Civil Engineering Body of Knowledge

Preparing the Future Civil Engineer

Third Edition

Prepared by

Civil Engineering Body of Knowledge 3
Task Committee @seismicisolation
@seismicisolation

ASCE

Civil Engineering Body of Knowledge

Preparing the Future Civil Engineer

Third Edition

PREPARED BY
Civil Engineering Body of Knowledge 3 Task Committee

SPONSORED BY
Committee on Education of the
American Society of Civil Engineers

Published by the American Society of Civil Engineers

@seismicisolation
@seismicisolation

Library of Congress Cataloging-in-Publication Data

Names: American Society of Civil Engineers. Civil Engineering Body of Knowledge 3 Task Committee, editor. | American Society of Civil Engineers. Committee on Education, sponsoring body.
Title: Civil engineering body of knowledge : preparing the future civil engineer / prepared by Civil Engineering Body of Knowledge 3 Task Committee ; sponsored by Committee on Education of the American Society of Civil Engineers.
Other titles: Civil engineering body of knowledge for the 21st century.
Description: Third edition. | Reston, Virginia : American Society of Civil Engineers, [2019] | Includes bibliographical references and index.
Identifiers: LCCN 2018061679| ISBN 9780784415221 (print : alk. paper) | ISBN 9780784481974 (PDF) | ISBN 9780784481981 (ePub)
Subjects: LCSH: Civil engineering—Study and teaching (Higher)—United States. | Civil engineering—Vocational guidance—United States.
Classification: LCC T73 .C538 2019 | DDC 624—dc23
LC record available at https://lccn.loc.gov/2018061679

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4382
www.asce.org/bookstore | ascelibrary.org

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document. ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor. The information contained in these materials should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing such information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers—Registered in U.S. Patent and Trademark Office.

Photocopies and permissions. Permission to photocopy or reproduce material from ASCE publications can be requested by sending an email to permissions@asce.org or by locating a title in the ASCE Library (https://ascelibrary.org) and using the “Permissions” link.

Errata: Errata, if any, can be found at https://doi.org/10.1061/9780784415221.

Copyright © 2019 by the American Society of Civil Engineers.
All Rights Reserved.

ISBN 978-0-7844-1522-1 (print)
ISBN 978-0-7844-8197-4 (PDF)
ISBN 978-0-7844-8198-1 (ePub)

Manufactured in the United States of America.

25 24 23 22 21 20 19 1 2 3 4 5

@seismicisolation
@seismicisolation

Contents

@seismicisolation

@seismicisolation

@seismicisolation

@seismicisolation
@seismicisolation

Preface

> *We are wise not by the recollection of our past, but by the responsibility for our future.*
>
> —George Bernard Shaw

What is the *Civil Engineering Body of Knowledge*?

This Third Edition of the *Civil Engineering Body of Knowledge* (CEBOK3) is focused on preparing the future civil engineer for entry into the profession. Specifically, the *Civil Engineering Body of Knowledge* (CEBOK) defines the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level. As described in this report, 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.

Who Should Be Interested in the *Civil Engineering Body of Knowledge*?

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.

@seismicisolation

@seismicisolation
@seismicisolation

List of Figures and Tables

Figures

Tables

@seismicisolation

@seismicisolation

@seismicisolation

@seismicisolation
@seismicisolation

Executive Summary

> *It is a great profession. There is the fascination of watching a figment of the imagination emerge through the aid of science to plan on paper. Then it brings jobs and homes … it elevates the standard of living and adds to the comforts of life. That is an engineer's high privilege.*
>
> —Herbert Hoover

Civil engineering is an exciting and noble profession which serves all of humankind. 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. As noted in extensive research on the sociology of professions, a critical distinction and hallmark of a profession is its specialized work, grounded in an officially recognized body of knowledge that is based on abstract concepts and requires the exercise of discretionary judgment (Ressler 2011). Work on the *Civil Engineering Body of Knowledge* (CEBOK) began near the start of the 21st century with the publication of the First Edition of the *Civil Engineering Body of Knowledge* (CEBOK1) in early 2004. The Second Edition of the *Civil Engineering Body of Knowledge* (CEBOK2) followed in 2008, and this Third Edition of the *Civil Engineering Body of Knowledge* (CEBOK3) builds on the work of these previous editions. In addition to the prior editions of the CEBOK, the CEBOK3 draws heavily on two internationally recognized engineering competency models—the "Engineering Competency Model" (AAES and the US Dept. of Labor 2016) and the "Graduate Attributes and Professional Competencies" profiles (IEA 2013).

The *Civil Engineering Body of Knowledge* (CEBOK) is described by 21 outcomes in four categories as shown in Table ES-1 on the following page. Each of the 21 outcomes is described by an outcome rubric, which includes the level of achievement required for entry into the practice of civil engineering at the professional level. As with the CEBOK2, the outcomes rubrics are based on Bloom's taxonomy. In addition to using Bloom's *Taxonomy for the Cognitive Domain*, as was done with the CEBOK2, the CEBOK3 also incorporates Bloom's *Taxonomy for the Affective Domain* for 7 of the 21 outcomes. With the addition of the affective domain, the CEBOK now recognizes the need for civil engineers to internalize and have a value system that supports practice at the professional level. The CEBOK continues to recognize engineering as a profession of practice; as such, the preparation of a civil engineer requires both formal education and mentored experience. The *Civil Engineering Body of Knowledge* 3 Task Committee (CEBOK3TC) also recognized that individual civil engineers are also responsible for their own development and established self-development as a new component to fulfilling the CEBOK. Therefore, the CEBOK3 defines the typical pathway for fulfilling the level of achievement using

@seismicisolation

Table ES-1. *Civil Engineering Body of Knowledge* Outcomes.

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

four components: undergraduate education, postgraduate education, mentored experience, and self-development.

The CEBOK3 is the product of the *Civil Engineering Body of Knowledge* 3 Task Committee (CEBOK3TC), which had representatives from nearly every area within the civil engineering profession. The CEBOK3TC also sought extensive constituent input during the development of the CEBOK3 through a series of quantitative and qualitative surveys. The BOK3TC relied heavily on the constituent survey responses along with the aforementioned US Department of Labor and International Engineering Alliance reports (AAES and the US Dept. of Labor 2016, IEA 2013).

The CEBOK3 applies to all civil engineers, regardless of career path or area of practice. Accordingly, it should be of interest to a broad audience, including educators, students, early career civil engineers, professionals who mentor early career civil engineers, experienced engineers, among others. A series of focused companion materials accompany the CEBOK to help communicate important aspects of the CEBOK that may be most relevant to specific groups, such as students, faculty, early career engineers, mentors, and organizational leaders.

References

AAES (American Association of Engineering Societies) and the US Dept. of Labor. 2016. *Engineering competency model.* Accessed August 4, 2018. http://www.aaes.org/model.

Bloom, B. S., M. D. Englehart, E. J. Furst, W. H. Hill, and D. Krathwohl. 1956. *Taxonomy of educational objectives, the classification of educational goals. Handbook I: Cognitive domain.* New York: Longman.

@seismicisolation

IEA (International Engineering Alliance). 2013. "Graduate attributes and professional competencies." Accessed August 4, 2018. http://www.ieagreements.org/about-us/key-documents/.

Krathwohl, D. R., B. S. Bloom, and B. B. Masia. 1964. *Taxonomy of Educational Objectives: The classification of educational goals, Handbook II: Affective domain,* Boston: Allyn and Bacon.

Ressler, S. J. 2011. "Sociology of professions: Applications to the civil engineering 'Raise the Bar' initiative." *J. Prof. Issues Eng. Educ. Pract.* 137(3): 152–153. Accessed August 4, 2018. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000043.

@seismicisolation

@seismicisolation
@seismicisolation

CHAPTER 1

Introduction

> *All things are ready, if our mind be so.*
> William Shakespeare, from *Henry V*

A body of knowledge describes the complete set of concepts, terms, and activities that make up a professional domain and is typically defined by the relevant learned society or professional association (Ressler 2011). Accordingly, ASCE defines the Civil Engineering Body of Knowledge (CEBOK) as the set of knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level. As described in this report, 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 the CEBOK.

History of the CEBOK

The first edition of the *Civil Engineering Body of Knowledge* (CEBOK1) was published in 2004 and defined the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level (ASCE 2004). For the purposes of the CEBOK1, "entry into the practice of civil engineering at the professional level" was defined as becoming licensed as a professional engineer (P.E.). The CEBOK1 included 15 outcomes and used three levels of achievement: recognition, understanding, and ability. Since this first edition was published nearly 15 years ago, the format, content, and definition of the CEBOK evolved into a second and now, third edition.

The three levels of achievement used in the CEBOK1 were not based on any established learning system or taxonomy, and they were found to be inadequate with respect to educational design and assessment. ASCE convened a task committee to review how the CEBOK1 outcomes could be improved using a different approach to the levels of achievement. In 2005, the committee produced the level of achievement report (ASCE 2005) which recast the CEBOK1's 15 outcome rubrics based on Bloom's Taxonomy for the cognitive domain (Bloom et al. 1956).

@seismicisolation

The second edition of the *Civil Engineering Body of Knowledge* (CEBOK2) was published in 2008 and included 24 outcomes (ASCE 2008). As with CEBOK1, "entry into the practice of civil engineering at the professional level" was defined as becoming licensed as a P.E. (ASCE 2008). To better organize and communicate the 24 outcomes, the CEBOK2 introduced three categories for the outcomes: foundational, technical, and professional. The CEBOK2 presented the outcome rubrics based on Bloom's Taxonomy for the cognitive domain and included paths to fulfillment of the outcomes through formal education, both at the baccalaureate (B) and post-baccalaureate (M/30) levels, and experience (E) prior to licensure. Although not explicitly incorporated into the CEBOK, the CEBOK2 suggested "several outcomes … would be enhanced by descriptions in … the affective domain" (ASCE 2008).

CEBOK3 Task Committee

In October 2016, ASCE established the *Civil Engineering Body of Knowledge* 3 Task Committee (CEBOK3TC). The task committee consisted of 16 full members and 70 corresponding members representing a broad and diverse cross section of the civil engineering profession. 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; and
5. If warranted, develop the CEBOK3 report.

Additional details regarding the charge, process, and membership can be found in Appendix C.

Review of Literature

The CEBOK3TC completed a comprehensive and critical review of published papers, reports, and other documents. To accomplish this, the task committee was divided into four groups, with each group tasked with the review of a particular type of literature. One group reviewed non-ASCE Reports, including the US Department of Labor's "Professional Competencies for Engineering" (AAES and US Dept. of Labor 2016), the International Engineering Alliance's "Graduate Attributes and Professional Competencies" (IEA 2013), and the American Society for Engineering Education's "Transforming Undergraduate Education in Engineering" (ASEE 2013). Another group reviewed body of knowledge documents published by other organizations, including the National Society of Professional Engineers' *Engineering Body of Knowledge* (NSPE 2013), the American Society of Mechanical Engineers' *Vision 2030* (Kirkpatrick et al. 2012), the American Institute of Chemical Engineers' *Body of Knowledge for Chemical Engineers* (AIChE 2015), and the American Academy of Environmental Engineers' *Environmental Engineering Body of Knowledge* (AAEES 2009). A third group reviewed scholarly works published in venues such as ASCE's *Journal of Professional Issues in Engineering Education and Practice* (Ressler

@seismicisolation

2011, Carpenter et al. 2014) and the American Society for Engineering Education's annual conference proceedings (Estes et al. 2016; Fridley et al. 2009, 2016; Walesh 2012, 2014, 2015, 2016; Evans and Beiler 2015; Ressler and Lenox 2016). The final group reviewed other reference materials such as the United Nations Educational, Scientific and Cultural Organization's "Youth and Skills: Putting Education to Work" report (UNESCO 2012), the National Leadership Council for Liberal Education and America's Promise's "College Learning for the New Global Century" report (AACU 2007), and the National Academy of Engineering's "Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning" (NAE 2013). In total, the CEBOK3TC reviewed more than 50 separate publications during its evaluation of available literature; however, only those that had the greatest influence on the committee's deliberations are noted above.

Constituent Input

The CEBOK3TC engaged constituents through a series of three separate structured surveys. The first survey sought input on the CEBOK2 outcomes and ten possible new outcome topics that were identified through the literature review. Once the CEBOK3TC determined that a third edition of the CEBOK was needed and began to work on it, a second survey asked constituents to comment on and suggest levels of achievement on a pre-draft of the CEBOK3 outcome rubrics. The final survey sought input on the first full draft of the CEBOK3 outcome rubrics, which included levels of achievement, explanations for each of the outcomes, and typical pathways for fulfillment of the outcome. A full description of the three surveys and summary of the survey results is included in Appendix D.

Conclusion of the Task Committee

The CEBOK3TC undertook its charge, including a comprehensive literature review, a critical evaluation the CEBOK2, and engagement of constituencies through surveys. Based on numerous reports published since the release of the CEBOK2 and constituent input, the CEBOK3TC determined that a third edition of the CEBOK was needed. This third edition of the *Civil Engineering Body of Knowledge* (CEBOK3) completes the CEBOK3TC's charges.

Overview of the CEBOK3

The third edition of the *Civil Engineering Body of Knowledge* (CEBOK3) includes 21 outcomes in four categories as shown in Table 1-1. In addition to the three categories—foundational, technical, and professional—used in the CEBOK2, the CEBOK3 introduced a fourth new 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. Both the foundational and engineering fundamentals typically would be fulfilled as part of the undergraduate education. The technical outcomes specify knowledge more specific to civil engineering, and the professional outcomes focus on interpersonal and professional skills

@seismicisolation

needed to be successful in the practice of civil engineering at the professional level. In addition to using Bloom's Taxonomy for the cognitive domain, the third edition also formally introduces the application of Bloom's Taxonomy for the affective domain (Krathwohl et al. 1964) for sustainability and all of the professional outcomes.

Table 1-1. *Civil Engineering Body of Knowledge* Outcomes.

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

As with prior editions, the CEBOK3 includes a typical pathway to fulfillment. In addition to undergraduate education (UG), postgraduate education (PG), and mentored experience (ME), the CEBOK3 also includes self-development (SD) as part of the typical pathway. Self-development is the process by which one refines and extends their character or abilities through self-study and personal observation and reflection. This requires a civil engineer to identify needs and seek out mechanisms to develop the associated knowledge, skills, and attitudes of the outcome, and to assess their own progress and fulfillment of the outcome. Self-development was added as a pathway component primarily as a result of introducing the affective domain for some of the outcomes. Although formal education and mentored experience are appropriate and can be used to develop the knowledge and skills defined in the cognitive domain, the task committee considered the need for personal commitment by each civil engineer to develop some of the outcomes, particularly the value systems that are required for the affective domain.

The definition of the CEBOK, like its outcomes, has also 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 P.E. 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

@seismicisolation

removes the direct link to licensure and recognizes that the CEBOK applies to all civil engineers regardless of career path or area of practice.

References

AACU (Association of American Colleges and Universities). 2007. *College learning for the new global century.* Washington, DC: National Leadership Council for Liberal Education and America's Promise, AACU.

AAEES (American Academy of Environmental Engineers and Scientists). 2009. *Environmental engineering body of knowledge.* Annapolis, MD: AAEES.

AAES (American Association of Engineering Societies) and the US Dept. of Labor. 2016. "Engineering competency model." Accessed August 4, 2018. http://www.aaes.org/model/.

AIChE (American Institute of Chemical Engineers). 2015. *Body of knowledge for chemical engineers.* New York: AIChE.

ASCE. 2004. *Civil engineering Body of Knowledge for the 21st century: Preparing the civil engineer for the future*, 1st Ed. Reston, VA: ASCE.

ASCE. 2005. *Levels of achievement applicable to the Body of Knowledge required for entry into the practice of civil engineering at the professional level.* Reston, VA: ASCE.

ASCE. 2008. *Civil engineering Body of Knowledge for the 21st century: Preparing the civil engineer for the future,* 2nd Ed. Reston, VA: ASCE.

ASEE (American Society for Engineering Education). 2013. "Transforming undergraduate education in engineering. Phase I: Synthesizing and integrating industry perspectives." Accessed August 4, 2018. http://tuee.asee.org/phase-i/.

Bloom, B. S., M. D. Englehart, E. J. Furst, W. H. Hill, and D. Krathwohl. 1956. *Taxonomy of educational objectives, the classification of educational goals. Handbook I: Cognitive domain.* New York: David McKay Co.

Carpenter, D. D., T. S. Harding, J. A. Sutkus, and C. J. Finelli. 2014. "Assessing the ethical development of civil engineering undergraduates in support of the ASCE body of knowledge." *J. Prof. Issues Eng. Educ. Pract.* 140(4). doi.org/10.1061/(ASCE)EI.1943-5541.0000177.

Estes, A. C., T. A. Lenox, K. J. Fridley, and R. O. Anderson. 2016. "Accreditation insights and the next Body of Knowledge." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 14667. Washington, DC: ASEE.

Evans, J. C., and M. O. Beiler. 2015. "Humanities and social sciences outcomes for the third edition: Civil engineering Body of Knowledge." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 11626. Washington, DC: ASEE.

Fridley, K. J., et al. 2009. "Educating the future civil engineering for the new civil engineering Body of Knowledge." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 752. Washington, DC: ASEE.

Fridley, K. J., W. E. Back, and D. G. Williamson. 2016. "The ASCE BOK, ABET accreditation criteria, and NCEES FE exam—Are they appropriately aligned?" *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 15297. Washington, DC: ASEE.

IEA (International Engineering Alliance). 2013. "Graduate attributes and professional competencies." Accessed August 4, 2018. http://www.ieagreements.org/about-us/key-documents/.

@seismicisolation

Kirkpatrick, A. T., R. O. Warrington, R. N. Smith, K. A. Thole, W. J. Wepfer, and T. Perry. 2012. "Vision 2030: Creating the future of mechanical engineering education." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 2804. Washington, DC: ASEE.

Krathwohl, D. R., B. S. Bloom, and B. B. Masia. 1964. *The taxonomy of educational objectives: The classification of educational goals. Handbook II: Affective domain.* New York: David McKay Co.

NAE (National Academy of Engineering). 2013. *Educating engineers: Preparing 21st century leaders in the context of new modes of learning.* Washington, DC: National Academies Press.

NSPE (National Society of Professional Engineers). 2013. *Professional engineering body of knowledge.* Alexandria, VA: NSPE.

Ressler, S. J. 2011. "Sociology of professions: Applications to the civil engineering 'Raise the Bar' initiative." *J. Prof. Issues Eng. Educ. Pract.* 137 (3). doi.org/10.1061/(ASCE)EI.1943-5541.0000043.

Ressler, S. J., and T. A. Lenox. 2016. "Raising the bar for civil engineering: Implications of the International Engineering Alliance graduate attribute profiles." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 15068. Washington, DC: ASEE.

UNESCO. 2012. *Youth and skills: Putting education to work.* Paris: UNESCO.

Walesh, S. G. 2012. "Raise the bar initiative: The BOK and leadership lessons learned." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 3327. Washington, DC: ASEE.

Walesh, S. G. 2014. "NSPE's pan-engineering BOK." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 9110. Washington, DC: ASEE.

Walesh, S. G. 2015. "Creativity and innovation as part of the civil engineering BOK." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 11644. Washington, DC: ASEE.

Walesh, S. G. 2016. "Possible influences of the NSPE EBOK and the AAEK/DOL engineering competency model on the CEBOK3." *Proc., ASEE Ann. Conf. and Exposition.* Paper No. 14706. Washington, DC: ASEE.

@seismicisolation

CHAPTER 2

The Civil Engineering Body of Knowledge

> *"The essential characteristic of an ideal typical profession is the ability of its members to control their own work through the discretionary application of specialized knowledge."*
>
> —Stephen J. Ressler, Dist. M.ASCE, on the sociology of professions

This chapter presents the outcomes that constitute the third edition of the *Civil Engineering Body of Knowledge* (CEBOK3). The CEBOK3 consists of 21 outcomes divided into four categories. The foundational outcomes serve as the basis for knowledge for civil engineering as well as most other learned professions. 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 also for many other disciplines of engineering. Typically, the foundational and engineering fundamentals outcomes would be fulfilled as part of the undergraduate education. The technical outcomes specify knowledge more specific to civil engineering, and the professional outcomes focus on interpersonal and professional skills needed to be successful in the practice of civil engineering at the professional level.

