level as depicted in Appendix H of CEBOK2, 17 pathways were designated as experience (E) or 17.5%. CEBOK3 features 84 outcome statements in the cognitive domain in the full rubric required for entry into the practice of civil engineering at the professional level and of those 84, 24 pathways are designated as mentored experience (ME), which corresponds to 28.6%, an 11% increase.

Also, of the 29 outcome statements in the affective domain of CEBOK3, 8 or 27.6% are designated as mentored experience (ME). The self-developed pathway component appears 7 times and always after mentored experience because the CEBOK3TC concluded that mentored experience provides the foundation for continued self-development.

Changing the format

The CEBOK3 features a minor revision to the title of the report and significant changes to the format from the previous two editions. The title for the first two editions is "*Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*." To emphasize that the CEBOK is the roadmap for properly preparing future civil engineers not for practice as we know it today, but for the profession as we expect it to be tomorrow, the CEBOK3TC revised the title to "*Civil Engineering Body of Knowledge Third Edition, Preparing the Future Civil Engineer*."

The CEBOK2 followed a similar report structure as CEBOK1. This was specified in the charges to the CEBOK2TC which included "'follow the overall structure of the first edition" and to "move as much material as possible from the report's body into its appendices" [12]. The CEBOK3TC had no such constraints. In fact, the fifth charge to the committee was simply, "if warranted, develop the CEBOK3 report" [39]. As such, the CEBOK3TC took a fresh look at how to best communicate the CEBOK and decided to place the CEBOK outcomes in the main body of the report, emphasizing the principle focus of the CEBOK3 report.

The format of the CEBOK3 report is simple. An introductory chapter follows the standard front materials consisting of the preface, table of content, lists of tables and figures, and executive summary. Chapter 2 is the CEBOK and Chapter 3 provided a summary and conclusion. The CEBOK in Chapter 2 contains detailed explanations for each of the 21 outcome and follows a standard format of the outcome rubric in the cognitive domain, and where applicable for the affective domain, followed by sections on understanding the outcome, the rationale for including the outcome in the CEBOK3, the level of achievement required, and suggestions for a typical pathway for fulfillment of the outcome. Quite simply, the CEBOK3 is Chapter 2.

The appendices in the CEBOK3 are limited and focused on specific information supporting the development of the CEBOK3. The first three appendices are somewhat standard and include abbreviations, a glossary with definitions, and information on the committee. Five additional appendices provided supporting material.

The CEBOK3TC sought extensive constituent input during the development of the CEBOK3 through a series of quantitative and qualitative surveys and provides detail on the process and results in Appendix D. As noted above, CEBOK3 features changes in the application of Bloom's Taxonomy for the cognitive domain and adopted the application of Bloom's Taxonomy for the affective domain. Additional information on the taxonomies and their application is discussed in Appendix E.

As in CEBOK2, the CEBOK3 includes a complete rubric for all six levels of Bloom's Taxonomy in the cognitive domain and all five levels in the affective domain. These are in Appendix F along with tables listing the verbs used at each level for both domains and a tabular depiction of the typical pathway to achievement for the outcomes in both the cognitive and affective domain. The CEBOK3TC noted that many of the outcomes are related and provided a graphical representation of these relationship in Appendix G.

Finally, Appendix H provides a side-by-side comparison of CEBOK3 and CEBOK2 for each of the outcomes. For each outcome, both outcome rubrics are presented followed by a discussion on the summary of changes. The CEBOK3 provides no comparison or relationship to ABET outcomes. ASCE informs ABET on accreditation through a separate process, which as described by the long-term management of the BOK [17] follows the publication of CEBOK.

Recommending the development of companion materials to communicate important aspects of the CEBOK to various stakeholder groups

The final substantive change is a derivative of the format change. The CEBOK3TC concluded that it would be more effective to provide guidance to specific stakeholders and constituents through focused companion materials. This will permit the use of multi-media and different formats to provide an enhanced and more engaging presentation of these materials. Although the CEBOK3TC identified a base set of specific constituent groups, including students, faculty, early-career engineers, mentors, and organizational leaders, additional audiences may become apparent. The companion materials approach provides ASCE the flexibility to address additional audiences and keep the material updated and relevant until the CEBOK is updated in the future.

Future Plans (2019 & Beyond)

Although the CEBOK3TC will complete its charge with the publication of *The Third Edition of the Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer* in spring 2019, members continue to work on developing the series of focused companion materials to accompany the CEBOK3 to communicate important aspects of the CEBOK that are most relevant to specific constituent groups, such as students, faculty, early-career engineers, mentors, and organizational leaders.

As the preface to CEBOK3 states, “this Third Edition of the Civil Engineering Body of Knowledge is the roadmap for properly preparing our future civil engineers not for practice as we know it today, but for the profession as we expect it to be tomorrow. [38]” To ensure that our profession stays current with the ever-changing “tomorrow” and to maintain its relevancy in society, the long-term plan calls for work to begin on CEBOK4 in October 2024.

