

The 5Ws of the Third Edition of the Civil Engineering Body of Knowledge

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. 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.

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.

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Introduction

This paper is a follow-up to updates on the Third Edition of Civil Engineering Body of Knowledge (CEBOK3) that were presented at the 2017 [1] and 2018 [2] ASEE Annual Conventions, and provides a comprehensive overview of the Civil Engineering Body of Knowledge 3 Task Committee's (CEBOK3TC) effort and the process it followed to complete its charge. This will be done by focusing on the following 5W-based questions (Who, What, When, Where, and Why) related to the CEBOK3:

- What is the CEBOK?
- Why is a new edition of the CEBOK needed?
- Who should be interested in the CEBOK3?
- When was the CE community informed about the CEBOK3?
- Who served on the BOK3TC?
- What was the committee's charge?
- Who else was engaged with the effort?
- When will the CEBOK3 be implemented?
- Why have engineering economics, critical thinking, and data analysis been added?
- Where did contemporary and historical perspectives, public policy, business and public administration, and globalization outcomes go?
- Why is affective domain included for some outcomes?
- What is the typical pathway to fulfill the CEBOK3?
- What should be done with the CEBOK3?
- Where can additional information about the CEBOK3 be found?

What is the CEBOK?

The CEBOK3 [3] defines the Civil Engineering Body of Knowledge as “the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level.” The CEBOK3 report defines the knowledge, skills, and attitudes through the use of Bloom's Taxonomy and outcome rubrics [4-6], which are provided in Appendix A. The remainder of the definition of the CEBOK needs further explanation as it, like the outcomes of the CEBOK, has evolved. Prior editions of the CEBOK [7, 8] defined “entry into the practice of civil engineering at the professional level” as being that point when a civil engineer first becomes eligible for licensure as a Professional Engineer (PE). As part of the CEBOK3TC's effort to engage key constituents, including civil engineering department heads and the ASCE Board of Direction, it became clear that the CEBOK should still be supportive of licensure while being equally and fully applicable to “all civil engineers, regardless of career path or area of practice” [3] and whether or not licensure is included in one's career progression. This shift is intended to be more inclusive of all those who may practice civil engineering at the professional level, rather than focus only on those who will become licensed as Professional Engineers [9].

It is important to note that engineering is a profession of practice. The CEBOK3 [3] also states that “the preparation of the future civil engineer and the fulfillment of the CEBOK must include both formal education and mentored experience. Early-career experience, specifically experience that progresses with increasing complexity, quality, and responsibility and that is mentored by those who are practicing civil engineering at the professional level, is a necessary part of a civil engineer’s attainment of the CEBOK.” Accordingly, the CEBOK cannot be considered just an educational expectation. Structured, early-career experience under the mentorship of a civil engineer practicing at the professional level, which progresses in both complexity and level of responsibility, is critical to fulfilling the CEBOK, specifically the experiential or practice components of the CEBOK.

Related to this, the Raise the Bar Committee is in the process of recommending revisions to ASCE Policy Statement 465 [10]. The current PS 465 was adopted by the ASCE Board of Direction in 2017, but it is focused on attaining the CEBOK for licensure. The revisions will still support licensure, but will be focused on attaining the CEBOK for all civil engineers who may practice civil engineering at the professional level.

Why is a New Edition of the CEBOK Needed?

The CEBOK3TC undertook its charge (see the later section, “What was the CEBOK3TC’s Charge?”), which included critically reviewing published literature regarding the future of engineering, other disciplines, and civil engineering practice; evaluating the second edition of the civil engineering body of knowledge (CEBOK2); and proactively soliciting constituent input. All this allowed the task committee to determine if a third edition of the Civil Engineering Body of Knowledge (CEBOK3) report was warranted. Considering all the information the CEBOK3TC reviewed, constituent input and two specific reports were key in the CEBOK3TC’s decision that a new edition of the CEBOK was needed. The two reports, one by the American Association of Engineering Societies (AAES) and the US Department of Labor [11] and one by the International Engineering Alliance [12] were published after the CEBOK2 [8] was completed, and the CEBOK3TC felt each presented persuasive arguments for considering new outcomes for the CEBOK, such as research skills, engineering economics, innovation, and safety. Additionally, the constituency input also supported significant changes were needed to the CEBOK [13]. While other references and input also supported the need for a new edition, these were the key inputs that led to the comprehensive revision of the CEBOK.