The remainder of this chapter contains detailed explanations for each of the 21 outcomes. For each outcome, the rubric for the cognitive domain and, where applicable, the affective domain, is presented. Each rubric is followed by a section 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.

The rubric tables feature three columns. The first is the level of achievement for the cognitive domain and, where applicable, for the affective domain. Each row contains the name of the level from Bloom's Taxonomy as well as a brief description of the level. More information on the use of Bloom's Taxonomy in the *Civil Engineering Body of Knowledge* (CEBOK) is presented in Appendix E.

The second column states the expected knowledge, skills, and/or attitudes for each level of a given outcome. The unshaded area within the bold borders in the tables defines the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level. These outcome statements are the essence of the CEBOK. 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. These statements are included for completeness and to fully

@seismicisolation

define the outcome because some individuals may choose to go beyond the minimum expected for entry into the practice of civil engineering at the professional level.

The third column represents the typical pathway for fulfillment of the outcome. As the name implies, the typical pathway is what the CEBOK3TC considered to be the most common way for an individual to achieve the outcome. However, this typical pathway is by no means the only pathway to fulfillment.

For the CEBOK3, the four components of 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).
- 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 1 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.

Many of the outcomes are related, connected, and linked to one another. The explanations highlight some of these connections, and a graphical representation of this mapping is presented in Appendix G.

@seismicisolation

Foundational Outcomes

> *Education is the foundation upon which we build our future.*
> —Christine Gregoire

Mathematics

Table 2-1. Mathematics (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of mathematics, including differential equations and numerical methods.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of mathematics, including differential equations and numerical methods.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering problems.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of mathematics to solve civil engineering problems.	
5 Synthesize (put learned material together to form a new whole)	**Develop** mathematical models to solve civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** mathematical models used to solve civil engineering problems.	

Understanding the Outcome

Mathematics deals with the science of structure, order, and relation that has evolved from counting, measuring, and describing the shapes of objects. It uses logical reasoning and quantitative calculation. Since the seventeenth century, mathematics has been an indispensable tool for the physical sciences and technology and is considered the underlying language of science and engineering (Courant et al. 1996). The primary areas of mathematics relevant to civil engineering include algebra, calculus, linear algebra, geometry and topology, differential equations, computation and numerical analysis, probability, set theory, statistics, and trigonometry.

@seismicisolation
@seismicisolation

Differential equations are the basis for many of the analysis and design equations used in civil engineering. The outcome rubric explicitly references differential equations for two primary reasons. First, differential equations is the highest level of math expected in the CEBOK. Although some civil engineering programs may require additional mathematics, differential equations is the minimal level of mathematics needed and expected for all civil engineers. Second, by including differential equations in the rubric, calculus (as well as other lower-level math topics such as algebra, trigonometry, and geometry) is functionally included as well because of established high school and college math sequences. In other words, the ability to apply knowledge of differential equations requires the ability to apply knowledge of algebra, geometry, trigonometry, and calculus.

Numerical methods is an area of mathematics and computer science focused on the development and use of algorithms for obtaining approximate solutions to complex mathematical problems. Although numerical analysis has been used to solve problems from the very earliest days of mathematics (as early as 1600 BCE), numerical methods are integral to modern mathematical, science, and engineering software (Trefethen 2006). For civil engineers to responsibly and effectively use analysis and design software, they should first have a deep working knowledge of numerical methods.

Probability and statistics are not referenced in this outcome, even though these are topics within the general area of mathematics. Probability and statistics are included as part of the Risk and Uncertainty outcome.

Other areas of mathematics may be important for some civil engineers. Although differential equations (which includes algebra, geometry, trigonometry, and calculus) and numerical methods are specifically mentioned, linear algebra, abstract algebra, multivariate calculus, and discrete mathematics are topics which may be applicable and useful to some civil engineers.

Rationale

Mathematics has always been an integral part of engineering and has been part of the CEBOK since its inception. All areas of civil engineering rely on mathematics for the performance of quantitative analysis of engineering systems. A core of knowledge and breadth of coverage in mathematics and the ability to apply this knowledge to analyze and solve engineering problems are essential skills for civil engineers. Differential equations is specifically referenced because it is the highest level of mathematics expected of all civil engineers, and a working knowledge of calculus is required to apply knowledge of differential equations. Numerical analysis is included in recognition of its importance and broad use in analyzing and solving complex problems in civil engineering, as well as being the basis for most mathematical, science, and engineering software.

Level of Achievement

Mathematics is a foundational tool that is applied to analyze and solve civil engineering problems. Accordingly, for entry into the practice of civil engineering at the professional level, all civil engineers should be at the application level and be able to "apply concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering

@seismicisolation

problems." This level of achievement recognizes the application of mathematics in all the engineering fundamental outcomes (materials science, engineering mechanics, experimental methods and data analysis, and critical thinking and problem solving) and several of the technical outcomes (e.g., risk and uncertainty and engineering economics).

Typical Pathway for Fulfillment of the Outcome

The basic and broad knowledge, comprehension, and application of mathematics, including differential equations and numerical methods, required for civil engineering practice should be learned at the undergraduate level. Undergraduate education should prepare students to apply mathematics in subsequent engineering courses and in practice following graduation. Therefore, the Mathematics outcome is expected to be typically fulfilled through undergraduate education.

@seismicisolation
@seismicisolation

Natural Sciences

Table 2-2. Natural Sciences (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences, to solve civil engineering problems.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of natural sciences to solve civil engineering problems.	
5 Synthesize (put learned material together to form a new whole)	**Integrate** appropriate concepts and principles of natural sciences to solve civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving concepts and principles of natural sciences.	

Understanding the Outcome

Underlying the professional role of the civil engineer as the master integrator and technical leader is a firm foundation in the natural sciences. Natural science is the knowledge of objects or processes observable in nature such as physical earth and life sciences, for example, biology, physics, chemistry, as distinguished from the abstract or theoretical sciences such as mathematics or philosophy (*Oxford English Dictionary* n.d.). It involves the description, prediction, and understanding of natural phenomena, based on empirical evidence from observation and experimentation. Chemistry and physics are two disciplines of the natural sciences that have historically served as basic foundations for civil engineering. Additional disciplines of natural science, including biology, ecology, geology, meteorology, and others are also important in various specialty areas of civil engineering practice.

Chemistry is the science that deals with the properties, composition, and structure of substances (elements and compounds), the reactions and transformations they undergo, and the energy released or absorbed during those processes. Chemistry is concerned with atoms as building blocks, everything in the material world, and all living things. Branches of chemistry include inorganic, organic, physical, and analytical chemistry; biochemistry; electrochemistry;

@seismicisolation
@seismicisolation

and geochemistry. Some areas of civil engineering, including environmental engineering and construction materials, rely on chemistry for explaining phenomena and obtaining solutions to problems. A core of knowledge and breadth of coverage in chemistry is necessary for individuals to solve related problems in civil and environmental engineering.

Physics is concerned with understanding the structure of the natural world and explaining natural phenomena in a fundamental way in terms of elementary principles and laws. The fundamentals of physics are mechanics and field theory. Mechanics is concerned with the equilibrium and motion of particles or bodies under the action of given forces. The physics of fields encompasses the origin, nature, and properties of gravitational, electromagnetic, nuclear, and other force fields. Taken together, mechanics and field theory constitute the most fundamental approach to an understanding of natural phenomena that science offers. Physics is characterized by accurate instrumentation, precision of measurement, and the expression of its results in mathematical terms. Many areas of civil engineering rely on calculus-based physics for understanding the underlying governing principles and for obtaining solutions to problems. A core of knowledge and breadth in coverage in calculus-based physics, and the ability to apply it to solve engineering problems, are essential for civil engineers.

Arguably, all physics is calculus-based; however, calculus-based physics is defined as physics taught with explicit reference to and incorporation of calculus as the underlying mathematical principle of physics. Calculus-based physics differs from other types of physics where connections to calculus and the application of first principles to solve nonstandard problems may not be specifically evident. Calculus-based physics is required because civil engineers are expected to have thorough understanding of the mathematical connection between physics and engineering applications.

Indeed, the International Engineering Alliance "Graduate Attributes and Professional Competencies" (IEA 2013) describes the most critical distinction between engineers, technologists, and technicians as the class of problems they are called on to serve. Engineers solve complex problems, technologists solve broadly defined problems, and technicians solve well-defined problems. The critical component of the definition of a "complex problem" is that it "cannot be resolved without in-depth engineering knowledge … which allows a fundamentals-based, first principles analytical approach" (IEA 2013). Moreover, the knowledge profile in IEA (2013) includes "a systematic, theory-based understanding of the natural sciences applicable to the discipline," "conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling," and "a systematic, theory-based formulation of engineering fundamentals required in the engineering discipline." Clearly the expectation is for civil engineers to have a strong understanding of the underlying engineering principles upon which they rely to solve problems and deliver projects.

Additional knowledge in at least one additional area of natural science is required to provide well-rounded exposure in the sciences. Disciplines of natural science of particular relevance to civil engineering include, but are not limited to, biology, ecology, geology, and meteorology.

Rationale

A core of knowledge and breadth of coverage in the natural sciences and the ability to apply this knowledge to analyze and solve engineering problems are essential skills for civil engineers.

@seismicisolation

Civil engineers must have the basic scientific literacy that will enable them to be conversant with technical issues pertaining to environmental and physical systems, public health and safety, durability of construction materials, and other such subjects. With technological advances in science and their applications to civil engineering beyond physics and chemistry, study in an additional area of natural science is required to prepare the civil engineer of the future and to keep the profession relevant.

In addition to the technical content of the natural sciences and the application to civil engineering, the study of the natural sciences also develops critical thinking, analytical skills, and problem-solving skills.

Level of Achievement

Natural science is foundational in the analysis and solution of engineering and civil engineering problems. Accordingly, for entry into the practice of civil engineering at the professional level, all civil engineers should be at the application level and be able to "apply concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences, to solve civil engineering problems."

Typical Pathway for Fulfillment of the Outcome

The basic knowledge, comprehension, and application of natural sciences required for civil engineering practice should be learned at the undergraduate level and should prepare students to apply it in subsequent engineering courses and in practice following graduation. Thus, the Natural Sciences outcome is expected to be fulfilled through undergraduate education.

@seismicisolation

Social Sciences

Table 2-3. Social Sciences (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of social sciences.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of social sciences.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of social sciences relevant to civil engineering.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of social sciences to solve civil engineering problems.	
5 Synthesize (put learned material together to form a new whole)	**Integrate** appropriate concepts and principles of social sciences to solve civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving concepts and principles of social sciences.	

Understanding the Outcome

The social sciences are the study of society and the manner in which people behave and influence the world around them (ESRC 2018). Social science disciplines include, but are not limited to, anthropology, communication studies, economics, geography, law, linguistics, political science, sociology, and psychology. Social sciences are scientific, analytical, and data-driven and use the scientific method, including both qualitative and quantitative methods. To be effective, civil engineers must work within a social framework. This outcome is intended to guide civil engineers in making connections between their technical education and their education in the social sciences. Effective delivery of engineering services depends critically on these connections. For example, an understanding of political processes provides civil engineers insights into project funding and stakeholder needs and wants. An understanding of geography would provide civil engineers valuable considerations for material selection and other aspects of solving problems.

Rationale

Civil engineers must be able to recognize and incorporate various aspects of social science considerations into the development, delivery, and evaluation of civil engineering projects. They

@seismicisolation
@seismicisolation

must think with an open mind and acknowledge the inputs and impacts from a social sciences perspective. They must also recognize and assess the assumptions, implications, and practical consequences of their work. Continued development of professional competence comes from lifelong learning, mentorship from senior engineers, and practical experience, built on a firm foundation of the social sciences.

Level of Achievement

It is critical that civil engineers be able to apply principles of the social sciences to develop an appreciation of their importance in the development of engineering solutions. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the application level and be able to "apply concepts and principles of social sciences relevant to civil engineering."

Typical Pathway for Fulfillment of the Outcome

The foundational knowledge, understanding, and application of the social sciences necessary for civil engineering practice should be learned at the undergraduate level. Students should be able to apply their understanding of the social sciences in subsequent engineering courses and in the practice of civil engineering following graduation. Recognizing that the application of social sciences in practice can be situational and vary by specialty areas of practice, sectors of the engineering profession, and geographic areas of projects, the Social Sciences outcome is expected to be fulfilled entirely through undergraduate education. Examples of opportunities to demonstrate this ability at the undergraduate level include incorporating the application of social sciences in engineering courses as well as in a capstone or major design experience.

@seismicisolation

Humanities

Table 2-4. Humanities (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Recognize** relationships between the humanities and the practice of civil engineering.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** relationships between the humanities and the practice of civil engineering.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** aspects of the humanities to the solution of civil engineering problems.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Illustrate** aspects of the humanities in the solution of civil engineering problems.	
5 Synthesize (put learned material together to form a new whole)	**Integrate** aspects of the humanities into the solution of civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the integration of the humanities into the solution of civil engineering problems.	

Understanding the Outcome

The humanities can be defined as the study of the human aspects of the world, including how people process and document the human experience. The humanities include philosophy, history, literature, the visual and performing arts, language, and religion. This outcome is intended to define the importance of the humanities and its relationship to the practice of civil engineering. The understanding of humanities is critical to the delivery of civil engineering services to people and communities. In addition, an understanding of the humanities is supportive of the development of several other outcomes. For example, ethics is, in its basic form, a branch of philosophy that includes the study of how people should act and the concepts of right and wrong behavior. The humanities can also support critical thinking skills, effective and persuasive communication, the importance of sustainability, and the ability to develop a sense of value for human experience that is associated, in general, with the affective domain (Liu 2014, Ottino and Morson 2016).

Rationale

Civil engineers must think with an open mind within diverse systems of thought, recognizing and assessing, as need be, the assumptions, implications, and perhaps most importantly, the

@seismicisolation

practical consequences of their work. They must be informed not only by mathematics and the natural and social sciences, but also by the humanities. To be effective, civil engineers must be critical thinkers and possess the ability to raise vital questions and problems and then formulate them clearly and appropriately. They must gather and assess relevant information, use abstract ideas to interpret the information effectively, and come to well-reasoned conclusions and solutions, testing them against relevant criteria and standards. Critical to the success of any civil engineering project is the thoughtful consideration of the impact the project will have on people and the human experience, and the foundation for this thoughtful consideration is a foundational knowledge, understanding, and application of the humanities.

Level of Achievement

Some level of knowledge and appreciation of the humanities is fundamental to all citizens within society. Humanities are similarly fundamental to a civil engineer's ability to develop solutions that positively impact people, the human condition, and support community growth. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the application level and be able to "apply aspects of the humanities to the solution of civil engineering problems."

Typical Pathway for Fulfillment of the Outcome

The foundational knowledge, understanding, and application of the humanities necessary for civil engineering practice should be learned at the undergraduate level. Students should be able to apply their understanding of the humanities in subsequent engineering courses and in the practice of civil engineering following graduation. Recognizing that the application of humanities in practice can be situational and vary by specialty areas of practice, sectors of the engineering profession, and geographic areas of projects, the Humanities outcome is expected to be fulfilled through undergraduate education.

@seismicisolation

Engineering Fundamentals Outcomes

> *Perhaps the single most important element in mastering the techniques and tactics of racing is experience. But once you have the fundamentals, acquiring the experience is a matter of time.*
>
> —Greg LeMond

Materials Science

Table 2-5. Materials Science (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of materials science.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of materials science.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of materials science to solve civil engineering problems.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of materials science to solve civil engineering problems.	
5 Synthesize (put learned material together to form a new whole)	**Develop** new applications in materials science to solve civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving new applications in materials science.	

Understanding the Outcome

Materials science in the context of civil engineering is the scientific study of the properties and applications of materials in construction or manufacturing. Civil engineering materials include, but are not limited to, concrete, asphalt, wood, steel, polymers, fibers, glass, water, rock, soil, geosynthetics, and biofiltration. Civil engineers must be familiar with the properties and behaviors of these materials for selection of material type and to create appropriate specifications for their use.

@seismicisolation
@seismicisolation

Rationale

Civil engineers are responsible for specifying appropriate materials in civil engineering projects. The civil engineer should have knowledge of how materials interact with the environment so that durable materials that withstand aggressive environments can be specified as needed. This includes the understanding of materials at the macroscopic and microscopic levels and the growing importance of recycling and reuse of materials and resources in a sustainable manner. A technical core of knowledge and breadth of coverage in materials science appropriate to civil engineering is necessary for individuals to solve a variety of civil engineering problems.

Level of Achievement

Civil engineers are expected to identify and explain the concepts and principles of materials science and then apply these principles and concepts to solve civil engineering problems. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the application level and be able to "apply concepts and principles of materials science to solve civil engineering problems."

Typical Pathway for Fulfillment of the Outcome

The basic knowledge, comprehension, and application of materials science required for civil engineering practice should be learned at the undergraduate level and should prepare students to apply it in subsequent engineering courses and in practice following graduation. The Materials Science outcome is expected to be fulfilled entirely through undergraduate education.

@seismicisolation

Engineering Mechanics

Table 2-6. Engineering Mechanics (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of solid and fluid mechanics.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of solid and fluid mechanics.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of solid and fluid mechanics to solve civil engineering problems.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of solid and/or fluid mechanics to solve civil engineering problems.	
5 Synthesize (put learned material together to form a new whole)	**Develop** new methods in solid and/or fluid mechanics to solve civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving new methods in solid and/or fluid mechanics.	

Understanding the Outcome

Engineering mechanics is the study of the behavior of systems under the action of forces. These systems include both solids and fluids. Mechanics is subdivided according to the types of systems and phenomena involved. The Newtonian laws of classical mechanics can adequately describe those systems encountered in most civil engineering areas. Engineering mechanics encompasses statics, dynamics, mechanics of materials, and fluid mechanics.

Rationale

Mechanics in civil engineering encompasses the mechanics of continuous and particulate solids subjected to loads, and the mechanics of fluid flow through pipes, channels, and porous media. A technical core of knowledge and breadth of coverage in both solid and fluid mechanics, and the ability to apply it to solve civil engineering problems, are essential for civil engineers. Areas of civil engineering that rely on mechanics include, but are not limited to, structural engineering, geotechnical engineering, environmental engineering, and water resources engineering. Engineering mechanics is often integrated into the engineering design software specific to various civil engineering applications.

@seismicisolation
@seismicisolation

Engineering mechanics expands on the basic information learned in physics. Solving civil engineering problems that involve engineering mechanics also requires the application of mathematics. Engineering mechanics knowledge is often applied in the process of solving complex problems in civil engineering and in the design process. Different specialty areas rely on engineering mechanics knowledge to varying degrees.

Level of Achievement

Engineering mechanics encompasses concepts and principles that are applied to solve civil engineering problems. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the application level and be able to "apply concepts and principles of solid and fluid mechanics to solve civil engineering problems."

Typical Pathway for Fulfillment of the Outcome

The engineering mechanics capabilities required for the practice of civil engineering should be learned at the undergraduate level. Undergraduate civil engineering students should be prepared to apply mechanics knowledge in subsequent civil engineering courses and in practice. Acknowledging that the application of mechanics in practice can vary greatly, particularly in different areas of civil engineering, the Engineering Mechanics outcome is expected to be fulfilled through undergraduate education.

@seismicisolation

Experimental Methods and Data Analysis

Table 2-7. Experimental Methods and Data Analysis (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** the procedures and equipment necessary to conduct experiments in at least two specialty areas of civil engineering.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** the purpose, procedures, equipment, and practical applications of experiments in at least two specialty areas of civil engineering.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Conduct** experiments in at least two specialty areas of civil engineering and **report** the results.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate experiments and **analyze** the results in the solution of civil engineering problems.	Postgraduate education
5 Synthesize (put learned material together to form a new whole)	**Develop** new experimental methods and/or **integrate** the results of multiple experiments for the solution of civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** new experimental methods and/or the results of multiple experiments for the solution of civil engineering problems.	