References

[1] Brandes, Horst, et al., (2019) “The Role of the Civil Engineering Body of Knowledge in ASCE’s Raise the Bar Effort.” Proceedings of the 2019 Annual Conference & Exposition of the American Society for Engineering Education, June 2019.

[2] Mann, C. R. 1918. *A study of engineering education, prepared for the Joint Committee on Engineering Education of the National Engineering Societies. Bull. No. 11*, The Carnegie Foundation for the Advancement of Teaching, New York.

[3] Russell, J.S., Lenox, T.A. (2012) “The Raise the Bar Initiative: Charting the Future by Understanding the Path to the Present – An Overview.” Proceedings of the 2017 ASEE Annual Conference & Exposition, June 2012.

[4] American Society of Civil Engineers. 1995. *Summary Report: 1995 Civil Engineering Education Conference (CEEC ’95)*. ASCE, Reston, VA.

[5] American Society of Civil Engineers. 2001. *Engineering the Future of Civil Engineering*. Report of the Task Committee on the First Professional Degree, ASCE, Reston, VA.

[6] *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*. (2004) American Society of Civil Engineers (ASCE), Reston, VA.

[7] ABET, Inc., 2004. Engineering Accreditation Commission, Criteria for Accrediting Engineering Programs, Effective for Evaluations during the 2004-2005 Accreditation Cycle, Baltimore, Maryland.

[8] American Society of Civil Engineers. *Levels of Achievement Applicable to the Body of Knowledge Required for Entry into the Practice of Civil Engineering at the Professional Level*, Report of the Levels of Achievement Subcommittee to the ASCE Committee on Academic Prerequisites for Professional Practice, September 2, 2005.

[9] American Society of Civil Engineers. 2004. “ASCE Policy Statement 465: Academic Prerequisites for Licensure and Professional Practice.” ASCE, April.

[10] National Academy of Engineering. 2004. *The Engineer of 2020: Visions of Engineering in the New Century*, NAE, Washington, DC.

[11] National Academy of Engineering. 2005. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, NAE, Washington, DC.

[12] *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*, Second Edition. (2008) American Society of Civil Engineers (ASCE), Reston, VA.

[13] Gronlund, N. E. *Stating Objectives for Classroom Instruction, 2nd Edition*, New York: Macmillan, 1978.

[14] Nelson, J.K.; Fridley, K.; and Hall, K. (2012). "The Raise the Bar Initiative: Charting the Future by Understanding the Path to the Present -- How Are BSCE Curricula Responding?" *Proceedings of the 2012 Conference of the American Society for Engineering Education*, June.

[15] Phillips, M. and Holly, F. (2012). "The Raise the Bar Initiative: Charting the Future Through Strengthened Experiential Guidelines." *Proceedings of the 2012 Conference of the American Society for Engineering Education*, June.

[16] Ressler, S. J., "Sociology of Professions: Application to the Civil Engineering "Raise the Bar" Initiative. *Journal of Professional Issues in Engineering Education & Practice,* vol. 137, No. 3, July 1, 2011.

[17] Ressler, S.J., Lynch D.R. (2011) "The Civil Engineering Body of Knowledge and Accreditation Criteria: A Plan for Long-Term Management of Change." Proceedings of the 2011 ASEE Annual Conference & Exposition, June 2011.

[18] *Engineering Competency Model.* (2016) American Association of Engineering Societies and the U.S. Department of Labor (http://www.aaes.org/model).

[19] *Graduate Attributes and Professional Competencies.* (2013) International Engineering Alliance (http://www.ieagreements.org).

[20] *Transforming Undergraduate Education in Engineering, Phase I: Synthesizing and Integrating Industry Perspectives.* (2013) American Society for Engineering Education (http://tuee.asee.org/phase-i/).

[21] *Professional Engineering Body of Knowledge.* (2013) National Society of Professional Engineers (NSPE), Alexandria, VA.

[22] *Vision 2030: Creating the Future of Mechanical Engineering Education.* (2012) American Society of Mechanical Engineers (ASME), New York, NY

.

[23] *Body of Knowledge for Chemical Engineers.* (2015) American Institute of Chemical Engineers (AIChE), New York, NY.

[24] *Environmental Engineering Body of Knowledge.* (2009) American Academy of Environmental Engineers and Scientists (AAEES), Annapolis, MD.

[25] Carpenter, D.D., Harding, T.S., Sutkus, J.A., and Finelli, C.J. (2014) "Assessing the Ethical Development of Civil Engineering Undergraduates in Support of the ASCE Body of Knowledge." ASCE *Journal of Professional Issues in Engineering Education & Practice*, Vol. 140, No. 4.

[26] Estes, A.C., Lenox, T.A., Fridley, K.J., and Anderson, R.O. (2016) "Accreditation Insights and the Next Body of Knowledge." Proceedings of the 2016 Annual Conference of the American Society for Engineering Education, June 2016.

[27] Fridley, K.J., et al. (2009) "Educating the Future Civil Engineering for the New Civil Engineering Body of Knowledge." Proceedings of the 2009 Annual Conference of the American Society for Engineering Education, June 2009.