Who Should Be Interested in the CEBOK3?

As stated in the preface to the CEBOK3 [3]: “All civil engineers, including students studying civil engineering, those who teach civil engineering, early-career civil engineers, those who mentor early-career civil engineers, those who employ civil engineers, those who design civil engineering projects, those who lead and manage groups of civil engineers and civil engineering projects, and those who conduct research in civil engineering, should be very interested in the CEBOK3. Essentially, all members of the civil engineering profession should be interested in the CEBOK3 as we all, as members of an amazing and exciting profession, should be committed to and supportive of preparing the next generation of civil engineers. 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.” The CEBOK is also an integral part of ASCE’s Raise The Bar initiative [14], which in turn supports a variety of initiatives promoting the profession.

When Was the Civil Engineering Community Informed About the CEBOK3?

In October 2016, ASCE launched the Civil Engineering Body of Knowledge 3 Task Committee (CEBOK3TC). In the summer of 2016, a broad call for membership was made through numerous ASCE communications. The CEBOK3TC completed its charge in the fall of 2018, and the report was prepared by the CEBOK3TC and will be published by ASCE in the spring of 2019. During the 2-year life of the committee, several updates were provided through various ASCE committees, papers were presented and published and several constituency surveys were widely distributed [1, 2, 4-6, 9, 13, 15, 16].

Who Served on the CEBOK3 Task Committee?

The CEBOK3 Task Committee (CEBOK3TC) was formed in fall 2016 from applicants to a broad call for members distributed to the ASCE membership during the summer of 2016. Over 62 applications were received and membership on the task committee was offered to a selection of the applicants. The remaining applicants were invited to be corresponding members to the committee and the majority accepted that invitation.

The following were members of the CEBOK3TC:

Kenneth J. Fridley, Ph.D., F.ASCE, (Chair) University of Alabama
Decker B. Hains, Ph.D., P.E., M.ASCE, (Editor) Western Michigan University
Brock E. Barry, Ph.D., P.E., F.ASCE, United States Military Academy
Angela R. Bielefeldt, Ph.D., P.E., M.ASCE, University of Colorado
Horst G. Brandes, Ph.D., P.E., F.ASCE, University of Hawaii
Norbert J. Delatte, Jr., Ph.D., P.E., F.ASCE, Oklahoma State University
Norman D. Dennis, Jr., Ph.D., P.E., D.GE, F.ASCE, University of Arkansas
Ryan K. Giles, Ph.D., A.M.ASCE, SUNY Stony Brook Port
Beth L. Hartmann, Ph.D., P.E., M.ASCE, Iowa State University
Muthusamy Krishnamurthy, Ph.D., P.E., F.ASCE, Hydro Modeling, Inc.
Audra N. Morse, Ph.D., P.E., F.ASCE Michigan Technological Institute
David A. Pezza, Dr.Eng., P.E., D.GE, F.ASCE, US Army Corps of Engineers (Retired)
Monte L. Phillips, Ph.D., P.E., Dist.M.ASCE, (Retired)
Matthew W. Roberts, Ph.D., P.E., M.ASCE, Southern Utah University
Kristen L. Sanford Bernhardt, Ph.D., P.E., M.ASCE, Lafayette College
Camilo Torres, EIT, C.Eng, M.ASCE, Pontificia Universidad
Leslie E. Nolen, CAE, Aff.M.ASCE, (Staff Liaison) American Society of Civil Engineers
James J. O’Brien, Jr., P.E., M.ASCE, (Staff Liaison) American Society of Civil Engineers

While the vast majority of the CEBOK3TC members had university affiliations, 11 members also had extensive industry experience, including 5 with 10 or more years, and 2 with over 35 years of industry experience. In addition to the full members of the committee, 64 others served

as corresponding members to the task committee, including several civil engineering department chairs who also participated in several of the committee's face-to-face meetings.

What was the CEBOK3TC's Charge?