Understanding the Outcome

An experiment is a procedure carried out to determine something that is unknown, to evaluate a hypothesis, to demonstrate a fact, or to provide an insight into cause and effect. Experiments include those conducted in the field, the laboratory, or through virtual experimentation or numerical simulation. Methods are either prescribed in industry standards or they may have to be developed based on the scientific method. Experiments should always include repeatable procedures and logical analysis of the results. Experimentation is not limited to physical procedures or operations; they may also be virtual in nature to include numerical simulations and analysis with existing data sets. Data analysis is a process for obtaining raw data and converting it into information useful for engineering decision making.

Breadth of experience in experimentation and reporting results is required in at least two specialty areas of civil engineering. Specialty areas in civil engineering include, but are not limited to, construction engineering, environmental engineering, geotechnical engineering, water resources engineering, structural engineering, surveying, and transportation engineering.

@seismicisolation
@seismicisolation

Other specialty areas relevant to civil engineering may include areas in which

- ASCE has an institute or technical division in the area,
- ASCE publishes a journal in the area,
- ASCE sponsors a specialty conference in the area,
- There are civil engineering consulting firms that specialize in the area, or
- The area is emerging and the connection to civil engineering can be reasonably justified.

Experimentation and related data analysis methods are informed by foundational knowledge, such as mathematics and natural sciences, and provide crucial knowledge to technical aspects of civil engineering.

Rationale

Experimentation and data analysis are essential for many civil engineering projects, including material characterization, understanding the relationship between specific cause and effect, and evaluating a particular hypothesis. The need for experimentation and data analysis can arise during any phase of a project, including conceptual planning, detailed design, delivery, execution, or performance evaluation. Because engineering is based on scientific principles, experimentation in the course of civil engineering must adhere to the scientific method and be based on repeatable procedures and logical analysis of the results.

Level of Achievement

Civil engineers must be familiar with the purpose, procedures, equipment, and computational methods associated with standardized experiments and report results in at least two related specialty areas of civil engineering. Civil engineers also are expected to have the ability to select appropriate experiments and analyze the resulting data. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the analysis level and be able to "select appropriate experiments and analyze the results in the solution of civil engineering problems."

Typical Pathway for Fulfillment of the Outcome

The Experimental Methods and Data Analysis outcome is attained through a combination of undergraduate education and postgraduate education. Standardized test methods and data reporting procedures are typically learned at the undergraduate level in classroom and laboratory courses. The ability to select appropriate test methods and provide more thorough interpretation and analysis of the results is more often achieved through postgraduate education.

@seismicisolation
@seismicisolation

Critical Thinking and Problem Solving

Table 2-8. Critical Thinking and Problem Solving (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** and **define** a complex problem, question, or issue relevant to civil engineering.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** the scope and context of a complex problem, question, or issue relevant to civil engineering.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Formulate** a possible solution to a complex problem, question, or issue relevant to civil engineering.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** a possible solution to a complex problem, question, or issue relevant to civil engineering.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Develop** a set of appropriate solutions to a complex problem, question, or issue relevant to civil engineering.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** a set of solutions to determine the most appropriate solution to a complex problem, question, or issue relevant to civil engineering.	

Understanding the Outcome

Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication as a means to recognize and solve problems (Foundation for Critical Thinking 2017).

An engineering problem is a problem that exists in any domain that can be solved by the application of engineering knowledge and skills and generic competencies (IEA 2013). In civil engineering, problem solving consists of identifying and defining engineering problems; obtaining background knowledge; understanding existing requirements and/or constraints; articulating the problem through technical communication; formulating alternative solutions, both routine and creative; and recommending feasible solutions. The application of the engineering problem solving process to obtain the most appropriate solution requires critical thinking skills. Attributes of critical thinkers include many of those listed in the Professional Attitudes outcome such as creativity, curiosity, flexibility, and persistence.

@seismicisolation

Rationale

Critical thinking skills enable civil engineers to define, address, and solve complex and ambiguous problems. As members of a profession, civil engineers exercise discretionary judgment, which requires critical thinking. Through observation, experience, reflection, and reasoning, civil engineers move from simply solving problems to creating the most appropriate solutions.

Level of Achievement

Critical thinking and problem solving are essential in the practice of civil engineering. Civil engineers must possess and continuously use critical thinking and problem-solving skills. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and be able to "develop a set of appropriate solutions to a complex problem, question, or issue relevant to civil engineering."

Typical Pathway for Fulfillment of the Outcome

The Critical Thinking and Problem Solving outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. The foundation of critical thinking and problem solving should be learned at the undergraduate level. This includes properly identifying and defining problems, explaining the scope and context of problems, and generating possible solutions. This is usually accomplished in upper-level courses and in a capstone design or culminating experience. Through mentored experience, which progresses in both complexity and level of responsibility, civil engineers should further refine these skills to progress from generating solutions to analyzing solutions and developing a set of appropriate solutions to complex problems.

@seismicisolation

Technical Outcomes

> *Problem-solving is essential to engineering. Engineers are constantly on the lookout for a better way to do things.*
>
> — Dinesh Paliwal

Project Management

Table 2-9. Project Management (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of project management.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of project management.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of project management in the practice of civil engineering.	Mentored experience
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** components of a project management plan for a complex civil engineering project.	
5 Synthesize (put learned material together to form a new whole)	**Integrate** components into a complete project management plan for a complex civil engineering project.	
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** a complete project management plan for a complex civil engineering project.	

Understanding the Outcome

Project management within the practice of civil engineering can be defined as the disciplined application of specialized civil engineering knowledge, skills, tools, and techniques to civil engineering project activities, including project initiation, planning, execution, monitoring and controlling, and closing, to meet project requirements. There are standard components within a typical project management plan that are usually applicable regardless of the type of project. These standard components include, but are not limited to, statement of scope, critical path, success factors, deliverables, schedule, budget, quality control, human resources, communication, and risk management.

@seismicisolation

Rationale

Successful civil engineering projects rely on both technical and nontechnical knowledge, skills, and attitudes, including knowledge and skills associated with project management. Civil engineers must work closely and coordinate with the myriad of other disciplines and constituencies associated with complex civil engineering projects. When projects are not managed well, there can be significant, mostly negative, consequences, including additional costs. One report indicated nearly one-half of assessed projects went over budget and more than half were completed behind schedule (PMI 2016). Project management has strong relationships with other outcomes, including the Engineering Economics outcome, the Risk and Uncertainty outcome, the Communication outcome, and the Teamwork and Leadership outcome. Developing appropriate project management knowledge and skills benefit both civil engineers and civil engineering projects through improved efficiencies and effectiveness.

Level of Achievement

Project management encompasses concepts and principles that are used to successfully initiate, plan, execute, monitor and control, and close complex civil engineering projects. Although many civil engineers will achieve higher levels of achievement through both formal education and experience during the course of their careers, for entry into the practice of civil engineering at the professional level all civil engineers should be at the application level and be able to "apply concepts and principles of project management in the practice of civil engineering."

Typical Pathway for Fulfillment of the Outcome

The Project Management outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. Experience is critical to fulfilling this outcome owing to the diversity of issues and the dynamic nature of real-world civil engineering projects. An understanding of the concepts and principles of project management and the ability to explain this understanding should be learned at the undergraduate level. Application of this understanding within the practice of civil engineering needs to be further developed during early career engineering experiences. Therefore, the Project Management outcome should be fulfilled through mentored experience, which should progress in both complexity and level of responsibility.

@seismicisolation

Engineering Economics

Table 2-10. Engineering Economics (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of engineering economics.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of engineering economics.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of engineering economics in the practice of civil engineering.	Mentored experience
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of engineering economics for the practice of civil engineering.	
5 Synthesize (put learned material together to form a new whole)	**Integrate** engineering economics analyses in the practice of civil engineering.	
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the effectiveness of engineering economic analyses in the practice of civil engineering.	

Understanding the Outcome

The term engineering economics may be slightly misleading because it really involves more than economics for engineering. Engineering economics is more comprehensive and is the traditional and common term used for the application of both business and economics to engineering projects. Concepts and principles of engineering economics include the time value of money; interest rates; categorization of costs, including incremental, average, and sunk costs; estimation of cash flows, including inflows and outflows such as initial capital, annual operation, maintenance, repair, salvage value, and replacement costs; economic analyses, including present and/or annual worth, return on investment, and cost-benefit; depreciation and taxes; type and breakdowns of costs, including fixed, variable, direct and indirect, and labor; accounting, including financial statements and overhead cost allocations; capital budgeting; financial risk identification; profit and loss; supply and demand; and life-cycle analysis (AAES and US Dept. of Labor 2016).

Rationale

Civil engineers must hold the safety, health, and welfare of the public paramount in their professional practice. Within this context, all civil engineers should understand that project decisions

@seismicisolation
@seismicisolation

have broad economic implications, and they must be able to estimate these impacts. Successful, sustainable civil engineering projects rely in part on the effective application of the concepts and principles of engineering economics. Engineering economics is a critical component of project management and incorporates concepts of risk and uncertainty. Knowledge and skills in engineering economics benefit civil engineers and civil engineering projects through improved efficiencies and effectiveness, supporting public safety, health, and welfare through both traditional and innovative methods.

Level of Achievement

An understanding of and the capability to apply concepts and principles of engineering economics to civil engineering projects is needed for success as a civil engineer. For entry into professional practice, all civil engineers should be at the application level and be able to "apply concepts and principles of engineering economics in the practice of civil engineering."

Typical Pathway for Fulfillment of the Outcome

It is expected that the Engineering Economics outcome will be fulfilled through a combination of undergraduate education and mentored experience. An understanding of the concepts and principles of engineering economics should be learned at the undergraduate level. The ability to apply the concepts and principles of engineering economics in the practice of civil engineering is expected to be fulfilled through mentored experience, which should progress in both complexity and level of responsibility.

@seismicisolation
@seismicisolation

Risk and Uncertainty

Table 2-11. Risk and Uncertainty (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of probability, statistics, and risk relevant to civil engineering.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of probability, statistics, and risk relevant to civil engineering.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of probability and statistics to determine risk relevant to civil engineering.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of probability and statistics and **analyze** risk in a complex civil engineering problem.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Integrate** risk analyses into the solutions to complex civil engineering problems.	
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the acceptability of the risks associated with solutions to complex civil engineering problems.	

Understanding the Outcome

Risk may be defined as the most likely consequence of a particular hazard or vulnerability combined with the likelihood or probability of it occurring. Uncertainties are unavoidable in any engineering project and can be data-based (variability and quality of data) or knowledge-based (limited or incomplete information). Both risk and uncertainty are pervasive throughout all traditional and emerging areas of civil engineering, and they are an integral part of project management, civil engineering design, and sustainability. To address issues related to risk and uncertainty in civil engineering projects, civil engineers need a firm grasp of concepts and principles of probability and statistics. Probability theory is used to predict the likelihood of an event, or how often some event may occur, and statistics is used to characterize data and sets of data. Civil engineers must understand how to use both probability and statistics and to incorporate this knowledge into the consideration of vulnerability, fragility, hazards, and consequences of failure in the analysis of risk. This is especially true when noting that the health, safety, and welfare of the public is of paramount importance to all engineers.

@seismicisolation
@seismicisolation

Rationale

The concepts and principles of both probability and statistics, in combination with other foundational, engineering fundamental, technical, and professional topics, are essential for modeling and quantifying risk and uncertainty in complex civil engineering problems and projects. This includes the identification of major sources of uncertainties, determining their significance, determining probabilities and consequences of failure, and ultimately analyzing risk. The fundamentals of probability and statistics must be applied so that the risk associated with civil engineering projects can be analyzed and, inasmuch as possible, be mitigated to safeguard the health, safety, and welfare of the public.

Level of Achievement

The civil engineer must possess the ability to quantify uncertainties and analyze risks that are inherently a part of any complex project or design. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the analysis level and be able to both "select appropriate concepts and principles of probability and statistics" to determine the likelihood of some event, and "analyze risk in complex civil engineering problems" using the appropriate mathematical, probability, and statistical tools.

Typical Pathway for Fulfillment of the Outcome

A basic understanding of probability and statistics and the ability to apply this understanding to determine risk is appropriate as part of the undergraduate education of a civil engineer. However, in recognition that risk and uncertainty can be dependent on the specific type of complex civil engineering problems being solved and a greater depth of technical knowledge being needed, mentored experience is also necessary to fulfill the Risk and Uncertainty outcome.

@seismicisolation

Breadth in Civil Engineering Areas

Table 2-12. Breadth in Civil Engineering Areas (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles to solve complex problems in at least four specialty areas appropriate to the practice of civil engineering.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** complex problems that cross multiple specialty areas appropriate to the practice of civil engineering.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Integrate** solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.	
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.	

Understanding the Outcome

Civil engineering is an inherently broad field encompassing a wide array of specialty areas and most civil engineering problems and projects draw on ideas, concepts, and principles from across the discipline. Civil engineers must possess technical breadth and strong problem-solving ability in multiple specialty areas of the civil engineering discipline. Specialty areas in civil engineering include, but are not limited to construction engineering, environmental engineering, geotechnical engineering, water resources engineering, structural engineering, surveying, and transportation engineering. Other specialty areas relevant to civil engineering may include areas in which

- ASCE has an institute or technical division in the area,
- ASCE publishes a journal in the area,
- ASCE sponsors a specialty conference in the area,
- There are civil engineering consulting firms that specialize in the area, or
- The area is emerging and the connection to civil engineering can be reasonably justified.

@seismicisolation

Rationale

Application of knowledge in at least four specialty areas appropriate to civil engineering is necessary to solve complex civil engineering problems. Possessing this breadth enables civil engineers to appreciate and relate to other engineers when working on complex civil engineering projects. Civil engineering practice requires the ability to analyze complex problems across more than one area of civil engineering.

Level of Achievement

This outcome requires the application of concepts and principles to solve civil engineering problems in at least four specialty areas appropriate to the practice of civil engineering. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the analysis level and be able to "analyze complex problems that cross multiple specialty areas appropriate to the practice of civil engineering."

Typical Pathway for Fulfillment of the Outcome

The Breadth in Civil Engineering Areas outcome is attained through a combination of undergraduate education and mentored experience. The ability to apply concepts and principles in at least four specialty areas of civil engineering typically is achieved through undergraduate education and requires a firm foundation in the engineering fundamentals outcomes. Such exposure to a range of disciplines enhances the creativity and innovation needed to develop specialized expertise within the technical depth outcome. Civil engineers are expected to gain the ability to analyze complex problems that cross multiple specialty areas appropriate to the practice of civil engineering through mentored experience, which progresses in both complexity and level of responsibility.

@seismicisolation

Design

Table 2-13. Design (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Define** engineering design and the engineering design process.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** engineering design and the engineering design process.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** the engineering design process to a given set of requirements and constraints to solve a complex civil engineering problem.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** a complex civil engineering project to determine design requirements and constraints.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Develop** an appropriate design alternative for a complex civil engineering project that considers realistic requirements and constraints.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** design alternatives for a complex civil engineering project for compliance with customary standards of practice, user and project needs, and relevant constraints.	

Understanding the Outcome

Design is a decision-making process, often iterative, in which mathematics, natural science, and fundamentals of engineering are applied to convert resources to meet a stated need. Activities such as problem definition, specifying requirements, consideration of constraints, selection or development of design options, analysis, detailed design, performance prediction, implementation, observation, and testing are all parts of the engineering design process. Design problems are often ill-defined, making defining the scope and design objectives and identifying the constraints governing a particular problem essential to the design process.

The Mathematics and Natural Sciences foundational outcomes and engineering fundamentals outcomes are the cornerstones of all technical outcomes in the CEBOK and thus support the technical aspects of design. The Humanities and Social Sciences foundational outcomes provide a historical and cultural perspective, which informs the civil engineer on the societal, political, and global needs in decision making during the design process. The breadth and depth outcomes provide expertise in one or more specialty areas of civil engineering while affording the civil engineer an appreciation of interrelationships between their own specialty area and all other subdisciplines required in completing a design. A formal quantitative consideration of

@seismicisolation

uncertainty as it affects risk and uncertainty is a design imperative, as is the incorporation of the principles of sustainability. It is the designer's professional responsibility to ensure safety principles are addressable for every phase of a project's life cycle.

Rationale

As Henry Petroski famously stated, "Science is about knowing; engineering is about doing" (Petroski 2010). Engineers combine science, mathematics, technology, and creativity to create innovative solutions to problems and the development of products. In fact, the essence of civil engineering is the iterative process of designing, predicting performance, constructing, and testing. The design process is open-ended and involves a number of possible correct solutions, including creative and innovative approaches. Thus, successful design requires application of the fundamentals in natural science, mathematics, and engineering fundamentals, detailed knowledge of the design process, critical thinking, an appreciation of the uncertainties involved, and the use of engineering judgment. A breadth of knowledge in several recognized and/or emerging areas of the civil engineering discipline is necessary for understanding the relationship and interaction of different elements in a designed system or environment.

Level of Achievement

Design encompasses fundamental concepts and principles used to solve problems with realistic needs, constraints, and standards. Civil engineers must consider issues such as risk assessment, societal and environmental impacts, standards, codes, regulations, safety, security, sustainability, resilience, constructability, and operability at various stages of the design process. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and be able to "develop an appropriate design alternative for a complex civil engineering project that considers realistic requirements and constraints."

Typical Pathway for Fulfillment of the Outcome

The National Academy of Engineering, National Academies of Sciences (2004a) recommends that the design process be introduced to students from the "earliest stages of the curriculum, including the first year." Fostering creative knowledge in students prepares them to handle a future of increasing complexity that relies on a multidisciplinary approach to solving problems (Parcover and McCuen 1995). The design component at the undergraduate level should involve application of the design process under a defined set of standards and constraints. Mentored experience, which progresses in both complexity and level of responsibility, should reach the synthesis level and include opportunities to use many or all aspects of the design process, including problem definition; project planning; scoping the design objective; the development of design options; adherence to codes, regulations, and standards; economic aspects; safety; constructability; operability; sustainability; and resilience. Experience at this level should include familiarity with interactions among planning, design, construction, and operations and should take into account design life-cycle assessment.

@seismicisolation

Depth in a Civil Engineering Area

Table 2-14. Depth in a Civil Engineering Area (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Define** advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering.	Postgraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering.	Postgraduate education
5 Synthesize (put learned material together to form a new whole)	**Integrate** advanced concepts and principles into the solutions of complex problems in a specialty area appropriate to the practice of civil engineering.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** advanced concepts and principles in the solutions of complex problems in a specialty area appropriate to the practice of civil engineering.	

Understanding the Outcome

Depth in a civil engineering area is required in the practice of civil engineering and involves the need for a deeper understanding and ability within one or more areas appropriate to the practice of civil engineering to meet the demand for detailed and expanded knowledge. This depth requires deeper understanding of both theory and application and involves advanced concepts and principles in a specialty area appropriate to the practice of civil engineering.

Specialty areas in civil engineering include, but are not limited to, construction engineering, environmental engineering, geotechnical engineering, water resources engineering, structural engineering, surveying, and transportation engineering. Some civil engineers pursue a general civil engineering practice, requiring advanced education and experience across a broad range of civil engineering subjects.

Other specialty areas relevant to civil engineering may include areas in which

- ASCE has an institute or technical division in the area,
- ASCE publishes a journal in the area,

@seismicisolation

- ASCE sponsors a specialty conference in the area,
- There are civil engineering consulting firms that specialize in the area, or
- The area is emerging and the connection to civil engineering can be reasonably justified.

Rationale

The increasing complexity of engineering projects and growing volume of technical knowledge combined with the specialized nature of civil engineering practice requires civil engineers to develop a depth of expertise within a specialty area. This depth may be reflected in emerging efforts for certifications, specialty licensing, and post-licensure credentialing in some areas of practice. Depth of specialized knowledge is one of the hallmarks of a learned profession such as civil engineering (Ressler 2011, Freidson 2001).

Level of Achievement

Depth in a civil engineering area involves not only a deeper understanding of concepts and principles but also requires a higher level of achievement than expected for Breadth in Civil Engineering Areas. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and be able to "integrate advanced concepts and principles into the solutions of complex problems in a specialty area appropriate to the practice of civil engineering."