[28] Walesh, S.G. (2012) "Raise the Bar Initiative: The BOK and Leadership Lessons Learned." Proceedings of the 2012 Annual Conference of the American Society for Engineering Education, June 2012.

[29] Walesh, S.G. (2014) "NSPE's Pan-Engineering BOK." Proceedings of the 2014 Annual Conference of the American Society for Engineering Education, June 2014.

[30] Evans, J.C., and Beiler, M.O. (2015) "Humanities and Social Sciences Outcomes for the Third Edition: Civil Engineering Body of Knowledge." Proceedings of the 2015 Annual Conference of the American Society for Engineering Education, June 2015.

[31] Walesh, S.G. (2015) "Creativity and Innovation as Part of the Civil Engineering BOK." Proceedings of the 2015 Annual Conference of the American Society for Engineering Education, June 2015.

[32] Walesh, S.G. (2016) "Possible Influences of the NSPE EBOK and the AAEK/DOL Engineering Competency Model on the CEBOK3." Proceedings of the 2016 Annual Conference of the American Society for Engineering Education, June 2016.

[33] Ressler, S.J., and Lenox, T.A. (2016) "Raising the Bar for Civil Engineering: Implications of the International Engineering Alliance Graduate Attribute Profiles." Proceedings of the 2016 Annual Conference of the American Society for Engineering Education, June 2016.

[34] Fridley, K.J., Back, W.E., and Williamson, D.G. (2016) "The ASCE BOK, ABET Accreditation Criteria, and NCEES FE Exam – Are They Appropriately Aligned?" Proceedings of the 2016 Annual Conference of the American Society for Engineering Education, June 2016.

[35] *Youth and Skills: Putting Education to Work, Report on Skills Gap*. (2012) United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France.

[36] *College Learning for the New Global Century*. (2007) National Leadership Council for Liberal Education and America's Promise, Association of American Colleges and Universities (AACU), Washington, DC.

[37] *Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning*. (2013) National Academy of Engineering (NAE), National Academies Press, Washington, DC.

[38] Fridley, K.J., Hains, D.B., Nolen, L., Barry, B.E., Hartmann, B.L. (2017) "Is It Time for a Third Edition of the Civil Engineering Body of Knowledge (BOK)?" Proceedings of the 2017 ASEE Annual Conference & Exposition, June 2017.

[39] ASCE. *Civil Engineering Body of Knowledge Third Edition, Preparing the Future Civil Engineer*. Final Draft, November 1, 2018. Prepared by the Civil Engineering Body of Knowledge 3 Task Committee.

[40] Walesh, S.G., (2012) "The Raise the Bar Effort: Charting the Future by Understanding the Path to Present The BOK and Lessons Learned." Proceedings of the 2018 ASEE Annual Conference & Exposition, June 2018.

[41] Bielefeldt, Angela, Barry Brock, Hains, Decker B., et al. (2019) "Constituent Input in the Process of Developing the Third Edition of the Civil Engineering Body of Knowledge (CEBOK3)." Proceedings of the 2019 Annual Conference & Exposition of the American Society for Engineering Education, June 2019.

[42] Bloom, B.S., Englehart, M.D., Furst, E.J., Hill, W.H. and Krathwohl, D.R. *Taxonomy of Educational Objectives, the Classification of Educational Goals, Handbook I: Cognitive Domain*. New York: David McKay Company, 1956

[43] Anderson, L., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., and Wittrock, M. C. *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives.* New York: Longman, 2001.

[44] Hains, D.B., Fridley, K.J., Nolan, L., Barry, B.E. (2018) "Revising the Civil Engineering Body of Knowledge (BOK): The Application of the Cognitive Domain of Bloom's Taxonomy." Proceedings of the 2018 ASEE Annual Conference & Exposition, June 2018.

[45] Krathwohl, D. R., Bloom, B.S. and Masia, B.B. 1964. *The Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook II: Affective Domain*. David McKay Company, New York, NY.

[46] Dennis, N.D., Hains, D.B. Brandes, H., Delatte, N. (2018) "Assessing the Civil Engineering Body of Knowledge in the Affective Domain." Proceedings of the 2018 ASEE Annual Conference & Exposition, June 2018.

[47] Bielefeldt, A.R., (2013), Pedagogies to Achieve Sustainability Learning Outcomes in Civil and Environmental Engineering Students, Sustainability, MDPI Open Access Journals, doi, 10.3390/su5104479, accessed at http://www.mdpi.com/2017-1050/5/10/4479/htm on 25 Jan, 2018.

[48] Lynch D.R., Russell, J.S., Evans, J.C., Sutterer, K.G., (2009), Beyond the Cognitive, The Affective Domain, Values and the Achievement of the Vision, ASCE Journal of Professional Issues in Engineering Education and Practice, Vol. 135, No. 1, pp 47-56.

[49] Freidson, E. (2001). *Professionalism: The third logic—On the practice of knowledge*, University of Chicago Press, Chicago.

[50] Dennis, Norman D., Hains, Decker B, et. al. "Achieving the Civil Engineering Body of Knowledge in the Affective Domain." Proceedings of the 2019 Annual Conference & Exposition of the American Society for Engineering Education, June 2019.