The Civil Engineering Body of Knowledge 3 Task Committee (CEBOK3TC) was given the following charge:

- Critically review published literature regarding the future of engineering, other disciplines, and civil engineering practice;
- Evaluate the second edition of the civil engineering body of knowledge (CEBOK2);
- Proactively solicit constituent input;
- Determine if a third edition of the Civil Engineering Body of Knowledge (CEBOK3) report was warranted; and,
- If warranted, develop the CEBOK3 report.

Several papers [1, 2, 4-6, 9, 13, 15, 16] have presented various aspects of the CEBOK3TC's effort and fulfillment of its charge.

Who Else was Engaged with the CEBOK3 Effort?

The CEBOK3TC made a deliberate and concerted effort to proactively seek input from various constituents through three structured surveys. Bielefeldt et al. [13] describes the survey development, distribution, and responses of three structured surveys.

In addition, ASCE's Society Committees were invited in March 2018 to offer comments on the first draft of the revised CEBOK. Additionally, a presentation with a question and answer session and a short survey was presented to professionals at a regional conference [16]. Presentations with question and answer sessions were made to the ASCE Board of Direction, the ASCE Industry Leaders Council, and the National Civil Engineering Department Heads Conference. Both the quantitative and qualitative input from these various presentations was also used by the CEBOK3TC.

When Will the CEBOK3 Be Implemented?

The CEBOK3 itself is not implemented, per se. Rather, the CEBOK3 is the first part of a process defined by ASCE [17]. The CEBOK3 task committee was established in October, 2016, and the product of their work, the CEBOK3 report [3] will be published in the spring of 2019. Hopefully, students, members, educational programs, employers, and others will review the report and consider it and implement actions that are appropriate to their own situation or that of their organization. Following the publication of the CEBOK3, a task committee will be formed in the fall of 2020 to review the CEBOK3 and consider possible changes to the ABET CE program criteria, in accordance with a schedule previously adopted by ASCE [17]. Considering ABET's process, any changes to the Civil Engineering Program Criteria (CEPC) would not occur until the fall of 2024.

As noted previously, ASCE is in the process of considering revisions to ASCE Policy Statement 465 [10]. The current PS 465 is focused on entry into the practice of civil engineering and how the CEBOK, in general, may influence licensure requirements. The revisions currently being considered will still recognize the CEBOK's role in supporting licensure, but will be refocused on attaining the CEBOK for civil engineers, regardless of career path and licensure, for entry into the practice of civil engineering at the professional level. The revised policy will likely also promote actions to be taken by ASCE to influence and reinforce the importance of both formal education and mentored, early-career experience in attaining the CEBOK3.

Why have engineering economics, critical thinking, and data analysis been added?

Engineering economics is, perhaps, a bit of a misnomer as it involves more than economics for engineering. It is more focused on the application of both business principles and economics to engineering projects, and it was included, at least indirectly, in the CEBOK2 [8] within the project management and the business and public administration outcomes. The decision to include engineering economics in the CEBOK3 was based in large part on results from the constituency survey and because the AAES/U.S. Department of Labor [11] report classifies engineering economics as an Industry-wide Technical Competency in its Engineering Competency Model. The AAES/U.S. Department of Labor [11] defines engineering economics to include topics such as the time value of money, interest rates, categorization of costs, estimation of cash flows, present and annual worth, return on investment, depreciation and taxes, project accounting, capital budgeting, supply and demand, and life-cycle analysis.

Critical thinking is now explicitly included with problem solving in the CEBOK3, replacing the problem recognition and solving outcome of the CEBOK2. Support for this change came from feedback through the multiple constituent surveys. Some may say that losing problem recognition from the CEBOK2 is ill-advised or short-sighted; however, critical thinking and problem solving requires problem recognition and definition, so this aspect, while eliminated from the outcome title, remains an important part of the outcome. A related change that should be noted is the intentional change from "well-defined problems" and "ill-defined problems" in the CEBOK2 to a "complex problems" in CEBOK3. This was done to align with the International Engineering Alliance (IEA), Graduate Attributes and Professional Competencies [12] and ABET accreditation criteria [18].

Data analysis was added to the title of the experimental methods outcome in order to place greater emphasis on the data analysis aspect of civil engineering. Data analysis was included in the CEBOK2 and, as it was in the CEBOK2, the CEBOK3 refers to data analysis principally in terms of data obtained from experiments conducted by the individual. However, a broader interpretation of data analysis is implied in CEBOK3 to also include data analysis methods for data gathered from other sources as well as through experiments conducted by the individual.