Typical Pathway for Fulfillment of the Outcome

The Depth in a Civil Engineering Area outcome is attained through a combination of undergraduate education, postgraduate education, and mentored experience. This depth may build on a foundation from the Breadth in Civil Engineering Areas outcome. A substantial portion of this outcome is typically achieved through postgraduate education and culminates in the use of advanced knowledge in practice under mentored experience, which progresses both in complexity and level of responsibility. Postgraduate education and mentored experience provide opportunities for creativity and innovation, which will help advance the civil engineering profession.

@seismicisolation

Sustainability

Table 2-15a. Sustainability (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of sustainability.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of sustainability.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of sustainability to the solution of complex civil engineering problems.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** the sustainable performance of complex civil engineering projects from a systems perspective.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Develop** practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.	
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.	

Table 2-15b. Sustainability (Affective Domain).

Affective Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of sustainability in civil engineering.	Undergraduate education
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Comply** with the concepts and principles of sustainability in civil engineering.	Undergraduate education
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** the benefits of sustainability in the practice of civil engineering.	Mentored experience
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Integrate** a commitment to sustainability principles into the practice of civil engineering.	Self-developed
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** principles of sustainability.	

@seismicisolation
@seismicisolation

Understanding the Outcome

Sustainability for civil engineers is defined as "a set of economic, environmental and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or the availability of economic, environmental and social resources." (ASCE 2016b). The concepts and principles needed to meet the requirements of sustainability are rooted in the foundational outcomes of natural sciences, social sciences, and the humanities (Committee on Sustainability 2004). Sustainability encompasses life-cycle cost analysis and, therefore, integrates the Engineering Economics outcome. Sustainability is also fundamentally linked to the Design outcome because every design should be sustainable. This commitment to sustainability in design is linked to the Professional Ethics outcome as civil engineers are committed to "strive to comply with the principles of sustainable development in the performance of their professional duties" (ASCE 2017).

A civil engineering system is a combination of elements or subsystems that are organized to solve a complex civil engineering problem. Each element or subsystem can be designed and evaluated for sustainability individually; however, a systems perspective for sustainability considers how the parts of the project interrelate and how the project fits into the wider economic, environmental, and social contexts (Walden et al. 2015). Each individual civil engineering project exists in a larger system and the cumulative sustainability effects of those projects need to be considered.

Resiliency and sustainability are also fundamentally linked (Bocchini et al. 2014). Resiliency is the ability of a system to withstand an extreme event and recover efficiently. The extreme events have a probability of occurrence during the life span of the civil engineering system. The recovery from these extreme events has economic, environmental, and social costs that can be calculated. As stated in ASCE Policy 418, "Sustainability requires planning for the impact natural and man-made disasters and changing conditions can have on economic, environmental, and social resources." (ASCE 2016b). Resiliency links sustainability to the Risk and Uncertainty outcome because an understanding of the risks of extreme events is essential to build resilient infrastructure. Further, climate change will lead to an increased risk due to certain extreme events (ASCE 2016a). As noted in the Materials Science outcome, civil engineers must consider the increasing importance of recycling and reuse of materials and resources.

Rationale

Civil engineers must be able to address the sustainability of a project during planning and to help stakeholders understand the environmental, economic, and social impacts. Civil engineers also are responsible for addressing sustainability issues throughout the life cycle of the project, including any extreme events that may occur. The effects of climate change further highlight the need for engineers to be knowledgeable in resilient and sustainable practices (ASCE 2016a). Sustainability is part of the ASCE Code of Ethics and permeates all professional work of civil engineers (ASCE 2017). Envisioning sustainable solutions to civil engineering problems requires creativity and innovation to develop new solutions.

Simply obtaining knowledge and skills may not guarantee that these will be applied in practice. The application of the principles and concepts of sustainability requires a commitment to their importance to the civil engineering profession and society at large. Embracing

@seismicisolation

sustainability in the development of a value system aids in situations in which sustainability requires judgment that goes beyond the cognitive ability to monetize costs.

Level of Achievement

Cognitive Domain

Sustainability is critical to the civil engineering profession and civil engineers must be expected to be proficient in the application and analysis of principles of sustainability in all design work they perform. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the analysis level and have the ability to "analyze the sustainable performance of complex civil engineering projects from a systems perspective." This analysis should be holistic and include the environmental, economic, and social factors at both the level of the individual project and the systems level.

Affective Domain

Civil engineers must also be expected to internalize and prioritize sustainability in all designs, decisions, and recommendations. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the organize level and have the ability to "integrate a commitment to sustainability principles into the practice of civil engineering."

Typical Pathway for Fulfillment of the Outcome

Cognitive Domain

In the cognitive domain, the Sustainability outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. Just as sustainability permeates the practice of civil engineering, its associated knowledge, skills, and attitudes must permeate the undergraduate experience. Undergraduate education should address the first three levels of the cognitive understanding of sustainability and ensure graduates have the ability to "apply concepts and principles of sustainability to the solution of complex civil engineering projects." Mentored experience, which progresses in both complexity and level of responsibility, should build on these fundamentals to extend the civil engineer's ability to analyze "the sustainable performance of complex civil engineering projects from a systems perspective."

Affective Domain

In the affective domain, the Sustainability outcome is expected to be fulfilled through a combination of undergraduate education, mentored experience, and self-development. While learning knowledge and skills of sustainable development, the undergraduate should develop attitudes that correspond to the first two levels of the affective domain. They should acknowledge the importance of sustainability and comply with its concepts and principles. Through the experience of working on civil engineering projects under directed mentorship, civil engineers learn to value the benefits of sustainability in the practice of civil engineering. Ultimately, each individual civil engineer is responsible for integrating a commitment to sustainability principles in everyday practice through self-development and reflection.

@seismicisolation
@seismicisolation

Professional Outcomes

> *Experience serves not only to confirm theory but differs from it without disturbing it; it leads to new truths which theory only has not been able to reach.*
>
> –Jean le Rond d'Alembert

Communication

Table 2-16a. Communication (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of effective and persuasive communication to technical and nontechnical audiences.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of effective and persuasive communication to technical and nontechnical audiences.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Formulate** effective and persuasive communication to technical and nontechnical audiences.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** effective and persuasive communication to technical and nontechnical audiences.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Integrate** different forms of effective and persuasive communication to technical and nontechnical audiences.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the effectiveness and persuasiveness of communication to technical and nontechnical audiences.	

@seismicisolation

Table 2-16b. Communication (Affective Domain).

Affective Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of effective and persuasive communication to technical and nontechnical audiences.	Undergraduate education
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Practice** effective and persuasive communication to technical and nontechnical audiences.	Undergraduate education
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** effective and persuasive communication to technical and nontechnical audiences.	Mentored experience
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Display** effective and persuasive communication to technical and nontechnical audiences.	Self-developed
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate** for effective and persuasive communication to technical and nontechnical audiences.	

Understanding the Outcome

Civil engineers should be adept at using all forms of communication in their work (AAES and the US Dept. of Labor 2016). The successful civil engineer communicates effectively and persuasively using appropriate interpersonal skills with technical and nontechnical audiences in a variety of settings.

Effective communication conveys information clearly, correctly, and succinctly and includes not only the skills to transmit information, but also to verify that the receiver has correctly understood the information (AAES and US Dept. of Labor 2016). In a global setting, civil engineers must have sufficient knowledge of other cultures to effectively communicate the intended message.

Persuasive communication shapes, reinforces, or changes the response of the receiver (Stiff and Mongeau 2016). Although all communication can persuade, it is important that civil engineers know how to communicate in a manner intentionally designed to persuade others. Persuasive communication leads to a noticeable response and action by the receiver. Not all communication by civil engineers is intended to be persuasive, but when persuasion is needed, civil engineers must be adept in the skills of persuasive communication, while maintaining the highest ethical standards.

@seismicisolation

The Communication outcome is linked to many other outcomes, especially the Humanities outcome, and the Teamwork and Leadership outcome. Studying the humanities provides a "detailed understanding of human behaviour" (Liu 2014) and helps develop the empathy needed to effectively communication with diverse clients and stakeholders (Ottino and Morson 2016). Forms of the humanities, such as literature and theater, serve as a model of effective and persuasive communication. Leaders and team members cannot be successful without effective and persuasive communication skills.

In creating designs that benefit all, the civil engineer must be able to listen and convey information appropriately to diverse audiences. The implementation of innovative and creative engineering solutions also requires the civil engineer to effectively communicate ideas in a persuasive manner. As a master integrator, civil engineers must be able to lead multidisciplinary teams and cannot be successful without developing competency in communication. In addition, civil engineers are called on to be "leaders in discussions and decisions shaping public environmental and infrastructure policy" (ASCE 2007), which requires proficiency in effective and persuasive communication.

Rationale

Effective communication is essential to the success of the civil engineer. The focus of this outcome is on developing communication skills that are effective and persuasive. Strong communication skills are key attributes associated with high-performing civil engineers who lead successful projects.

Civil engineers are more effective communicators when they value the need for accurate, succinct, and persuasive communication using appropriate forms. An appreciation of the receiver's perspective is also essential for the communication to be effective and persuasive. This appreciation is particularly important when communicating with diverse stakeholders and communicating technical issues to nontechnical audiences.

Level of Achievement

Cognitive Domain

When civil engineers communicate, they integrate multiple forms of communication appropriate for the audience, such as listening, observing, speaking, writing, as well as nonverbal, visual, and graphical communication. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and be able to "integrate different forms of effective and persuasive communication to technical and nontechnical audiences."

Affective Domain

Civil engineers recognize the importance of effective and persuasive communication as part of their value system for professional practice. The importance that the civil engineer attaches to communication should manifest itself in efforts to improve communication through self-development. For entry into the practice of civil engineering at the professional level, all civil

@seismicisolation

engineers should be at the organize level and have the ability to "display effective and persuasive communication to technical and nontechnical audiences."

Typical Pathway for Fulfillment of the Outcome

Cognitive Domain

In the cognitive domain, the Communication outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. Communication fundamentals and applications can be woven into mathematics, science, and technical and professional practice courses as well as into humanities and social science courses. Co-curricular and extracurricular activities such as cooperative education and active participation in campus organizations offer opportunities to communicate using various means in a variety of situations.

Mentored experience should build on and extend these fundamentals to solidify the civil engineer's communication skills. Engineering practice provides numerous real-world opportunities to analyze and synthesize communication knowledge and skills. The engineer should seek out and be encouraged by mentors to take on tasks and functions that involve ever more challenging communication with increasingly diverse audiences. Mentored experience, which progresses in both complexity and level of responsibility, should play an integral role in helping the civil engineer reach the analysis and synthesis levels.

Affective Domain

In the affective domain, the Communication outcome is expected to be fulfilled through a combination of undergraduate education, mentored experience, and self-development.

At the undergraduate level, civil engineering students should acknowledge the importance of effective and persuasive communication and actively participate in communication activities. Mentored experience should help the civil engineer to place value on communication skills. Once the civil engineer values communication skills, dedicated self-development will be used to further develop effective and persuasive communication skills.

@seismicisolation
@seismicisolation

Teamwork and Leadership

Table 2-17a. Teamwork and Leadership (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** concepts and principles of teamwork and leadership, including diversity and inclusion.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of teamwork and leadership, including diversity and inclusion.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** concepts and principles of effective teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Integrate** concepts and principles of effective teamwork and leadership, including diversity and inclusion, into the solutions of civil engineering problems.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** the effectiveness of leaders and teams in the solution of civil engineering problems.	

Table 2-17b. Teamwork and Leadership (Affective Domain).

Affective Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of teamwork, leadership, diversity, and inclusion.	Undergraduate education
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Practice** concepts and principles of teamwork, leadership, diversity, and inclusion.	Undergraduate education
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** the need for teamwork, leadership, diversity, and inclusion.	Mentored experience
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Display** effective teamwork and leadership, including support of diversity and inclusion.	Self-developed
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** teamwork, leadership, diversity, and inclusion.	

@seismicisolation
@seismicisolation

Understanding the Outcome

Engineers frequently work in teams, as team members and/or leaders. This requires an understanding of team formation and evolution, personality profiles, team dynamics, collaboration among diverse disciplines, problem solving, and time management as well-being able to foster inclusion of diverse perspectives, cultural backgrounds, knowledge, and experience (Parker 1994). Also, engineers may work in teams and lead in asynchronous space and time, often in a virtual environment.

In a broad sense, leadership is developing and engaging others in a common vision, clearly planning and organizing resources, developing and maintaining trust, sharing perspectives, inspiring creativity, heightening motivation, and being sensitive to competing needs. Leadership is the art, science, and craft of influencing others to accomplish a task and improve the organization. Leaders can be assigned formal roles or can emerge without a formal role or position within a group.

Qualities and attributes of leaders include vision, enthusiasm, industriousness, initiative, competence, commitment, selflessness, integrity, high ethical standards, adaptability, communication skills, discipline, agility, confidence, courage, curiosity, and persistence (Farr et al. 1997, Weingardt 1999, Wooden and Jamison 2005).

Being able to function as a member of a team and leading a team are two distinct, yet complementary, skill sets. A team that includes individuals with diverse characteristics, for example, race, ethnicity, gender, and disciplinary backgrounds, leads to better outcomes for the entire team (Phillips 2014).

Rationale

Roles change with experience, project scope, and circumstances. Therefore, engineers must be able to function effectively on teams, and to understand and fulfill different roles including that of a leader. Engineers must be willing to lead when confronted with professional and/or ethical issues. Although technical competence and broad managerial skills will remain important, success in engineering will be more a result of leadership in applying that competence and those skills, rather than the competence and skills themselves (National Academy of Engineering, National Academies of Sciences 2004b). An understanding of leadership from team members often makes teams function more smoothly.

More often "employers [are] calling for graduates who are not merely expert in design and analysis but who possess the leadership skills to apply their technical expertise and to capitalize on emerging construction and information technologies, management models, and organizational structures" (Bowman and Farr 2000). Many also argue that "an engineer is hired for his or her technical skills, fired for poor people skills, and promoted for leadership and management skills" (Russell and Yao 1996).

The report, *The Engineer of 2020: Visions of Engineering in the New Century*, states that "engineers must understand the principles of leadership and be able to practice them as their careers advance" (National Academy of Engineering, National Academies of Sciences 2004b). Clearly the acquisition of leadership skills and the art of practicing leadership are vital to the future of civil engineering. By the very nature of a profession that requires the attainment of strong

@seismicisolation

analytical and rational decision-making skills, engineers are particularly well-suited to assume leadership roles.

Level of Achievement

Cognitive Domain

Civil engineers must understand and be able to both function as a member of a team and lead. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and have the ability to "integrate concepts and principles of effective teamwork and leadership, including diversity and inclusion, into the solutions of civil engineering problems."

Affective Domain

Civil engineers also must value, internalize, and prioritize teamwork and leadership in the practice of civil engineering. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the organize level and have the ability to "display effective teamwork and leadership, including support of diversity and inclusion."

Typical Pathway for Fulfillment of the Outcome

Cognitive Domain

In the cognitive domain, the Teamwork and Leadership outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience.

Leadership can be taught and learned. Leadership principles include being technically competent; knowing oneself and seeking self-improvement; making sound and timely decisions; setting the example; seeking responsibility and taking responsibility for one's actions; communicating with and developing subordinates, both as individuals and as a team; and ensuring that the project is understood, supervised, and accomplished. The formal education process has the potential to make a significant impact through teaching leadership principles and developing leadership attributes (Bowman and Farr 2000). Examples of leadership opportunities in the undergraduate program include leadership of design teams; leadership opportunities within capstone or culminating design experiences; and leadership within such organizations as ASCE's student chapters, student competitions, civic organizations, honor societies, athletic teams, student government, and fraternities and sororities.

Civil engineers must continue to grow as valued team members and leaders through mentored experience and participation in professional organizations and societies, such as ASCE and others as appropriate. Mentors should encourage engineers to pursue development opportunities to enhance their professional skills, including interpersonal skills and leadership, through work experiences as well as professional development seminars and participation in professional and community organizations.

@seismicisolation
@seismicisolation

Affective Domain

In the affective domain, the Teamwork and Leadership outcome is expected to be fulfilled through a combination of undergraduate education, mentored experience, and self-development. While learning to identify, explain, and apply the concepts and principles of teamwork, leadership, diversity, and inclusion, the undergraduate should also acknowledge the importance of teamwork, leadership, diversity, and inclusion, and practice these concepts and principles. Through mentored experience, which progresses in both complexity and level of responsibility, civil engineers learn to value the need for teamwork, leadership, diversity, and inclusion, and through self-development and reflection, civil engineers should be able to display behaviors to effectively work in teams and lead teams.

@seismicisolation

Lifelong Learning

Table 2-18a. Lifelong Learning (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Acquire** new knowledge, skills, and attitudes relevant to civil engineering through self-directed learning.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** new knowledge, skills, and attitudes relevant to civil engineering acquired through self-directed learning.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Integrate** new knowledge, skills, and attitudes acquired through self-directed learning into the practice of civil engineering.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** the effectiveness of additional knowledge, skills, and attitudes acquired through self-directed learning.	

Table 2-18b. Lifelong Learning (Affective Domain).

Affective Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the need for lifelong learning.	Undergraduate education
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Participate** in lifelong learning opportunities.	Undergraduate education
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** lifelong learning in the practice of civil engineering.	Mentored experience
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Establish** a lifelong learning plan to support one's own professional development.	Self-developed
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** lifelong learning in the practice of civil engineering.	

@seismicisolation

Understanding the Outcome

Lifelong learning is the ability and commitment to acquire knowledge, skills, and attitudes throughout one's professional career. The levels of achievement in the cognitive domain focus on the knowledge and skills, whereas the affective domain addresses motivation and attitudes. The affective domain describes the value of and desire to acquire the knowledge, skills and attitudes to support lifelong learning.

Rationale

Because of the ever-increasing quantity of technical and nontechnical knowledge required of civil engineers, the ability to engage in lifelong learning is essential. Knowledge, skills, and attitudes acquired at any point in time will not be sufficient for successful continued practice of civil engineering at the professional level spanning several decades. This outcome sets a foundation for the integration of and planning for lifelong learning required throughout a career. Self-directed learning is incorporated into the outcome statements to highlight the need for the individual to take ownership of the growth of the knowledge, skills, and attitudes, which should begin during their undergraduate education and continue through the rest of the individual's career.

Lifelong learning supports attainment of the other outcomes in the CEBOK by providing the civil engineer with the knowledge, skills, and attitudes to develop as an individual and as a civil engineer. Lifelong learning supports creative and innovative thinking and provides the motivation for continued learning to put new ideas together in new and different contexts to solve complex civil engineering problems. As such, this outcome supports civil engineers in the role of master integrator advancing the profession and ensuring those in the profession are capable of solving the problems of the future.

Level of Achievement

Cognitive Domain

Lifelong learning is crucial to the civil engineering profession and civil engineers must be expected to be lifelong students with the ability to continuously learn across various topics. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and have the ability to "integrate new knowledge skills, and attitudes acquired through self-directed learning into the practice of civil engineering."

Affective Domain

Civil engineers must also be expected to value and pursue lifelong learning necessary to advance their careers and develop as engineers and professionals to keep up with an ever-changing world. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the organize level and be able to "establish a lifelong learning plan to support one's own professional development."

@seismicisolation

Typical Pathway for Fulfillment of the Outcome

Cognitive Domain

In the cognitive domain, the Lifelong Learning outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. Independent study projects and open-ended problems requiring additional knowledge that is not presented in a formal class setting are examples of ways to provide opportunities for self-directed learning in an undergraduate program. Civil engineers should engage in lifelong learning through continuing education, professional practice experience, and active involvement in professional societies, community service, coaching, mentoring, and other learning and growth activities.

Affective Domain

In the affective domain, the Lifelong Learning outcome is expected to be fulfilled through a combination of undergraduate education, mentored experience, and self-development. Through their undergraduate experience, students should acknowledge the need for lifelong learning and participate in lifelong learning opportunities. Opportunities include membership in ASCE and other organizations, attending professional development seminars, professional goal setting, and career mapping activities. Mentors must demonstrate and be role models in valuing the importance of lifelong learning. Mentors should encourage professional development to reinforce the value of continuing education and lifelong learning. Having internalized the value of lifelong learning through mentored experience, civil engineers must establish their own lifelong learning plan to support their own self-development and career advancement.