Where did contemporary and historical perspectives, public policy, business and public administration, and globalization outcomes go?

Contemporary and historical perspectives, public policy, business and public administration, and globalization were included in the CEBOK2 [8] as separate outcomes. These were removed as

separate outcomes in CEBOK3 [3], but portions of them are included within other outcomes. Contemporary and historical perspectives, public policy, and globalization are related to the new professional responsibilities outcome and are included in the outcome's write-up as topics important to the profession. Also, many concepts in the business and public administration outcome are incorporated into new outcome on engineering economics, along with the teamwork and leadership outcome and the aforementioned professional responsibilities outcome. The CEBOK3TC, based on input from constituency groups and review of related literature, did not feel these topics rose to the level of importance to the entire civil engineering profession to be stand-alone outcomes [2, 3, 9].

Why is affective domain included for some outcomes?

The affective domain was introduced for the CEBOK in Appendix G of CEBOK2; however, it was not included as a formal part of the CEBOK2 [8]. The CEBOK3TC felt it important in the evolution of the CEBOK and for the development of the next generation of civil engineering, to formally include both the cognitive and affective domains in the CEBOK3 [3, 5, 6, 9]. One reason behind this was the deemed importance of civil engineers internalizing a sense of value for the people served by the profession and for their human experience.

The CEBOK3TC initially considered including the affective domain for all of the CEBOK3 outcomes. While possible, the committee ultimately felt it best to formally introduce the affective domain into the CEBOK for a selection of outcomes only. The sustainability outcome and all of the professional outcomes (communication, teamwork and leadership, lifelong learning, professional attitudes, professional responsibilities, and ethical responsibilities) were selected by the task committee as being the most appropriate to including in both the cognitive and affective domain.

What is a Typical Pathway to Fulfill the CEBOK3?

The CEBOK3 [3] defines “a typical pathway” to fulfill each of the 21 outcomes, including in the affective domain. It is important to note the typical pathway provided in the CEBOK3 is actually “a typical pathway” that the CEBOK3TC considered to be the most common way for an individual to achieve each of the CEBOK3 outcomes. This typical pathway is by no means the only pathway to fulfillment.

For CEBOK3, the four components to the typical pathways are defined as follows:

Undergraduate Education (UG): Undergraduate education leading to a bachelor's degree in civil engineering or a closely related engineering discipline, in general, from a four-year program accredited by the Engineering Accreditation Commission of ABET (EAC/ABET). Prior editions of the CEBOK referred to this as “B” for baccalaureate-level education, which actually means the same thing. The change in terminology was driven more by changes in other components.

Postgraduate Education (PG): Postgraduate education equivalent to or leading to a master's degree in civil engineering or a closely related engineering discipline, in general, equivalent to one year of full-time study. Prior editions of the CEBOK referred to this as “M/30” for a masters in civil engineering or equivalent 30 semester hours of coursework.

The CEBOK3TC opted for “PG” as it is essentially the same but does not include a prescriptive number of credit hours.

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. Prior editions of the CEBOK referred to this as “E” for experience. The CEBOK3TC wanted to emphasize early career mentoring as part of the experience and adopted this new terminology to reflect and promote the importance of mentoring.

Self-Developed (SD): individual self-development through formal or informal activities and personal observation and reflection. This is a new component of a typical pathway that was introduced in the CEBOK3. The CEBOK3TC felt that it was important for the future civil engineer to be personally invested in and committed to achieving the CEBOK3. To reflect this, the committee introduced “SD” as a component to fulfilling the CEBOK3 and included in all of the affective domain outcomes (i.e., sustainability communication, teamwork and leadership, lifelong learning, professional attitudes, professional responsibilities, and ethical responsibilities).

The typical pathway defined in the CEBOK3 is summarized in Appendix B.

What Should be Done with the CEBOK3?

Several groups were identified in the first section of this paper, “Who Should be Interested in the CEBOK3?”, including students studying civil engineering, those who teach civil engineering, early-career civil engineers, those who mentor early-career civil engineers, those who employ civil engineers, those who design civil engineering projects, those who lead and manage groups of civil engineers and civil engineering projects, and those who conduct research in civil engineering. ASCE is in the process of developing focused, short information sheets for many of these groups. These will be important for those groups to understand what they may consider doing with the CEBOK3.