@seismicisolation
@seismicisolation

Professional Attitudes

Table 2-19a. Professional Attitudes (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** knowledge of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Mentored experience
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Illustrate** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Integrate** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the effectiveness of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	

@seismicisolation

Table 2-19b. Professional Attitudes (Affective Domain).

Affective Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Undergraduate education
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Practice** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Undergraduate education
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Mentored experience
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Establish** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Self-developed
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	

Understanding the Outcome

Attitudes can be described as learned predispositions to respond in a consistently favorable or unfavorable manner (Fishbein and Ajzen 1975). Professional attitudes are the positive and constructive attitudes that a civil engineer should display. Professional attitudes encompass a range of elements including creativity, curiosity, flexibility, and dependability. Although neither specifically listed in the outcome statements nor required for every civil engineer, other professional attitudes that are important include commitment, confidence, consideration of others, empathy, entrepreneurship, fairness, high expectations, honesty, integrity, intuition, good judgment, optimism, persistence, positivity, respect, self-esteem, sensitivity, thoughtfulness, thoroughness, and tolerance (ASCE 2008).

Creativity is the ability to make new things or form new ideas and is needed to solve complex civil engineering problems that do not have obvious solutions. Curiosity is the urge to know about something and is essential for the civil engineer to gain new knowledge and to be more creative. Flexibility is the ability to change or be changed according to the situation and is critical for civil engineers working within a diverse group and in an ever-changing environment. Dependability is defined as the quality of being able to be counted on or relied upon and is an attitude civil engineers should display (McCuen et al. 2011).

@seismicisolation

Rationale

Positive professional attitudes create a more effective and pleasant workplace. Perceptions of civil engineers may be enhanced by exhibiting positive attitudes, which will likely lead to better career opportunities for civil engineers.

ASCE calls for civil engineers to be innovators and integrators of ideas and technology across public, private, and academic sectors. To achieve this vision, civil engineers must be creative, dependable, flexible, and curious about new ideas.

Having a professional attitude enhances the attainment of other CEBOK outcomes such as the Ethical Responsibilities outcome, the Professional Responsibilities outcome, the Lifelong Learning outcome, and many others.

Level of Achievement

Cognitive Domain

Possessing and displaying the appropriate attitudes are essential to working effectively in the civil engineering profession. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the analysis level and have the ability to “illustrate professional attitudes including creativity, curiosity, flexibility, and dependability in the practice of civil engineering.”

Affective Domain

Civil engineers must also be expected to internalize and prioritize the appropriate professional attitudes in practice of civil engineering. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the organize level and have the ability to “establish professional attitudes including creativity, curiosity, flexibility, and dependability in the practice of civil engineering.”

Typical Pathway for Fulfillment of the Outcome

Cognitive Domain

In the cognitive domain, the Professional Attitudes outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. The undergraduate experience should plant the seeds of professional attitudes and include education and basic practice in creativity, curiosity, flexibility, and dependability. Mentored experience should build on and extend these fundamentals to further the civil engineer’s ability to apply and illustrate professional attitudes that enhance the practice of civil engineering.

Affective Domain

In the affective domain, the Professional Attitudes outcome is expected to be fulfilled through a combination of undergraduate education, mentored experience, and self-development. While learning to identify and explain professional attitudes, the undergraduate should also

@seismicisolation

acknowledge the importance of professional attitudes and begin to put them into practice. Through mentored experience civil engineers learn to value the benefits of professional attitudes in the practice of civil engineering. Ultimately, each individual civil engineer is responsible for integrating these professional attitudes in everyday practice through self-development and reflection.

@seismicisolation
@seismicisolation

Professional Responsibilities

Table 2-20a. Professional Responsibilities (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	Mentored experience
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Illustrate** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Integrate** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the integration of professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	

@seismicisolation

Table 2-20b. Professional Responsibilities (Affective Domain).

Affective Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Receive (be aware of, willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.	Undergraduate education
2 Respond (actively participate in activity, attend to task, react to motivation)	**Examine** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.	Undergraduate education
3 Value (attach value to particular object, phenomenon, or behavior)	**Value** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.	Mentored experience
4 Organize (sort values into priorities by contrasting different values, resolve conflicts between them, and creating a unique value system)	**Form judgments** about professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.	Self-developed
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.	

Understanding the Outcome

Professional responsibilities encompass a range of elements including safety, legal issues, licensure, credentialing, and innovation. Although neither specifically listed in the outcome statements nor required for every civil engineer, other professional responsibilities that are important include knowledge and appreciation of the history and heritage of the profession, cultural perspectives, public policy, and global perspectives.

The primary responsibility of a civil engineer is to ensure public safety, and to keep this goal at the forefront during engineering design.

A civil engineer must be aware of the wide variety of legal and regulatory responsibilities that pertain to the practice of civil engineering, including regulations, standards, codes, contracts, and guidelines relevant to the jurisdiction, which can span federal, state, and local requirements. This is inclusive of behavior in compliance with ethical requirements, which is included as a standalone outcome in the CEBOK3.

Civil engineers must appreciate and understand the importance of professional licensure, when licensure is required, the process of becoming a licensed professional engineer (P.E.), and the responsibilities associated with licensed practice. This includes lifelong learning to stay current with advances in civil engineering practice.

@seismicisolation

Credentials include a variety of licenses and certifications that relate to civil engineering and recognize various types and levels of professional expertise. Credentialing requires a specialized knowledge and an expectation of additional professional responsibilities.

Innovation is a new idea, process, or device that alters societal ways of doing or being. Innovation is an essential part of engineering as engineers create what has not previously existed. It stems from creative thinking, which includes the capacity to combine or synthesize existing ideas and expertise in original ways. Those who are innovative and creative often use divergent thinking and are willing to take risks. The creative/innovative cycle from formulation to diffusion needs to be done at all scales, including within the profession, within organizations, and as individuals.

Professional responsibilities include the responsibility for being knowledgeable of and demonstrating professional attitudes. This includes treating all persons fairly, as articulated in the ASCE Code of Ethics Canon 8 (ASCE 2017) and includes promoting sustainability in civil engineering. These responsibilities are discussed in more details in other parts of the CEBOK3 including the Sustainability outcome and Ethical Responsibilities outcome.

Rationale

Each problem that a civil engineer faces is unique owing to a combination of technical, safety, historical, environmental, political, and cultural issues. In addition to technical competence, civil engineers are expected to understand and consider a plethora of design, construction, and operational constraints that fall under the umbrella of professional responsibility. Civil engineers are expected to have the ability to recognize and discharge their professional responsibilities in engineering situations and make informed judgments, considering the impact of engineering solutions in a global, economic, environmental, societal, and historical context. Determining appropriate solutions to complex problems requires innovation, adherence to standards, and consideration of many nontechnical factors.

Level of Achievement

Cognitive Domain

Civil engineers must understand and be able to integrate various professional issues and responsibilities into the practice of civil engineering. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and have the ability to "integrate professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation."

Affective Domain

Civil engineers also must value, internalize, and prioritize the various professional responsibilities in the practice of civil engineering. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the organize level and have the ability to "form judgments about professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation."

@seismicisolation

Typical Pathway for Fulfillment of the Outcome

Cognitive Domain

In the cognitive domain, the Professional Responsibilities outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. The undergraduate experience should include education on safety, legal issues, licensure, credentialing, and innovation, and may include such topics as history and heritage of the profession, cultural perspectives, public policy, and global perspectives. This may be accomplished through professional development seminars during a capstone or culminating design experience, or through other in-course exercises and discussions. Civil engineers face many of these issues and responsibilities in practice and further development, to include the application, illustration, and integration of professional responsibilities in practice, occurs through mentored experience.

Affective Domain

In the affective domain, the Professional Responsibilities outcome is expected to be fulfilled through a combination of undergraduate education, mentored experience, and self-development. While learning to identify and explain the professional responsibilities of a civil engineer, the undergraduate should also acknowledge the importance of professional responsibilities in the practice of civil engineering and examine these responsibilities as they pertain to civil engineering. Through mentored experience civil engineers learn to value these professional responsibilities, and through self-development and reflection, civil engineers should be able to resolve conflicts among them and form judgments about them.

@seismicisolation

Ethical Responsibilities

Table 2-21a. Ethical Responsibilities (Cognitive Domain).

Cognitive Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Remember (remember previously learned material)	**Identify** the ethical responsibilities of a civil engineer.	Undergraduate education
2 Comprehend (grasp the meaning of learned material)	**Explain** the ethical responsibilities of a civil engineer.	Undergraduate education
3 Apply (use learned material in new and concrete situations)	**Apply** appropriate reasoning to an ethical dilemma.	Undergraduate education
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** ethical dilemmas to determine possible courses of action.	Mentored experience
5 Synthesize (put learned material together to form a new whole)	**Develop** courses of action to ethical dilemmas in complex situations.	Mentored experience
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** courses of resolution to ethical dilemmas in complex situations.	

Table 2-21b. Ethical Responsibilities (Affective Domain).

Affective Domain Level of Achievement	Demonstrated Ability	Typical Pathway
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of ethical behavior.	Undergraduate education
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Comply** with applicable ethical codes.	Undergraduate education
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** ethical behavior in the practice of civil engineering.	Mentored experience
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Display** ethical behavior in the practice of civil engineering.	Mentored experience
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** ethical behavior in the practice of civil engineering.	Self-developed

@seismicisolation

Understanding the Outcome

Civil engineers have a privileged position in society and have a responsibility to hold paramount the health, safety, and welfare of the public. They must exhibit high levels of honesty, integrity, and fairness, and must continually guard against conflicts of interest, either real or perceived. Ethical practice is the means to gain and maintain the public trust.

Civil engineers are expected to practice in accordance with the ethical codes of the societies in which they are members, for example, ASCE and the National Society of Professional Engineers (NSPE). They also are expected to adhere to the ethical standards established by their clients and employers. Students are subject to codes of conduct at universities and colleges. Licensed professional engineers have a legal, as well as an ethical, responsibility to practice in compliance with the code of conduct in the jurisdictions in which they practice.

Rationale

Civil engineers are expected to uphold and advance the integrity, honor, and dignity of the engineering profession by practicing in compliance with the ASCE Code of Ethics (ASCE 2017) and other applicable codes. Civil engineers are expected to have the ability to recognize ethical responsibilities in engineering situations and make informed judgments, considering the impact of engineering solutions in a global, economic, environmental, and societal context. To advocate for ethical behavior within the profession, civil engineers must internalize the value of ethical behavior.

Level of Achievement

Cognitive Domain

Ethical responsibilities are essential in the practice of civil engineering and civil engineers must be able to appropriately address ethical issues. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the synthesis level and have the ability to "develop courses of action to ethical dilemmas in complex situations."

Affective Domain

Civil engineers must also value, internalize, and display ethical behavior, and be expected to internalize and prioritize the appropriate professional attitudes in the practice of civil engineering. For entry into the practice of civil engineering at the professional level, all civil engineers should be at the characterize level and have the ability to "advocate for ethical behavior in the practice of civil engineering."

Typical Pathway for Fulfillment of the Outcome

Cognitive Domain

In the cognitive domain, the Ethical Responsibilities outcome is expected to be fulfilled through a combination of undergraduate education and mentored experience. The undergraduate

@seismicisolation

experience should include an introduction to ethical practices, the ASCE Code of Ethics (ASCE 2017), and the importance of statutory requirements. This is usually accomplished through professional development seminars during a capstone or culminating design experience, through other in-course exercises and discussions, or sometimes through entire courses on engineering ethics. When faced with ethical dilemmas in practice, civil engineers should reach out for guidance from more experienced engineers. Mentored experience, which progresses in both complexity and level of responsibility, should build on the undergraduate education to further the civil engineer's ability to apply appropriate ethical requirements and analyze ethical dilemmas to develop courses of action to address ethical dilemmas in complex situations.

Affective Domain

In the affective domain, the Ethical Responsibilities outcome is expected to be fulfilled through a combination of undergraduate education, mentored experience, and self-development. While learning to identify and explain the ethical responsibilities of a civil engineer, the undergraduate should also acknowledge the importance of ethical behavior in the practice of civil engineering and comply with the ASCE Code of Ethics (ASCE 2017). Through mentored experience, civil engineers learn to value ethical behavior and adhere to ethical standards. Advocating for ethical behavior in the practice of civil engineering essentially comes from self-development and an internalization of the requirements and benefits of ethical behavior.

References

AAES (American Association of Engineering Societies) and the US Dept. of Labor. 2016. "Engineering competency model." Accessed August 4, 2018. http://www.aaes.org/model.

ASCE. 2007. *Vision for civil engineering in 2025.* Reston, VA: ASCE.

ASCE. 2008. *Civil engineering Body of Knowledge for the 21st century: Preparing the civil engineer for the future.* 2nd ed. Reston, VA: ASCE.

ASCE. 2016a. "Policy Statement 360—Impact of climate change." Reston, VA: ASCE. Accessed August 4, 2018. https://www.asce.org/issues-and-advocacy/public-policy/policy-statement-360---impact-of-climate-change/.

ASCE. 2016b. "Policy Statement 418—The role of the civil engineer in sustainable development." Reston, VA: ASCE. Accessed August 4, 2018. https://www.asce.org/issues-and-advocacy/public-policy/policy-statement-418---the-role-of-the-civil-engineer-in-sustainable-development/.

ASCE. 2017. "Code of ethics." Reston, VA: ASCE. Accessed August 4, 2018. https://www.asce.org/code-of-ethics/.

Bocchini, P., D. M. Frangopol, T. Ummenhofer, and T. Zinke. 2014. "Resilience and sustainability of civil infrastructure: Toward a unified approach," *J. Infrastruct. Syst.* 20 (2): 04014004. Accessed August 4, 2018. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000177.

Bowman, B. A. and J. V. Farr. 2000. "Embedding leadership in civil engineering education." *J. Prof. Issues Eng. Educ. Pract.* 126 (1): 16–20. https://doi.org/10.1061/(ASCE)1052-3928(2000)126:1(16).

@seismicisolation

Committee on Sustainability. 2004. *Sustainable engineering practice: An introduction.* Edited by Jorge A. Vanegas. Reston, VA: ASCE.

Courant, R., H. Robbins, and I. Stewart. 1996. *What is mathematics: An elementary approach to ideas and methods.* 2nd ed. New York: Oxford University Press.

ESRC (Economic and Social Research Council). 2018. "What is social science?" Accessed August 4, 2018. https://esrc.ukri.org/about-us/what-is-social-science/.

Farr, J. V., S. G. Walesh, and G. B. Forsythe. 1997. "Leadership development for engineering managers." *J. Manage. Eng.* 13 (4): 38–41. https://doi.org/10.1061/(ASCE)0742-597X(1997)13:4(38).

Fishbein, M. and I. Ajzen. 1975. *Belief, attitude, intention, and behavior: An introduction to theory and research.* Reading, MA: Addison-Wesley. Accessed August 4, 2018. http://people.umass.edu/aizen/f&a1975.html.

Foundation for Critical Thinking. 2017. "Defining critical thinking." Accessed August 4, 2018. https://www.criticalthinking.org/pages/defining-critical-thinking/766.

Freidson, E. 2001. *Professionalism, the third logic: On the practice of knowledge.* Chicago: University of Chicago Press.

IEA (International Engineering Alliance). 2013. "Graduate attributes and professional competencies." Accessed August 4, 2018. http://www.ieagreements.org/about-us/key-documents/.

Liu, A. 2014. "What are the humanities?" *4Humanities: Advocating for the Humanities* (blog). Accessed August 4, 2018. http://4humanities.org/2014/12/what-are-the-humanities/.

McCuen, R. H., E. Z. Ezzel, and M. K. Wong. 2011. "Attitudes." In *Fundamentals of civil engineering: An introduction to the ASCE Body of Knowledge*, 147–166. Boca Raton, FL: CRC Press.

NAE (National Academy of Engineering), National Academies of Sciences. 2004a. *Educating the engineer of 2020: Adapting engineering education to the new century.* Washington, DC: National Academies Press. Accessed August 4, 2018. https://www.nap.edu/catalog/11338/educating-the-engineer-of-2020-adapting-engineering-education-to-the.

NAE, National Academies of Sciences. 2004b. *The engineer of 2020: Visions of engineering in the new century.* Washington, DC: National Academies Press. Accessed August 4, 2018. https://www.nap.edu/catalog/10999/the-engineer-of-2020-visions-of-engineering-in-the-new.

Ottino, J. M., and G. S. Morson. 2016. "Building a bridge between engineering and the humanities." *Chron. High. Educ.*, February 14, 2016.

Oxford English Dictionary, 2nd Ed. 1989. 20 vols. Oxford: Oxford Univ. Press. Continually updated at http://www.oed.com/.

Parcover, J. A. and R. H. McCuen. 1995. "Discovery approach to teaching engineering design." *J. Prof. Issues Eng. Educ. Pract.* 121(4): 236–241. https://doi.org/10.1061/(ASCE)1052-3928(1995)121:4(236).

Parker, G. M. 1994. *Cross functional teams: Working with allies, enemies and other strangers.* San Francisco: Jossey-Boss.

Petroski, H. 2010. *The essential engineer: Why science alone will not solve our global problems.* New York: Knopf.

@seismicisolation

Phillips, K. W. 2014. "How diversity works." *Sci. Am.* 311(4): 42–47. doi:10.1038/scientificamerican1014-42.
PMI (Project Management Institute). 2016. *The high cost of low performance: How will you improve business results.* Newtown Square, PA: PMI.
Ressler, S. J. 2011. "Sociology of professions: Applications to the civil engineering 'Raise the Bar' initiative." *J. Prof. Issues Eng. Educ. Pract.* 137(3): 152–153. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000043.
Russell, J. S. and J. T. P. Yao. 1996. "Consensus! Students need more management education: Education conference delivers initiatives." *J. Manage. Eng.* 12(6): 17–26.
Stiff, J. B., and P. A. Mongeau. 2016. *Persuasive communication.* 3rd ed. New York: Guilford.
Trefethen, L. N. 2006. "Numerical analysis." *Princeton companion of mathematics.* T. Gowers and J. Barrow-Green, eds. Princeton, NJ: Princeton Univ. Press.
Walden, D. D., G. J. Roedler, K. J. Forsberg, R. D. Hamelin, and T. M. Shortel, eds. 2015. *INCOSE Systems engineering handbook: A guide for system life cycle processes and activities,* 4th Ed. New York: Wiley.
Weingardt, R. G. 1999. "Closure to 'Leadership: The world is run by those who show up' by Richard G. Weingardt." *J. Manage. Eng.* 15 (1): 92. doi.org/10.1061/(ASCE)0742-597X(1999).
Wooden, J. and S. Jamison. 2005. *Wooden on leadership.* New York: McGraw-Hill.

@seismicisolation
@seismicisolation

@seismicisolation
@seismicisolation

CHAPTER 3

Summary and Conclusions

> *At its heart, engineering is about using science to find creative, practical solutions. It is a noble profession.*
>
> —Queen Elizabeth II

ASCE defines the Civil Engineering Body of Knowledge (CEBOK) as the set of knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level. 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 the CEBOK.

The *Civil Engineering Body of Knowledge* 3 Task Committee (CEBOK3TC) formed in October 2016 with the charge of critically reviewing published literature regarding the future of engineering, other disciplines, and civil engineering practice; proactively soliciting constituent input; evaluating the second edition of the *Civil Engineering Body of Knowledge* (CEBOK2); determining if a third edition of the *Civil Engineering Body of Knowledge* (CEBOK3) was warranted, and, if warranted, development of the CEBOK3 report. Through its 2-year duration, the task committee used many sources, including those from the charge, to develop this third edition of the CEBOK that presents a future-focused summary of the knowledge, skills, and attitudes necessary to enter the practice of civil engineering at the professional level. The 21 CEBOK3 outcomes apply to every civil engineer entering the profession.