ASCE previously defined a process for consideration of accreditation changes that may result from new editions of the CEBOK [17]. Shortly following the publication of a new edition CEBOK, a task committee is to be created to review the new edition of the CEBOK and recommend possible changes to ABET’s Program Criteria for Civil and Similarly Named Engineering Programs [18], for which ASCE serves as the lead society. Fridley et al. [19] has completed an initial comparison of the CEBOK3 outcomes associate with undergraduate education with the current ABET accreditation criteria [18]. Delatte, et al. [20] provide a summary of civil engineering department head perspectives on the current ABET civil engineering program criteria and the CEBOK3.

Whereas ABET accreditation is mandatory, many civil engineering academic programs have opted to go “above and beyond” ABET and have adopted, all or in part, the outcomes included in the CEBOK2 [8]. These, as well as others, may similarly consider adopting the CEBOK3. Fridley et al. [21] presents potential curricular changes necessary in three different civil engineering programs to be compliant with the outcomes of the CEBOK3.

Where Can Additional Information Be Found Regarding the CEBOK3?

A variety of papers have been published, many of which are referenced in this paper. ASCE also hosts a website specifically designed to provide the civil engineering community with the latest information regarding the CEBOK [22]. For additional information on the CEBOK3, as well as the two prior editions, visit https://www.asce.org/civil_engineering_body_of_knowledge/.

Summary

This paper concludes a series of papers that updated the progress of the Third Edition of Civil Engineering Body of Knowledge (CEBOK3). The first two papers were presented at the 2017 [1] and 2018 [2] ASEE Annual Conventions, and provided comprehensive overviews of the Civil Engineering Body of Knowledge 3 Task Committee's (CEBOK3TC) effort as it proceeded to fulfill its charge. With the CEBOK3TC completing its charge in late 2018 and the CEBOK3 published in late spring of 2019, this paper is a final update to the civil engineering community regarding the new edition of the CEBOK. This final update was done by focusing on some of the 5Ws (Who, What, When, Where, and Why) of the CEBOK3 and referencing many other papers that address some of the specific aspects of the new CEBOK3.

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Appendix A: Full CEBOK3 Outcome Rubric [3]

Tables A.1 and A.2 provide the cognitive domain and the affective domain outcome rubrics of the CEBOK3 [3], respectively. The unshaded areas within the bold borders of the tables defines the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level, and the darker shaded areas contain the levels of achievement beyond what is necessary for entry into the practice of civil engineering at the professional level.

The components of the typical pathway are noted in parentheses after each outcome statement at each level. As defined in the CEBOK3 [3], the four components to the typical pathway are defined as follows:

- Undergraduate Education (UG): undergraduate education leading to a bachelor's degree in civil engineering or a closely related engineering discipline, in general, from a four-year program accredited by the Engineering Accreditation Commission of ABET (EAC/ABET).
- Postgraduate Education (PG): postgraduate education equivalent to or leading to a master's degree in civil engineering or a closely related engineering discipline, in general, 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 A.1 The Civil Engineering Body of Knowledge Cognitive Domain Outcome Rubrics

Outcome	Cognitive Domain Level of Achievement <i>The cognitive domain describes the development of intellectual skills, ranging from the simple recollection of specific facts to the integration and evaluation of complex ideas and concepts.</i>					
	Level 1 Remember <i>The ability to remember previously learned material.</i>	Level 2 Comprehend <i>The ability to grasp the meaning of learned material.</i>	Level 3 Apply <i>The ability to use learned material in new and concrete situations.</i>	Level 4 Analyze <i>The ability to break down learned material into its component parts so that its organizational structure may be understood.</i>	Level 5 Synthesize <i>The ability to put learned material together to form a new whole.</i>	Level 6 Evaluate <i>The ability to judge the significance and importance of learned material for a given purpose.</i>
Foundational Outcomes						
Mathematics	Identify concepts and principles of mathematics, including differential equations and numerical methods. (UG)	Explain concepts and principles of mathematics, including differential equations and numerical methods. (UG)	Apply concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering problems. (UG)	Select appropriate concepts and principles of mathematics to solve civil engineering problems.	Develop mathematical models to solve civil engineering problems.	Assess mathematical models used to solve civil engineering problems.
Natural Sciences	Identify concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences. (UG)	Explain concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences. (UG)	Apply concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences, to solve civil engineering problems. (UG)	Select appropriate concepts and principles of natural sciences to solve civil engineering problems.	Integrate appropriate concepts and principles of natural sciences to solve civil engineering problems.	Evaluate solutions to civil engineering problems involving concepts and principles of natural sciences.

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Social Sciences	Identify concepts and principles of social sciences. (UG)	Explain concepts and principles of social sciences. (UG)	Apply concepts and principles of social sciences relevant to civil engineering. (UG)	Select appropriate concepts and principles of social sciences to solve civil engineering problems.	Integrate appropriate concepts and principles of social sciences to solve civil engineering problems.	Evaluate solutions to civil engineering problems involving concepts and principles of social sciences.
Humanities	Recognize relationships between the humanities and the practice of civil engineering. (UG)	Explain relationships between the humanities and the practice of civil engineering. (UG)	Apply aspects of the humanities to the solution of civil engineering problems. (UG)	Illustrate aspects of the humanities in the solution of civil engineering problems.	Integrate aspects of the humanities into the solution of civil engineering problems.	Assess the integration of the humanities into the solution of civil engineering problems.
Engineering Fundamentals Outcomes						
Materials Science	Identify concepts and principles of materials science. (UG)	Explain concepts and principles of materials science. (UG)	Apply concepts and principles of materials science to solve civil engineering problems. (UG)	Select appropriate concepts and principles of materials science to solve civil engineering problems.	Develop new applications in materials science to solve civil engineering problems.	Evaluate solutions to civil engineering problems involving new applications in materials science.
Engineering Mechanics	Identify concepts and principles of solid and fluid mechanics. (UG)	Explain concepts and principles of solid and fluid mechanics. (UG)	Apply concepts and principles of solid and fluid mechanics to solve civil engineering problems. (UG)	Select appropriate concepts and principles of solid and/or fluid mechanics to solve civil engineering problems.	Develop new methods in solid and/or fluid mechanics to solve civil engineering problems.	Evaluate solutions to civil engineering problems involving new methods in solid and/or fluid mechanics.

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Experimental Methods & Data Analysis	Identify the procedures and equipment necessary to conduct experiments in at least two specialty areas of civil engineering. (UG)	Explain the purpose, procedures, equipment, and practical applications of experiments in at least two specialty areas of civil engineering. (UG)	Conduct experiments in at least two specialty areas of civil engineering, and report the results. (UG)	Select appropriate experiments, and analyze the results in the solution of civil engineering problems. (PG)	Develop new experimental methods, and/or integrate the results of multiple experiments for the solution of civil engineering problems.	Assess new experimental methods and/or the results of multiple experiments for the solution of civil engineering problems.
Critical Thinking & Problem Solving	Identify and define a complex problem, question, or issue relevant to civil engineering. (UG)	Explain the scope and context of a complex problem, question, or issue relevant to civil engineering. (UG)	Formulate a possible solution to a complex problem, question, or issue relevant to civil engineering. (UG)	Analyze a possible solution to a complex problem, question, or issue relevant to civil engineering. (ME)	Develop a set of appropriate solutions to a complex problem, question, or issue relevant to civil engineering. (ME)	Assess a set of solutions to determine the most appropriate solution to a complex problem, question, or issue relevant to civil engineering.
Technical Outcomes						
Project Management	Identify concepts and principles of project management. (UG)	Explain concepts and principles of project management. (UG)	Apply concepts and principles of project management in the practice of civil engineering. (ME)	Analyze components of a project management plan for a complex civil engineering project.	Integrate components into a complete project management plan for a complex civil engineering project.	Evaluate a complete project management plan for a complex civil engineering project.
Engineering Economics	Identify concepts and principles of engineering economics. (UG)	Explain concepts and principles of engineering economics. (UG)	Apply concepts and principles of engineering economics in the practice of civil engineering. (ME)	Select appropriate concepts and principles of engineering economics for the practice of civil engineering.	Integrate engineering economics analyses in the practice of civil engineering.	Assess the effectiveness of engineering economic analyses in the practice of civil engineering.