Those familiar with the CEBOK2 will note that several outcomes from that edition were not included in the third edition. These outcomes—Contemporary Issues and Historical Perspectives, Public Policy, Business and Public Administration, and Globalization—are vitally important to the *profession* of civil engineering. However, through a comprehensive review of the literature and constituent input, the committee determined that these four outcomes are not essential to the development of *each and every* civil engineer. Certain aspects of these outcomes, however, are critical to the success of the individual civil engineer and are included within several other outcomes of the third edition. For example, elements from Business and Public Administration and Public Policy heavily influenced the development of the new Engineering Economics outcome in the CEBOK3.

@seismicisolation
@seismicisolation

The CEBOK3TC relied heavily on two internationally recognized engineering competency models, the "Engineering Competency Model" (AAES and the US Dept. of Labor 2016) and the "Graduate Attributes and Professional Competencies" profiles (IEA 2013), when crafting the outcomes described in the CEBOK3. The many academic, personal, and professional competencies described in these two documents are congruent or complementary and formed a flexible framework for the task committee to establish the final 21 outcomes appearing in the CEBOK3. For example, when the CEBOK3TC decided to remove or replace an outcome that appeared in the CEBOK2, the decision was always based on the constituent survey responses and in consultation of the competencies and attributes described in one or both of the aforementioned models. As a result, the 21 outcomes appearing in the CEBOK3 are better aligned with these two well-recognized competency models that were published after the CEBOK2.

The CEBOK3TC also sought to highlight the future-focused nature of the CEBOK, leaving room for technological and societal change to be reflected in the outcomes. Further, the CEBOK should not be equated to the minimum standards for civil engineering programs assessed by the Engineering Accreditation Commission of ABET (ABET 2018). The CEBOK has a broad readership, including those who develop curricula for civil engineering programs, teach civil engineering students, and mentor early career civil engineers. The CEBOK3 is intended to provide guidance in these efforts. The CEBOK should influence the development of future versions of the ABET civil engineering program criteria. However, the task committee recognizes the importance of allowing flexibility within the program criteria for programs to lead their students toward fulfillment of the CEBOK in their own way. The task committee also envisions consulting companies and other employers using the CEBOK when considering mentoring and early career development programs for their new civil engineers.

The CEBOK is intended to apply to all civil engineers, regardless of subdiscipline or whether they intend to seek licensure. The audience for the CEBOK is quite broad and includes educators, students, early career civil engineers, professionals who mentor early career civil engineers, owners of companies, and so forth. To help these groups better understand the important aspects of the CEBOK most relevant to them, the task committee recommended that a series of focused companion pieces to the CEBOK be developed to communicate with students, faculty, and practitioners.

References

AAES (American Association of Engineering Societies) and the US Dept. of Labor. 2016. "Engineering competency model." Accessed August 4, 2018. http://www.aaes.org/model.

ABET. 2018. "Criteria for accrediting engineering programs, 2018-2019." Baltimore: ABET. Accessed August 4, 2018. http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/.

IEA (International Engineering Alliance). 2013. "Graduate attributes and professional competencies." Accessed August 4, 2018. http://www.ieagreements.org/about-us/key-documents/.

@seismicisolation

APPENDIX A

Abbreviations

ASCE	American Society of Civil Engineers
B	Portion of the CEBOK2 fulfilled through the baccalaureate degree
BOK	Body of knowledge
CEBOK	Civil engineering body of knowledge
CEBOK1	*Civil Engineering Body of Knowledge*, First Edition
CEBOK2	*Civil Engineering Body of Knowledge*, Second Edition
CEBOK3	*Civil Engineering Body of Knowledge*, Third Edition
CEBOK3TC	*Civil Engineering Body of Knowledge*, Third Edition, Task Committee
E	Portion of the CEBOK2 fulfilled through pre-licensure experience
M/30	Portion of the CEBOK2 fulfilled through the master's degree or equivalent (approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses in a specialize technical area and/or professional practice area related to civil engineering)
ME	Mentored experience early in one's career under the mentorship of a civil engineer practicing at the professional level, which progresses in both complexity and level of responsibility
NSPE	National Society of Professional Engineers
P.E.	Professional Engineer
PG	Post graduate 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
SD	Self-development through formal or informal activities and personal observation and reflection
UG	Undergraduate education leading to a bachelor's degree in civil engineering or closely related engineering discipline, generally from a four-year ABET/EAC-accredited program

@seismicisolation
@seismicisolation

@seismicisolation
@seismicisolation

APPENDIX B

Glossary and Definitions

Concepts and Principles

Advanced concepts and principles: Relationship and combination of ideas and theories with rules and methods that are ahead or further along in progress, complexity, knowledge, skill, and so forth, and related to specific situations or classes of problems taken as being at a higher level than standardized, established, or traditional (only used in the Depth in a Civil Engineering Area outcome).

Concepts and principles: Relationship and combination of general ideas and theories with rules and methods related to specific situations or classes of problems.

Design

Design alternative: One possible solution to an engineering design project.

Engineering design: The iterative, creative, decision-making process of devising a system, component, or process to meet desired needs and specifications within constraints, which involves identifying opportunities, developing requirements, performing analysis and synthesis, generating multiple solutions, evaluating solutions against requirements, considering risks, and making trade-offs, for the purpose of obtaining a high-quality solution under the given circumstances (ABET 2018).

Engineering design process: See definition for "engineering design."

Problems and Projects

Civil engineering problems: Problems (not necessarily complex) related to or involving civil engineering.

Complex civil engineering problems: Complex problems (see definition of "complex problems") related to or involving civil engineering.

Complex civil engineering projects: Complex projects (see definition of "complex projects") related to or involving civil engineering.

Complex problems: Problems requiring in-depth engineering knowledge (IEA 2013) and having, for example, wide-ranging or conflicting technical issues, no obvious solution, diverse

@seismicisolation

groups of stakeholders, multiple disciplines, or significant consequences in a range of contexts (ABET 2018). Engineers solve complex problems, technologists solve broadly defined problems, and technicians solve well-defined problems (IEA 2013).

Complex projects: Projects having, for example, wide-ranging or conflicting technical issues, no obvious solution, diverse groups of stakeholders, multiple disciplines, or significant consequences in a range of contexts.

Problems: Lessons or inquiries starting from a set of given conditions or constraints to investigate or demonstrate a theory, application, or process.

Projects: In contrast to problems, projects are individual or collaborative efforts larger in scope, often involving research or design, to achieve specific objectives.

Sustainability

Sustainable performance: ASCE defines sustainability as a set of environmental, economic, and social conditions—the triple bottom line—in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely, without degrading the quantity, quality, or the availability of natural, economic, and social resources (ASCE 2017). Sustainable performance of complex civil engineering projects would denote compliance with the triple bottom line.

Systems perspective: Consideration of a system as a whole in the context of its environment; a non-reductionist approach to describing the properties of a system itself.

Typical Pathway

Undergraduate education: Undergraduate education leading to a bachelor's degree in civil engineering or closely related engineering discipline, generally from a four-year program accredited by the Engineering Accreditation Commission of ABET.

Postgraduate education: 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: 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: Individual self-development through formal or informal activities and personal observation and reflection.

References

ABET. 2018. "Criteria for accrediting engineering programs, 2018-2019." Baltimore: ABET. Accessed August 4, 2018. http://www.abet.org/accreditation/ accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/.

ASCE. 2017. "Sustainability." Reston, VA: ASCE. Accessed August 4, 2018. https://www.asce.org/sustainability/.

IEA (International Engineering Alliance). 2013. "Graduate attributes and professional competencies." Accessed August 4, 2018. http://www.ieagreements.org/about-us/key-documents/.

@seismicisolation

APPENDIX C

Committee Charge, Process, and Membership

Charge

The charge to the *Civil Engineering Body of Knowledge* 3 Task Committee (CEBOK3TC) was to

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

Process

The CEBOK3TC was formed in the fall of 2016 from applicants to a broad call for members distributed to the ASCE membership during the summer of 2016. More than 62 applications were received, and the leadership of the committee selected 25 to invite to a workshop in August 2016 that explored the process behind developing the first and second editions of the *Civil Engineering Body of Knowledge*. Invitations for membership in the task committee were extended to 15 applicants in September 2016. The remaining applicants were invited to be corresponding members to the committee and the majority accepted that invitation.

The task committee met primarily by teleconference with weekly calls through most of 2017 and early 2018, with less frequent calls beginning in the summer of 2018. A total of 58 teleconferences were held beginning in September 2016 and concluding in October 2018. The CEBOK3TC also had four face-to-face meetings in October 2016, March 2017, November 2017, and May 2018.

A smaller editing task group also met three times in September 2017, January 2018, and August 2018, to edit the full group's work in preparation for key milestones.

@seismicisolation
@seismicisolation

Membership

The foundation of the CEBOK3TC work rests on efforts of its members and many others. The task committee is extremely grateful and appreciative of the efforts of the individuals, committees, and other entities, within and outside ASCE, including the CEBOK2 and CEBOK1 committees, all of whom contributed to this work in some way. The chair of the CEBOK3TC and editor of the CEBOK3 report extend a truly special thank you to all the members, corresponding members, and other contributors, including those who provided input through the three constituent surveys, all of whom were an integral part of the overall effort. Table C-1 lists the full members of the CEBOK3TC and Table C-2 lists the corresponding members. Affiliations are provided wherever possible.

Table C-1. CEBOK3TC Full Members.

Name	Affiliation	Location
Kenneth J. Fridley, Ph.D., F.ASCE (Chair)	University of Alabama	Tuscaloosa, AL
Decker B. Hains, Ph.D., P.E., M.ASCE (Editor)	Western Michigan University	Kalamazoo, MI
Brock E. Barry, Ph.D., P.E., F.ASCE	United States Military Academy	West Point, NY
Angela R. Bielefeldt, Ph.D., P.E., M.ASCE	University of Colorado	Boulder, CO
Horst G. Brandes, Ph.D., P.E., F.ASCE	University of Hawaii	Honolulu, HI
Norbert J. Delatte, Jr., Ph.D., P.E., F.ASCE	Oklahoma State University	Stillwater, OK
Norman D. Dennis, Jr., Ph.D., P.E., D.GE, F.ASCE	University of Arkansas	Fayetteville, AR
Ryan K. Giles, Ph.D., A.M.ASCE	Stony Brook University	Stony Brook, NY
Beth L. Hartmann, Ph.D., P.E., M.ASCE	Iowa State University	Ames, IA
Muthusamy Krishnamurthy, Ph.D., P.E., F.ASCE	Hydro Modeling, Inc.	Orlando, FL
Audra N. Morse, Ph.D., P.E., F.ASCE	Michigan Technological University	Houghton, MI
David A. Pezza, Dr.Eng., P.E., D.GE, F.ASCE	US Army Corps of Engineers (Retired)	Norfolk, VA
Monte L. Phillips, Ph.D., P.E., Dist.M.ASCE	University of North Dakota (Retired)	Park Rapids, MN
Matthew W. Roberts, Ph.D., P.E., M.ASCE	Southern Utah University	Cedar City, UT
Kristen L. Sanford Bernhardt, Ph.D., P.E., M.ASCE	Lafayette College	Easton, PA
Camilo Torres, EIT, C.Eng, M.ASCE	Pontificia Universidad Javeriana	Bogota, Colombia
Leslie E. Nolen, CAE, Aff.M.ASCE	ASCE	Reston, VA
James J. O'Brien, Jr., P.E., M.ASCE	ASCE	Reston, VA

@seismicisolation

Table C-2. CEBOK3TC Corresponding Members.

Name	Affiliation	Location
Caesar Abi Shdid, P.E., M.ASCE	Lebanese American University	New York, NY
Arzhang Alimoradi, Ph.D., P.E., M.ASCE	____	Las Vegas, NV
Daryl R. Armentrout, Ph.D., P.E., F.ASCE	____	Knoxville, TN
Carmine C. Balascio, Ph.D., P.E., M.ASCE	University of Delaware	Newark, DE
Amitabha Bandyopadhyay, Ph.D., P.E., F.ASCE	State University of New York, Farmingdale	Holbrook, NY
Morton A. Barlaz, Ph.D., P.E., F.ASCE	North Carolina State University	Raleigh, NC
Robert W. Barnes, Ph.D., P.E., M.ASCE	Auburn University	Auburn, AL
Deborah Besser, Ph.D., P.E., M.ASCE	University of St. Thomas	St. Paul, MN
M Asghar Bhatti, Ph.D., P.E., F.ASCE	University of Iowa	Iowa City, IA
J. Kelly Brumbelow, P.E., M.ASCE	Texas A&M University	College Station, TX
Ching Chiaw Choo, P.E., M.ASCE	California State University, Fresno	Fresno, CA
Marvin E. Criswell, Ph.D., P.E., F.ASCE	Colorado State University (Retired)	Estes Park, CO
Christina J. Curras, Ph.D., A.M.ASCE	University of Wisconsin, Platteville	Platteville, WI
Richard W. Earp, P.E., M.ASCE	____	Winter Garden, FL
W. Samuel Easterling, Ph.D., P.E., F.ASCE	Virginia Tech	Blacksburg, VA
Mark O. Federle, Ph.D., P.E., F.ASCE	Marquette University	Milwaukee, WI
Shannon M. Fisher, P.E., M.ASCE	____	Bismarck, ND
Mostafa M. Gad Alla, M.ASCE	____	Cairo, Egypt
Perry S. Green, Ph.D., P.E., F.SEI, F.ASCE	____	Myrtle Beach, SC
Sara E. Guntrum, A.M.ASCE	____	Windermere, FL
Charles N. Haas, Ph.D., F.ASCE	Drexel University	Philadelphia, PA
Jerome F. Hajjar, Ph.D., P.E., F.SEI, F.ASCE	Northeastern University	Boston, MA
Kevin D. Hall, Ph.D., P.E., M.ASCE	University of Arkansas	Fayetteville, AR
M. Aktaruzzaman Hasan, C.Eng, P.E., M.ASCE	____	Dhaka, Bangladesh
Liv M. Haselbach, Ph.D., P.E., F.ASCE	Lamar University	Galveston, TX
Kirk Hatfield, Ph.D., A.M.ASCE	University of Florida	Gainesville, FL
Donald F. Hayes, Ph.D., P.E., F.ASCE	University of Nevada, Las Vegas	Las Vegas, NV

(continued)

@seismicisolation

Table C-2. CEBOK3TC Corresponding Members. (Continued)

Name	Affiliation	Location
John N. Ivan, P.E., M.ASCE	University of Connecticut	Storrs Mansfield, CT
David W. Jensen, Ph.D., P.E., S.E., F.ASCE	Brigham Young University	Mapleton, UT
M. A. Karim, P.E., M.ASCE	____	Marietta, GA
Damodara U. Kini, P.E., M.ASCE	____	Parker, CO
Sanjeev Kumar, Ph.D., P.E., F.ASCE	Southern Illinois University	Carbondale, IL
Robert D. Latta, P.E., P.L.S., M.ASCE	UNC Charlotte, Lee College of Engineering	Charlotte, NC
Christopher W. Letchford, Ph.D., CPEng, F.SEI, F.ASCE	Rensselaer Polytechnic Institute	Troy, NY
Shun C. Ling, Ph.D., P.E., M.ASCE	____	Vienna, VA
Daniel G. Linzell, Ph.D., P.E., F.ASCE	University of Nebraska, Lincoln	Lincoln, NE
George F. List, P.E., F.ASCE	North Carolina State University	Garner, NC
Kamyar C. Mahboub, Ph.D., P.E., F.ASCE	University of Kentucky	Lexington, KY
John M. Mason, Ph.D., P.E., M.ASCE	Penn State Harrisburg	University Park, PA
Paul F. Mlakar, Ph.D., P.E., F.SEI, Dist.M.ASCE	US Army Corps of Engineers (Emeritus)	Vicksburg, MS
Michael O'Connor, P.E., M.ASCE	New York University	Kensington, MD
Philip J. Parker, Ph.D., A.M.ASCE	University of Wisconsin, Platteville	Platteville, WI
David B. Peterson, P.E., F.ASCE	RK&K (Rummel Klepper & Kahl, LLP)	Raleigh, NC
Lindsey Philpott, P.E., M.ASCE	____	Long Beach, CA
Daniel E. Pradel, Ph.D., P.E., D.GE, F.ASCE	The Ohio State University	Columbus, OH
Martin A. Querin, P.E., M.ASCE	____	Kingsburg, CA
Dennis A. Randolph, P.E., M.ASCE	____	Belton, MO
Joseph C. Reichenberger, P.E., F.ASCE	Loyola Marymount University	Los Angeles, CA
Karl Rockne, P.E., M.ASCE, BCEE	National Science Foundation	Alexandria, VA
Jerry R. Rogers, Ph.D., P.E., D.WRE, Dist.M.ASCE	University of Houston	Houston, TX
James E. Rowings, Jr., Ph.D., P.E., F.ASCE	Kiewit Corporation	Omaha, NE
Camilla M. Saviz, Ph.D., P.E., ENV SP, M.ASCE	University of the Pacific	Stockton, CA
John J. Schemmel, P.E., M.ASCE	Texas State University	San Marcos, TX
William P. Schonberg, Ph.D., P.E., F.ASCE	Missouri University of Science and Technology	Rolla, MO

@seismicisolation

Name	Affiliation	Location
J. Phillip Smith, P.E., F.ASCE	Chevron	Houston, TX
Chung R. Song, Ph.D., P.E., M.ASCE	University of Nebraska, Lincoln	Lincoln, NE
Steve K. Starrett, Ph.D., P.E., D.WRE, F.EWRI, F.ASCE	LeTourneau University	Longview, TX
Beena Sukumaran, Ph.D., M.ASCE	Rowan University	Glassboro, NJ
Kevin G. Sutterer, Ph.D., P.E., M.ASCE	Rose-Hulman Institute of Technology	Terre Haute, IN
Brian J. Swenty, Ph.D., P.E., M.ASCE	University of Evansville	Evansville, IN
James S. Talian, P.E., M.ASCE	City of Lynchburg	Lynchburg, VA
James M. Thompson, Ph.D., P.E., M.ASCE	Carnegie Mellon University	Pittsburgh, PA
Girum Urgessa, P.E., M.ASCE	George Mason University	Chantilly, VA
Mohan M. Venigalla, P.E., M.ASCE	George Mason University	Fairfax, VA
Daren C. Williams, P.E., M.ASCE	Virginia Department of Transportation	Suffolk, VA
James D. Worrell, P.E., M.ASCE	____	Raleigh, NC
Richard N. Wright, Ph.D., NAE, Dist.M.ASCE	____	Montgomery Village, MD
Sherif A. Yehia, P.E., M.ASCE	____	Portage, MI

Note: Not all credentials or affiliations are listed by request of the individual listed.

@seismicisolation

@seismicisolation
@seismicisolation

APPENDIX D

Constituent Engagement Through Surveys

The CEBOK3TC engaged constituents through a series of three separate structured surveys, which are described including summary results in this appendix.

CEBOK2 Survey, Winter 2017

A survey was developed to solicit input from constituents on the existing CEBOK2 and potential additions and changes to the CEBOK2. The first part of the survey asked respondents to consider each of the 24 outcomes in the CEBOK2. They were provided with a link to the rubric and the full CEBOK2 in the survey. Survey takers then rated the following:

1. Importance of each outcome using a 5-point scale:

   1 = not important

   2 = minor importance

   3 = neutral

   4 = moderately important

   5 = very important.

2. Description of each using a 5-point scale:

   1 = poorly described

   2 = not well described

   3 = neutral

   4 = well described

   5 = very well described.

Any ratings of 2 or below resulted in the survey participant being prompted to provide an explanation in an open text format.

@seismicisolation
@seismicisolation

In the second part of the survey, a list of 10 potential outcomes that were under consideration for future incorporation in the CEBOK3 was provided. These outcomes included the following:

- Critical and analytical thinking,
- Interpersonal skills,
- Engineering economics,
- Safety,
- Creativity and innovation,
- Information technology,
- Legal aspects,
- Civic learning/engagement,
- Systems engineering, and
- Research skills.

Respondents were asked to provide their opinion on the importance of each of these outcomes using a 5-point rating scale:

5 = very important

4 = moderately important

3 = no opinion

2 = minor importance

1 = not important.

When asked to consider these possible outcomes, descriptions were not provided, leaving it open for interpretation on what was intended. For example, Research Skills could mean many different things to different people. Therefore, respondents were asked to provide a brief, open text format definition for any of the 10 potential outcomes they had rated at 4 or higher. Another open response question also invited survey takers to "indicate any additional areas not on this list" that they thought should be considered as potential outcomes and to explain why.

In the third part of the survey, respondents were asked, "Should ASCE consider addressing post-licensure professional development and career advancement, for example, certification, in the CEBOK3?" Three response options were provided: yes, no, not sure/need more information. An open-ended question asked those who had indicated "yes" to the post-licensure question to discuss the question "How should post-licensure professional development and career advancement be addressed, and to what extent?" The survey concluded with demographic items. The survey was created and administered in SurveyMonkey.

Invitations were sent to key constituencies within the ASCE membership, including civil engineering department heads, through a targeted distribution to the ASCE Department Heads Council; ASCE's program evaluator volunteers (PEVs) through ABET; members of ASCE's Committee on Education and its constituent committees; ASCE section, branch, and region leaders; and members of the ASCE specialty academies. Notices about the survey were also placed in several ASCE publications. Participants were invited to take the CEBOK2 constituent

@seismicisolation

survey from January 23 through March 20, 2017. There were 303 survey responses. The demographics are summarized in Table D-1, and the quantitative survey results are summarized in Table D-2. The median amount of time individuals were logged in to the survey was 8 minutes.

The importance ratings among the 24 CEBOK2 outcomes ranged from an average of 4.75 for Problem Recognition and Solving to a low of 3.21 for Globalization, with a median of 4.15. The outcomes lower than 4.0 also included Business and Public Administration, Social Sciences, Humanities, Public Policy, and Contemporary Issues and Historical Perspectives. The CEBOK3TC removed four of the six CEBOK2 outcomes with average importance ratings below 4.0 as standalone outcomes in the CEBOK3 but kept the Humanities and Social Sciences outcomes due to their foundational aspects that support other outcomes.

Among the 10 outcomes proposed as potential additions, average importance ratings ranged from a high of 4.5 for Critical and Analytical Thinking to a low of 3.2 for Research Skills. Other outcomes with an average rating of 4.0 and higher also included Engineering Economics at 4.0, Safety at 4.0, and Interpersonal Skills at 4.1. There were 170 write-in responses to the invitation to define the additional outcomes that were rated 4 or higher. Most of the comments were not definitions, but rather a discussion of why these additional outcomes were important. Fifty-seven write-in comments were also provided in response to the prompt to indicate additional areas that should be included that were not among the list of 10. Many of the comments related to other aspects, such as overall length, interrelatedness of the outcomes, among others.

In response to the question of whether the CEBOK3 should address post-licensure professional development in the CEBOK3, there were 100 “yes,” 89 “no,” and 106 “not sure” responses. Ninety-six write-in comments were provided.

CEBOK3 Pre-draft Survey, Fall 2017

A second survey was developed to solicit feedback on a pre-draft version of 21 outcomes for the CEBOK3 (Fridley et al. 2018). In the first section, a pre-draft rubric for the cognitive domain was provided, with statements at each of the Bloom’s Taxonomy for the Cognitive Domain six levels of achievement. Individuals were asked to rate the minimum level of achievement appropriate for all civil engineers as they enter into the practice of civil engineering at the professional level. Respondents were also given the option to rate the outcome as “not applicable” and provide an explanation for that rating. Additional open-ended items allowed respondents to suggest improvements to any of the outcomes and recommendations for anything that may be missing.

The second section of the survey provided a pre-draft rubric statements for seven outcomes at each of the Bloom’s Taxonomy for the Affective Domain five levels of achievement. Respondents were asked to rate the minimum level of achievement appropriate for all civil engineers as they enter into the practice of civil engineering at the professional level. They were asked to explain any ratings of “not applicable,” to make suggestions for improvement of the affective domain outcome statements, and to discuss any elements they thought were missing from the affective domain. The survey was created and administered in SurveyMonkey.

Similar to the early 2017 survey, invitations were sent to key constituencies, as well as those who had responded to the earlier survey. Due to the brief response period of October 23 through November 8, 2017, notices were not placed in ASCE publications. There were 141 responses. Demographics are summarized in Table D-1, and the quantitative survey results are

@seismicisolation

summarized in Table D-3. The median amount of time individuals were logged in to the survey was 12 minutes. The CEBOT3TC used the survey feedback to determine which outcome statements should be revised and to develop the appropriate level of achievement.

CEBOK3 Survey, Spring 2018

A third survey was conducted on the first draft of the proposed CEBOK3 outcomes, and this survey was structured to allow individuals to provide feedback solely on the outcomes of most interest to each survey taker. In the first section of the survey, individuals were provided with a list of the names of the 21 proposed CEBOK3 outcomes and asked to indicate those they wished to review. The survey then provided the rubric for the outcome that was selected and a link to the detailed explanation.

The survey taker was asked to rate the following:

1. Importance of the outcome using a 5-point scale

   1 = not important

   2 = minor importance

   3 = neutral

   4 = moderately important

   5 = very important

2. Quality of outcome name using a 5-point scale

   1 = poorly described

   2 = not well described

   3 = neutral

   4 = well described

   5 = very well described

3. Rubric description using a 5-point scale

   1 = poorly described

   2 = not well described

   3 = neutral

   4 = well described

   5 = very well described.

4. Effectiveness of the explanation using a 5-point scale

   1 = not effective

   2 = somewhat effective

   3 = effective

   4 = moderately effective

   5 = very effective.

@seismicisolation

The survey then provided an open-ended response box and an invitation to explain the reason for any ratings of 3 or lower or any other comments about the outcome. For the seven outcomes that also had affective domain outcomes, the affective domain rubric was provided, and respondents were asked to rate the importance and quality of the affective description. After completing survey questions about each of the outcomes initially checked for interest, respondents were asked if they wanted to rate any additional outcomes. The same style of question was provided for each outcome requested. An open-ended question invited individuals to "provide any additional feedback on the CEBOK3 draft outcomes." The survey concluded with demographic items and was created and administered in a Qualtrics platform.

As with previous surveys, invitations were sent to key constituencies, and notices were placed in ASCE publications. Invitations were also sent to the members of the ASCE Board of Direction; all ASCE Society Committees, including the Committee on Advancing the Profession, the Committee on Education, the Member Communities Committee, the Public Policy Committee, and the Technical Activities Committee; and ASCE Institute leaders. The survey was open for responses from March 5 through May 2, 2018, and these responses were considered by the CEBOK3TC during their in-person meeting on May 19–20, 2018.

Qualtrics registered 288 responses. In other words, at least 288 individuals started the survey; unfortunately, many of those included no useful information. There were 142 fully completed responses and 35 additional responses in which one or more outcomes were rated. Those who completed the survey rated a median of 7 of the 21 outcomes. Among those who completed the survey, the median amount of time spent on the survey was 15 minutes. The majority of the started surveys answered at least the first question to indicate which outcomes they planned to rate and 48% to 68% of those outcomes were actually rated. Each of the 21 outcomes had a median of 58 ratings. The most commonly rated outcomes were Critical Thinking and Problem Solving, Ethical Responsibilities, and Professional Responsibilities, with response numbers ranging from 77 to 82. The outcome with the fewest ratings was Social Sciences, with only 27 responses. The quantitative survey results are summarized in Table D-4.

Only three of the 21 outcomes had average importance ratings in the cognitive domain below 4: Humanities, Social Sciences, and Project Management. The remaining 18 outcomes had average importance ratings from 4.2 to 4.9. Three outcomes with average descriptions of the quality of the name and rubric description below 4 were Social Sciences, Humanities, and Professional Attitudes. Consequently, the descriptions of these outcomes were revised significantly. The other 18 outcomes had description quality average ratings ranging from 4.0 to 4.5. Six outcomes had explanation effectiveness ratings that averaged below 4.0, and as a result, these were carefully reviewed and revised by the CEBOK3TC. Among the seven outcomes with affective domain rubrics, the importance of these outcomes in the affective domain had average ratings from 4.1 to 4.7. The rubric quality for these outcomes was rated at 4 or higher for all except the Professional Attitudes outcome (average of 3.8) and the Sustainability outcome (average of 3.9). Across the 21 outcomes, the median number of write-in comments was 17, ranging from a low of 8 for the Experimental Methods and Data Analysis outcome to a high of 23 for the Project Management outcome.

A summary of the demographic information provided by the respondents is provided in Table D-1. None of the partially completed responses included responses to the demographic items, and others skipped one or more of the demographic items.

@seismicisolation

Table D-1. Summary of Survey Respondent Demographics for Surveys.

		Number of Responses		
Question	**Categories**	**CEBOK2 Survey**	**CEBOK3 Pre-Draft Levels of Achievement Survey**	**CEBOK3 First Draft Survey**
Total	Total number of responses, *n*	303	141	149[a]
Level of Education	Bachelor's	67	48	33
	Master's	103	42	50
	Doctorate	122	51	54
Years of Civil Engineering Experience	1–5	12	13	9
	6–10	21	18	8
	11–15	16	16	8
	16–20	35	13	13
	21–25	32	12	18
	>25	176	69	25
Licensed P.E.	Yes	245	117	123
	No	47	24	16
Professional Grade	1–3. Engineer-in-training, engineering intern, assistant engineer, junior engineer, staff engineer, engineering instructor; GS 5-9	9	12	16
	4. Civil engineer, associate engineer, project engineer, resident engineer, assistant professor; GS-11	12	16	9
	5. Senior engineer, project manager, associate professor; GS-12	58	27	17
	6. Principal engineer, district engineer, engineering manager, professor; GS-13	58	32	32
	7. Director, program manager, city engineer, county engineer, division engineer, department head, vice president; GS-14	90	28	32
	8. Bureau engineer, director of public works, dean, president, owner, CEO; GS-15	30	17	27
	9. Other nonengineer, nontechnical, nonscience, students	2	1	2
	10. Retired	33	8	12
Current Employer	Academic/university	99	37	34
	Private-practice engineering consulting firm	78	32	54
	Government agency	39	50	20
	Sole proprietor	10	3	10
	Multidiscipline corporation	18	4	1
	Contractor/builder	4	1	3
	Military	4	2	0
	Association/nonprofit	2	2	2
	Other (please specify)	15	6	4

[a]Feedback on one or more outcomes but fewer answered demographic questions; 135–146.

@seismicisolation

Table D-2. Summary of CEBOK2 Survey Results.

Outcome	Average Importance	Average Outcome Description
Mathematics	4.13	3.64
Natural Sciences	4.17	3.63
Humanities	3.68	2.87
Social Sciences	3.68	2.96
Materials Science	4.31	3.70
Mechanics	4.56	3.86
Experiments	3.99	3.71
Problem Recognition and Solving	4.75	3.75
Design	4.73	3.88
Sustainability	4.15	3.26
Contemporary Issues and Historical Perspectives	3.75	3.41
Risk and Uncertainty	4.49	3.55
Project Management	4.18	3.02
Breadth in Civil Engineering Areas	4.14	3.69
Technical Specialization	4.03	3.31
Communication	4.73	3.93
Public Policy	3.75	3.30
Business and Public Administration	3.51	3.23
Globalization	3.21	3.01
Leadership	4.11	3.63
Teamwork	4.60	3.93
Attitudes	4.00	3.31
Lifelong Learning	4.42	3.43
Professional and Ethical Responsibility	4.68	3.66
Possible Outcomes		
Critical and Analytical Thinking	4.53	N/A
Interpersonal Skills	4.12	
Safety	4.02	
Engineering Economics	3.98	
Creativity and Innovation	3.88	
Information Technology	3.60	
Legal Aspects	3.54	
Systems Engineering	3.33	
Civil Learning/Engagement	3.28	
Research Skills	3.18	

@seismicisolation

@seismicisolation

Table D-3. Summary of CEBOK3 Pre-draft Level of Achievement Survey Results.

Outcome	Average Cognitive Level of Achievement (1 to 6 Scale)	Cognitive Domain N/A Responses (%)	Average Affective Level of Achievement (1 to 5 Scale)	Affective Domain N/A Responses (%)
Mathematics	4.25	0	—	—
Natural Sciences	3.85	0.7	—	—
Social Sciences	3.19	1.4	—	—
Humanities	3.12	2.8	—	—
Materials Science	3.96	0.7	—	—
Engineering Mechanics	4.18	0	—	—
Experimental Methods and Data Analysis	3.96	0	—	—
Critical Thinking and Problem Solving	4.78	0.7	—	—
Project Management	3.88	1.4	—	—
Engineering Economics	3.85	0.7	—	—
Risk and Uncertainty	3.78	0.7	—	—
Breadth in Civil Engineering Areas	3.80	2.1	—	—
Design	4.36	1.4	—	—
Depth in a Civil Engineering Area	4.02	0	—	—
Sustainability	3.53	1.4	3.07	4.3
Communication	4.11	0	3.49	1.5
Teamwork and Leadership	4.00	0.7	3.43	2.2
Professional Attitudes	3.88	8.5	3.49	5.8
Lifelong Learning	3.93	0	3.37	2.2
Professional Responsibilities	4.29	1.4	3.82	1.4
Ethical Responsibilities	4.54	0.7	4.07	2.2

@seismicisolation

Table D-4. Summary of CEBOK3 First Draft Survey Results.

Outcome	Average Cognitive Importance (1 to 5 Scale)	Average Cognitive Rubric Description (1 to 5 Scale)	Average Affective Importance (1 to 5 Scale)	Average Affective Rubric Description (1 to 5 Scale)	Average Effectiveness of the Explanation (1 to 5 Scale)
Mathematics	4.54	4.23	—	—	4.11
Natural Sciences	4.47	4.02	—	—	4.00
Social Sciences	3.78	3.85	—	—	3.76
Humanities	3.70	3.73	—	—	3.63
Materials Science	4.59	4.05	—	—	4.23
Engineering Mechanics	4.89	4.26	—	—	4.30
Experimental Methods and Data Analysis	4.40	4.25	—	—	4.06
Critical Thinking and Problem Solving	4.80	4.46	—	—	4.30
Project Management	3.80	3.98	—	—	3.94
Engineering Economics	4.25	4.00	—	—	3.96
Risk and Uncertainty	4.32	4.02	—	—	3.87
Breadth in Civil Engineering Areas	4.45	4.25	—	—	4.22
Design	4.45	4.31	—	—	4.22
Depth in a Civil Engineering Area	4.56	4.50	—	—	4.29
Sustainability	4.16	4.09	4.07	3.95	3.86
Communication	4.68	4.16	4.51	4.07	4.00
Teamwork and Leadership	4.53	4.22	4.50	4.29	4.29
Lifelong Learning	4.33	4.05	4.28	4.11	4.04
Professional Attitudes	4.38	3.81	4.43	3.78	3.78
Professional Responsibilities	4.47	4.12	4.51	4.00	4.10
Ethical Responsibilities	4.75	4.17	4.73	4.25	4.24

Reference

Fridley, K. J., D. B. Hains, B. E. Barry, K. L. Sanford Bernhardt, and L. Nolen. 2018. "The third edition of the Civil Engineering Body of Knowledge: An update and overview." *Proc., Ann. Conf. of the American Society for Engineering Education*. Paper No. 21527. Washington, DC: ASEE.

@seismicisolation

@seismicisolation
@seismicisolation

APPENDIX E

Application of Bloom's Taxonomy

Why a Taxonomy?

ASCE's original Body of Knowledge (BOK) released in 2004 defined three broad levels of competence: recognition, understanding, and ability (ASCE 2004). These were summarized as follows (ASCE 2005):

- Level 1 (recognition) represents a reasonable level of familiarity with a concept. At this level, the engineer is familiar with an idea, but lacks the knowledge to specify and procure solutions without additional expertise. For example, an engineer might *recognize* that a particular architectural plan poses significant construction difficulties without having the expertise to devise improved construction or design alternatives.
- Level 2 (understanding) implies a thorough mental grasp and comprehension of a concept or topic. Understanding typically requires more than abstract knowledge. For example, an engineer with an *understanding* of professional and ethical responsibility should be able to identify and to communicate ethical issues arising from a practical case study.
- Level 3 (ability) is a capability to perform with competence. An engineer with the *ability* to design a particular system can take responsibility for the system, identifying all the necessary aspects of the design, and match objectives with appropriate technological solutions. As an engineer develops, the engineer's abilities also develop so that more challenging and difficult problems can be solved.

The Levels of Achievement Subcommittee for the CEBOK2 concluded that these three levels created confusion when applied and that there were varied interpretations of the levels of competency. The Levels of Achievement Subcommittee recommended adopting a framework informed by educational research which comes in the form of a taxonomy, or classification scheme.

@seismicisolation

Educational Taxonomies

Cognitive Domain

Frameworks for assessing intellectual and emotional development have existed since at least the late 1800s, but a common framework and language that defined activities and concepts to effectively classify and assess intellectual and emotional development across the disparate groups in education did not exist (Bloom and Broder 1950). In the mid-twentieth century, a group of state educational examiners, led by Benjamin S. Bloom, committed themselves to create this common framework. They met annually as a working group through the late 1940s and early 1950s to create a common framework for the characterization and assessment of educational activities. Their goal was to create a common hierarchal set of terms and language that characterized educational objectives in a uniform and repeatable way.

The publication describing their early work presented the concept of three domains of educational activities. These domains included the cognitive domain, which deals with the recognition of knowledge and the progressive development of intellectual abilities; the affective domain, which describes changes in interests, attitudes, and values; and the psychomotor domain, which categorizes manipulative or motor skills (Bloom et al. 1956). Although the group found ample evidence in the literature to support development of a common framework in both the cognitive and affective domains, they found little research to support a common framework in the psychomotor domain.

Because previous research found the relationship between cognitive achievement and attitudes and values was poorly correlated (Adkins and Kuder 1940), the group chose to focus on the cognitive domain. Thus, the 1956 publication of this group provided a thorough description of the cognitive domain and established six major levels of successively higher intellectual development with each major level containing two to nine sublevels. In addition, various key words were suggested to describe activities that might be associated with attaining a particular level of intellectual development. The highlights of the taxonomy are briefly described in Table E-1 by presenting a short definition for each major level, a reduced set of keywords for each level, and two examples of activities that could be assessed. Note that Table E-1 represents an adaptation of Bloom's Taxonomy for the Cognitive Domain from the original (Bloom et al. 1956) and a subsequent revision by Anderson and Krathwohl (2001). Details of this adaptation are discussed in the "Implementing the Taxonomies" section later in this appendix.

The work in the cognitive domain by Bloom and his colleagues served as a seminal work in curriculum development for many years, with a number of researchers either developing refinements to the implementation of the taxonomy or deriding the taxonomy as having only limited benefit in assessing intellectual development. The work of Ormell (1974), Roberts (1976), and Seddon (1978) provide more detail on these efforts. Major revisions to Bloom's Taxonomy did not occur until 2001 when Anderson and Krathwohl proposed a revision to the hierarchy by reversing the order of *synthesis* and *evaluation*, adding a new dimension to the taxonomy that described cognitive processes associated with each level of the hierarchy, and adding a category of metacognitive knowledge (Anderson and Krathwohl 2001).

@seismicisolation

Affective Domain

The failure of the examiners to create a viable framework to classify objectives in the affective domain in their first publication (Bloom et al. 1956), motivated many members of the original group to continue seeking evidence to support the development of a taxonomy in the affective domain. The examiners found a large body of evidence to suggest that teachers regarded achievement in the cognitive domain to be public in nature and had no hesitation to assign a grade on the basis of performance. On the other hand, teachers felt that it was not appropriate to evaluate students based on their interests, attitudes, or character development, feeling these were more private in nature and certainly more difficult to assess. Their work over the next 8 years in organizing and categorizing behaviors in the affective domain ultimately resulted in the description of a continuum of activities ranging from simply being aware of a concept or phenomenon to completely internalizing the concept or phenomenon and making it a part of one's outlook on life (Krathwohl et al. 1964).