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Risk & Uncertainty	Identify concepts and principles of probability, statistics, and risk relevant to civil engineering. (UG)	Explain concepts and principles of probability, statistics, and risk relevant to civil engineering. (UG)	Apply concepts and principles of probability and statistics to determine risk relevant to civil engineering. (UG)	Select appropriate concepts and principles of probability and statistics and analyze risk in a complex civil engineering problem. (ME)	Integrate risk analyses into the solutions to complex civil engineering problems.	Assess the acceptability of the risks associated with solutions to complex civil engineering problems.
Breadth in Civil Engineering Areas	Identify concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering. (UG)	Explain concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering. (UG)	Apply concepts and principles to solve complex problems in at least four specialty areas appropriate to the practice of civil engineering. (UG)	Analyze complex problems that cross multiple specialty areas appropriate to the practice of civil engineering. (ME)	Integrate solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.	Evaluate solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.
Design	Define engineering design and the engineering design process. (UG)	Explain engineering design and the engineering design process. (UG)	Apply the engineering design process to a given set of requirements and constraints to solve a complex civil engineering problem. (UG)	Analyze a complex civil engineering project to determine design requirements and constraints. (ME)	Develop an appropriate design alternative for a complex civil engineering project that considers realistic requirements and constraints. (ME)	Evaluate design alternatives for a complex civil engineering project for compliance with customary standards of practice, user and project needs, and relevant constraints.

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Depth in a Civil Engineering Area	Define advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering. (UG)	Explain advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering. (UG)	Apply advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering. (PG)	Select appropriate advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering. (PG)	Integrate advanced concepts and principles into the solutions of complex problems in a specialty area appropriate to the practice of civil engineering. (ME)	Assess advanced concepts and principles in the solutions of complex problems in a specialty area appropriate to the practice of civil engineering.
Sustainability	Identify concepts and principles of sustainability. (UG)	Explain concepts and principles of sustainability. (UG)	Apply concepts and principles of sustainability to the solution of complex civil engineering problems. (UG)	Analyze the sustainable performance of complex civil engineering projects from a systems perspective. (ME)	Develop practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.	Assess practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.
Professional Outcomes						
Communication	Identify concepts and principles of effective and persuasive communication to technical and non-technical audiences. (UG)	Explain concepts and principles of effective and persuasive communication to technical and non-technical audiences. (UG)	Formulate effective and persuasive communication to technical and non-technical audiences. (UG)	Analyze effective and persuasive communication to technical and non-technical audiences. (ME)	Integrate different forms of effective and persuasive communication to technical and non-technical audiences. (ME)	Assess the effectiveness and persuasiveness of communication to technical and non-technical audiences.

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Teamwork & Leadership	Identify concepts and principles of teamwork and leadership, including diversity and inclusion. (UG)	Explain concepts and principles of teamwork and leadership, including diversity and inclusion. (UG)	Apply concepts and principles of teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems. (UG)	Select concepts and principles of effective teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems. (ME)	Integrate concepts and principles of effective teamwork and leadership, including diversity and inclusion, into the solutions of civil engineering problems. (ME)	Evaluate the effectiveness of leaders and teams in the solution of civil engineering problems.
Lifelong Learning	Identify the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning. (UG)	Explain the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning. (UG)	Acquire new knowledge, skills, and attitudes relevant to civil engineering through self-directed learning. (UG)	Analyze new knowledge, skills, and attitudes relevant to civil engineering acquired through self-directed learning. (ME)	Integrate new knowledge, skills, and attitudes acquired through self-directed learning into the practice of civil engineering. (ME)	Evaluate the effectiveness of additional knowledge, skills, and attitudes acquired through self-directed learning.
Professional Attitudes	Identify professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	Explain professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	Apply knowledge of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (ME)	Illustrate professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (ME)	Integrate professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Assess the effectiveness of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.

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 Responsibilities	Identify professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (UG)	Explain professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (UG)	Apply professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (ME)	Illustrate professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (ME)	Integrate professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (ME)	Assess the integration of professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.
Ethical Responsibilities	Identify the ethical responsibilities of a civil engineer. (UG)	Explain the ethical responsibilities of a civil engineer. (UG)	Apply appropriate reasoning to an ethical dilemma. (ME)	Analyze ethical dilemmas to determine possible courses of action. (ME)	Develop courses of action to ethical dilemmas in complex situations. (ME)	Assess courses of resolution to ethical dilemmas in complex situations.

Table A.2 The Civil Engineering Body of Knowledge Affective Domain Outcome Rubrics

Outcome	Affective Domain Level of Achievement <i>The affective domain describes an individual's level of internalization or sense of value for human experience, to include their degree of acceptance or rejection of a concept, process or phenomenon.</i>				
	Level 1 Receive <i>The ability to be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior.</i>	Level 2 Respond <i>The ability to actively participate in an activity, attend to a task, and react to motivation.</i>	Level 3 Value <i>The ability to attach value to a particular object, phenomenon, or behavior.</i>	Level 4 Organize <i>The ability to sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system.</i>	Level 5 Characterize <i>The ability to follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic.</i>
Technical Outcome					
Sustainability	Acknowledge the importance of sustainability in civil engineering. (UG)	Comply with the concepts and principles of sustainability in civil engineering. (UG)	Value the benefits of sustainability in the practice of civil engineering. (ME)	Integrate a commitment to sustainability principles into the practice of civil engineering. (SD)	Advocate for principles of sustainability.
Professional Outcomes					
Communication	Acknowledge the importance of effective and persuasive communication to technical and non-technical audiences. (UG)	Practice effective and persuasive communication to technical and non-technical audiences. (UG)	Value effective and persuasive communication to technical and non-technical audiences. (ME)	Display effective and persuasive communication to technical and non-technical audiences. (SD)	Advocate for effective and persuasive communication to technical and non-technical audiences.
Teamwork and Leadership	Acknowledge the importance of teamwork, leadership, diversity, and inclusion. (UG)	Practice concepts and principles of teamwork, leadership, diversity, and inclusion. (UG)	Value the need for teamwork, leadership, diversity, and inclusion. (ME)	Display effective teamwork and leadership, including support of diversity and inclusion. (SD)	Advocate for teamwork, leadership, diversity, and inclusion.
Lifelong Learning	Acknowledge the need for lifelong learning. (UG)	Participate in lifelong learning opportunities. (UG)	Value lifelong learning in the practice of civil engineering. (ME)	Establish a lifelong learning plan to support one's own professional development. (SD)	Advocate for lifelong learning in the practice of civil engineering.

Outcome	Affective Domain Level of Achievement				
	Level 1 Receive	Level 2 Respond	Level 3 Value	Level 4 Organize	Level 5 Characterize
Professional Attitudes	Acknowledge professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	Practice professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	Value professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (ME)	Establish professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (SD)	Advocate for professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.
Professional Responsibilities	Acknowledge professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (UG)	Examine professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (UG)	Value professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (ME)	Form judgements about professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (SD)	Advocate for professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.
Ethical Responsibilities	Acknowledge the importance of ethical behavior. (UG)	Comply with applicable ethical codes. (UG)	Value ethical behavior in the practice of civil engineering. (ME)	Display ethical behavior in the practice of civil engineering. (ME)	Advocate for ethical behavior in the practice of civil engineering. (SD)

Appendix B: Typical Pathway to Fulfill the CEBOK3 [3]

The components of the typical pathway are noted in parentheses after each outcome statement at each level. As defined in the CEBOK3 [3], the four components to the typical pathway are as follows:

- Undergraduate Education (UG): undergraduate education leading to a bachelor’s degree in civil engineering or a closely related engineering discipline, in general, from a four-year program accredited by the Engineering Accreditation Commission of ABET (EAC/ABET).
- Postgraduate Education (PG): postgraduate education equivalent to or leading to a master’s degree in civil engineering or a closely related engineering discipline, in general, 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 B.1 The Civil Engineering Body of Knowledge
Cognitive Domain Typical Pathway to Achievement

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	

Outcome	Cognitive Domain Level of Achievement					
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
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		
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 B.2 The Civil Engineering Body of Knowledge
Affective Domain Typical Pathway to Achievement

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