The classification scheme developed by Krathwohl and his colleagues is briefly summarized in Table E-2 with a collection of affective activities that represent an internalization continuum, in which Level 1, *receiving*, is the lowest level of internalization, and Level 5, *characterization by a value complex* is the highest. Also illustrated in Table E-2 is a set of affective behaviors that are associated with the continuum of activities.

In general, one's set of values are not significantly adjusted until one is willing to respond to or accept a concept or phenomenon. *Receiving* is the most basic level of the continuum and is achieved when the engineer is simply made aware of material, ideas, or phenomena and is willing to tolerate them. *Responding* is when an engineer is willing to participate in active discussion and perhaps question these new ideas or concepts in an attempt to better understand them. *Valuing* is when the engineer commits to a concept or idea and practices it because a perceived benefit can be derived or possibly because it is the right thing to do. *Organization* occurs when the engineer assigns a value to an idea or concept and internalizes it as a consistent behavioral philosophy by developing a prioritization scheme that is based on resolving conflict between contrasting values. *Characterization* occurs when the engineer acts consistently in accordance with internalized values. The highest level of the value system then forms consistent behavior at this level under all circumstances.

Table E-3 offers 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. Just as in the cognitive domain, the affective domain has a list of action verbs that can be used in defining activities and actions for each level of the domain. Table E-4 presents a partial list of those verbs.

@seismicisolation
@seismicisolation

Table E-1. Defining the Levels of Bloom's Taxonomy for the Cognitive Domain.

Bloom's Level	Examples and Keywords
1. Remember: Recall or retrieve previously learned information.	Example: Recite safety rules. List the steps in the engineering design process. Keywords: 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*.	Example: Explain how to conduct an experiment. Translate an equation into a spreadsheet. Keywords: 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.	Example: Calculate stress in a in a beam. Construct a free body diagram. Keywords: 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.	Example: Select the appropriate technique(s) to interpret data. Identify the largest bending moment in structure. Keywords: 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.	Example: Design a structure to carry specified loads. Create construction specifications for a project. Keywords: Categorize, compile, create, design, devise, plan, revise, summarize.
6. Evaluate: Making judgments about the value of ideas, work products or processes.	Example: Critique a proposed design. Justify a novel design or construction technique. Keywords: Assess, conclude critique, judge, justify, validate.

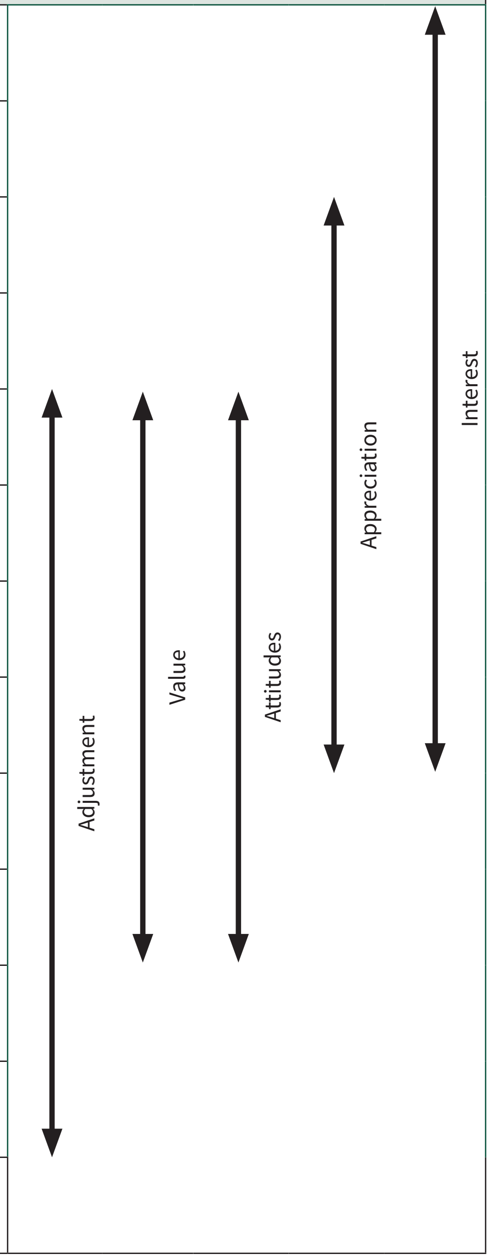
Source: Adapted from Anderson and Krathwohl (2001).

@seismicisolation

@seismicisolation

Table E-2. Levels of Internalization in the Affective Domain.

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



Source: Adapted from Krathwohl et al. (1964).

@seismicisolation

Table E-3. Example of Actions Demonstrating Affective Attainment.

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

Source: Adapted from Krathwohl et al. (1964).

Table E-4. Partial List of Action Verbs Appropriate for Each Level of the Affective Domain.

Receive	Respond	Value	Organize	Characterize
Acknowledge	Complete	Accept	Codify	Affect
Attend	Comply	Apply	Discriminate	Attest
Aware	Cooperate	Defend	Display	Confirm
Develop	Discuss	Devote	Order	Corroborate
Identify	Examine	Pursue	Organize	Internalize
Receive	Obey	Seek	Systematize	Substantiate
Recognize	Respond	Support	Weigh	Verify

Implementing the Taxonomies

Cognitive Domain

As one of its first tasks, 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. A subcommittee investigated several options and reported back to the entire committee. They considered Bloom's original taxonomy, Bloom's original taxonomy with subcategories, the revised Bloom's original taxonomy with a knowledge dimension, the revised Bloom's Taxonomy, the revised Bloom's Taxonomy without the knowledge dimension, and the original Bloom's Taxonomy with a knowledge dimension. Although other taxonomies were considered by the CEBOK3 subcommittee, they

@seismicisolation

were either too complex, not well-informed, or lacked the structural coherency of Bloom's original taxonomy for the cognitive domain.

Even though much has been written about the benefits of the revised taxonomy, the CEBOK3TC agreed with the CEBOK2 Task Committee and chose to use the original Bloom's Taxonomy hierarchy and not Anderson and Krathwohl's revisions to the hierarchy. Like the CEBOK2 Task Committee, the CEBOK3TC committee rejected Anderson's revision of the taxonomy's hierarchy, with the belief that in the field of engineering, one had to know how to create or design before one could evaluate the work of others or assess which design alternative might be best for a given situation. 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. The CEBOK3TC, like its predecessor, concluded that "Bloom's emphasis on the use of measurable, action-oriented verbs facilitated the creation of the outcome statements that lend themselves to more consistent and effective assessment" (ASCE 2008), which would be achieved as a result of formal education and experience.

To summarize, the result is the taxonomy hierarchy in Table E-1, which is an adaptation of Bloom's Taxonomy for the Cognitive Domain from the original in 1956 and subsequent revisions by Anderson and Krathwohl. Specifically, as noted previously, Levels 5 and 6 align with the original Bloom's Taxonomy hierarchy. The name for Level 2 also remained "Comprehend" from the original Bloom's Taxonomy. However, Level 1 was renamed "Remember" as used in the revised taxonomy. Finally, the levels are described by verbs as found in some forms of the revisions. The CEBOK3TC concluded that these modifications to the framework most effectively communicated the outcomes in the CEBOK.

Affective Domain

The CEBOK1 Task Committee concluded that knowledge and skills measurable in the cognitive domain, although necessary, were not sufficient to be a fully functioning professional civil engineer. A civil engineer's attitude, that is, the manner in which work is approached and valued, determines how effectively the engineer uses knowledge and skills. Accordingly, the original task committee concluded that attitude was an essential part of the CEBOK (ASCE 2007); however, they did not address how to assess attitude nor describe any level of attainment.

The CEBOK2 Task Committee discussed a methodology to address attitudes through the affective domain and even established an attainment matrix for certain outcomes, but they concluded that mechanisms to assess attainment in the affective domain would be ill-defined and it would be difficult to create a uniform assessment specification. Instead, the CEBOK2 Task Committee elected to create a separate, standalone outcome named Attitudes. Levels of attainment for the Attitudes outcome were described entirely within the cognitive domain (ASCE 2008). The 2006 ASCE Summit on The Future of Civil Engineering—2025 (ASCE 2007) portrayed the engineer of the future to be knowledgeable, skillful, and one who embraces attitudes conducive to professional practice. The first two attributes are conveniently measured in the cognitive domain, but attitudes most often are a reflection of one's value system and, as such, outcomes related to attitude should be measured in the affective domain. Duczyminski (2017) points out that, regardless of topic, affective outcomes are often closely related to deeper levels

@seismicisolation

of thinking. Students who are engaged in a subject and recognize its value can exhibit a change of attitude, and ultimately achieve a consistent behavior.

Several people in engineering education have recognized the need to supplement cognitive learning with the attainment of affective outcomes to promote deeper learning and have incorporated specific learning strategies to accomplish this (Ferris 2011, Lashari et al. 2012, Bielefeldt 2013). Bielefeldt (2013), for example, used project-based learning and project-based service learning to reach the synthesis level in the cognitive domain and the valuing or even the organize level in the affective domain. Again, this suggests that students learn deeper when affective outcomes are addressed. Lynch et al. (2009) suggest there is overlap between the affective and cognitive domains, especially at the lower levels of attainment in each domain. However, Lynch and colleagues point out that in addition to overlap, there is synergy among the two domains throughout all levels. The two domains can express concern about different aspects of a topic, and clearly, knowledge about something is different than internalization of a value related to it. Expressing that value in professional action is an attribute that must be developed through the educational and experiential processes that qualify an engineer for entry into the professional practice of civil engineering.

Based on this and other evidence in the literature, the CEBOK3TC was motivated to reconsider attainment of CEBOK outcomes in the affective domain. Initially the committee considered formulating an achievement matrix for all 21 outcomes of the CEBOK3. However, after much deliberation, the CEBOK3TC concluded that the achievement statements for the foundational, engineering fundamentals, and most of the technical outcomes sounded much like statements in the cognitive domain rather than the affective domain. As a result, rubrics for the affective domain are presented for the professional outcomes and for the Sustainability outcome, which the CEBOK3TC felt required the affective domain due to the nature of sustainability and its relationship to ethical behavior.

Finally, Tables E-2, E-3, and E-4 also include a slight modification and an adaptation of Bloom's *Taxonomy for the Affective Domain* in which the levels are described by verbs. The CEBOK3TC concluded that this modification to the framework made it consistent with the verb forms found in the cognitive domain and most effectively communicated the outcomes in the CEBOK.

References

Adkins, D. C. and G. F. Kuder. 1940. "The relation of primary mental abilities to activity preferences." *Psychometrica* 5(4): 251–262. doi.org/10.1007/BF02287971.

Alias, M., T. A. Lashari, Z. Akasah, Zainal A. Kesot, and J. Mohd. 2013. "Translating theory into practice: Integrating the affective and cognitive learning dimensions for effective instruction in engineering education." *Euro. J. Eng. Educ.* 39(2): 212–232. Accessed August 4, 2018. https://www.tandfonline.com/doi/abs/10.1080/03043797.2013.838543.

Anderson, L. W. and D. R. Krathwohl, eds. 2001. *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*, Abridged Ed. New York: Addison Wesley Longman.

ASCE. 2004. *Civil engineering Body of Knowledge for the 21st century: Preparing the civil engineer for the future,* 1st Ed. Reston, VA: ASCE.

@seismicisolation

ASCE. 2005. *Levels of achievement applicable to the Body of Knowledge required for entry into the practice of civil engineering at the professional level.* Reston, VA: ASCE.

ASCE. 2007. *Vision for civil engineering in 2025.* Reston, VA: ASCE.

ASCE. 2008. *Civil engineering Body of Knowledge for the 21st century: Preparing the civil engineer for the future*, 2nd Ed. Reston, VA: ASCE.

Bielefeldt, A. R. 2013. "Pedagogies to achieve sustainability learning outcomes in civil and environmental engineering students." *Sustainability* 5(10): 4479–4501. doi.org/10.3390/su5104479.

Bloom, B. S. and L. J. Broder. 1950. *Problem-solving processes for college students.* Chicago: Univ. of Chicago Press.

Bloom, B. S., M. D. Englehart, E. J. Furst, W. H. Hill, and D. Krathwohl. 1956. *Taxonomy of educational objectives; The classification of educational goals. Handbook I: Cognitive domain.* New York: David McKay Co.

Duczyminski, P. 2017. "Reaching students' affective domain of learning." Accessed January 10, 2018. https://www.fireengineering.com/articles/print/volume-170/issue-4/features/reaching-students-affective-domain-of-learning.html.

Ferris, L. J. 2011. "Bloom's affective domain in systems engineering education." *Proc., 5th Asia-Pacific Conf. on Systems Engineering.* Seoul, Korea, October 19–21. San Diego: APCOSE.

Krathwohl, D. R., B. S. Bloom, and B. B. Masia. 1964. *Taxonomy of educational objectives: The classification of educational goals, Handbook II: Affective Domain,* New York: David McKay Co.

Lashari, T. A., M. Alias, Z. A. Akasah, and M. J. Kesot. 2012. "An affective-cognitive teaching and learning framework in engineering education." *ASEAN J. Eng. Educ.* 1(1): 11–24. Accessed August 4, 2018. http://tree.utm.my/wp-content/uploads/2013/02/An-Affective-Cognitive-Teaching-and-Learning-Framework-in-Engineering-Education.pdf.

Lynch, D. R., J. S. Russell, J. C. Evans, and K. G. Sutterer. 2009. "Beyond the cognitive: The affective domain, values and the achievement of the vision." *J. Prof. Issues Eng. Educ. Pract.* 135 (1): 47–56. doi.org/10.1061/(ASCE)1052-3928(2009)135:1(47).

Ormell, C. P. 1974. "Bloom's taxonomy and the objectives of education." *Educ. Res.* 17(1): 3–18. doi.org/10.1080/0013188740170101.

Roberts, N. 1976. "Further verification of Bloom's taxonomy." *J. Exp. Educ.* 45(1): 16–19. https://doi-org.libproxy.library.wmich.edu/10.1080/00220973.1976.11011556

Sedden, G. M. 1978. "The properties of Bloom's taxonomy of educational objectives for the cognitive domain." *Rev. Educ. Res.* 48 (2): 303–323. https://www.jstor.org/stable/1170087.

@seismicisolation

@seismicisolation
@seismicisolation

APPENDIX F

The Civil Engineering Body of Knowledge

Outcome Rubrics

Appendix F presents a summary of the outcomes with the corresponding outcome statements at each level. Table F-1 contains the cognitive domain outcome rubrics and Table F-2 contains the affective domain outcome rubrics. The unshaded area within the bold borders in the tables defines the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level. These outcome statements are the essence of the CEBOK. 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. These statements are included for completeness and to fully define the outcome because some individuals may choose to go beyond the minimum expected for entry into the practice of civil engineering at the professional level.

The components of the typical pathway are annotated in parentheses after each outcome statement at each level. As the name implies, the typical pathway is what the CEBOK3TC considered to be the most common way for an individual to achieve the outcome. However, 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).
- 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.

@seismicisolation
@seismicisolation

Table F-1. The *Civil Engineering Body of Knowledge* (Third Edition) Cognitive Domain Outcome Rubrics.

Outcome	**Cognitive Domain Level of Achievement** *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.*					
	Level 1 **Remember** *The ability to remember previously learned material.*	**Level 2** **Comprehend** *The ability to grasp the meaning of learned material.*	**Level 3** **Apply** *The ability to use learned material in new and concrete situations.*	**Level 4** **Analyze** *The ability to break down learned material into its component parts so that its organizational structure may be understood.*	**Level 5** **Synthesize** *The ability to put learned material together to form a new whole.*	**Level 6** **Evaluate** *The ability to judge the significance and importance of learned material for a given purpose.*
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.

@seismicisolation
@seismicisolation

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.

(continued)

@seismicisolation

Table F-1. (Continued)

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 and 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 and 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.

@seismicisolation

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 and 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.

(continued)

@seismicisolation

Table F-1. (Continued)

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 nontechnical audiences. (UG)	**Explain** concepts and principles of effective and persuasive communication to technical and nontechnical audiences. (UG)	**Formulate** effective and persuasive communication to technical and nontechnical audiences. (UG)	**Analyze** effective and persuasive communication to technical and nontechnical audiences. (ME)	**Integrate** different forms of effective and persuasive communication to technical and nontechnical audiences. (ME)	**Assess** the effectiveness and persuasiveness of communication to technical and nontechnical audiences.

@seismicisolation

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 and 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.

(continued)

@seismicisolation
@seismicisolation

Table F-1. (Continued)

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.

@seismicisolation

Table F-2. Definitions of Verbs Used in the Cognitive Domain Outcome Rubrics.

Cognitive Domain Level of Achievement					
Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize	Level 6 Evaluate
Define: discover and set forth the meaning of. **Identify**: choose something for a number or group. **Recognize**: perceive clearly.	**Explain**: make plain or understandable.	**Acquire**: gain possession of; gain by one's own effort or actions. **Apply**: use for a particular purpose or in a particular case. **Conduct**: the act, manner, or process of carrying out (as a task) or carrying forward. **Formulate**: plan out in orderly fashion. **Report**: give an account of; to give a formal or official account or statement of.	**Analyze**: ascertain the components of or separate into component parts; determine carefully the fundamental elements of (as by separation or isolation) for close scrutiny and examination of constituents or for accurate resolution of an overall structure or nature. **Illustrate**: make clear by giving examples or instances. **Select**: choose something from a number or group.	**Develop**: open up; cause to become more completely unfolded so as to reveal hidden or unexpected qualities or potentialities; lay out (as a representation) into a clear, full, and explicit presentation. **Integrate**: make complete; form into a more complete, harmonious, or coordinated entity, often by the addition or arrangement of parts or elements.	**Assess**: critically judge definitively the nature, significance, status, or merit of; to determine the importance, size, or value of. **Evaluate**: examine and judge concerning the worth, quality, significance, amount, degree, or condition of.

@seismicisolation
@seismicisolation

Table F-3. The *Civil Engineering Body of Knowledge* (Third Edition) Affective Domain Outcome Rubrics.

Outcome	**Affective Domain Level of Achievement** *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.*				
	Level 1 Receive *The ability to be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior.*	**Level 2 Respond** *The ability to actively participate in an activity, attend to a task, and react to motivation.*	**Level 3 Value** *The ability to attach value to a particular object, phenomenon, or behavior.*	**Level 4 Organize** *The ability to sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system.*	**Level 5 Characterize** *The ability to follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic.*
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 nontechnical audiences. (UG)	**Practice** effective and persuasive communication to technical and nontechnical audiences. (UG)	**Value** effective and persuasive communication to technical and nontechnical audiences. (ME)	**Display** effective and persuasive communication to technical and nontechnical audiences. (SD)	**Advocate for** effective and persuasive communication to technical and nontechnical 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.

@seismicisolation

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 judgments** 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)

@seismicisolation
@seismicisolation

Table F-4. Definitions of Verbs Used in the Affective Domain Outcome Rubrics.

Affective Domain Level of Achievement				
Level 1 **Receive**	**Level 2** **Respond**	**Level 3** **Value**	**Level 4** **Organize**	**Level 5** **Characterize**
Acknowledge: admit to be real or true; recognize the existence, truth, or fact of.	**Comply**: act or be in accordance with wishes, requests, demands, requirements, conditions, etc. **Examine**: put to question in regard to conduct or knowledge of facts. **Participate**: take or have a part or share in, as with others. Practice: perform repeatedly in order to acquire skill or proficiency.	**Value**: consider with respect to worth, excellence, usefulness, or importance.	**Display**: show or exhibit; to show ostentatiously; flaunt. **Establish**: enact, or cause to be accepted or recognized; to bring about permanently. **Form judgments**: make decisions or form opinions objectively, authoritatively. **Integrate**: meld with and become part of the dominant culture.	**Advocate for**: speak or write in favor of; support or urge argument; recommend publicly.

@seismicisolation
@seismicisolation

Table F-5. 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 and Data Analysis	UG	UG	UG	PG		
Critical Thinking and Problem Solving	UG	UG	UG	ME	ME	
Technical Outcomes						
Project Management	UG	UG	ME			
Engineering Economics	UG	UG	ME			
Risk and 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		

(continued)

@seismicisolation

Table F-5. (Continued)

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 and 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 F-6. 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 and 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

@seismicisolation

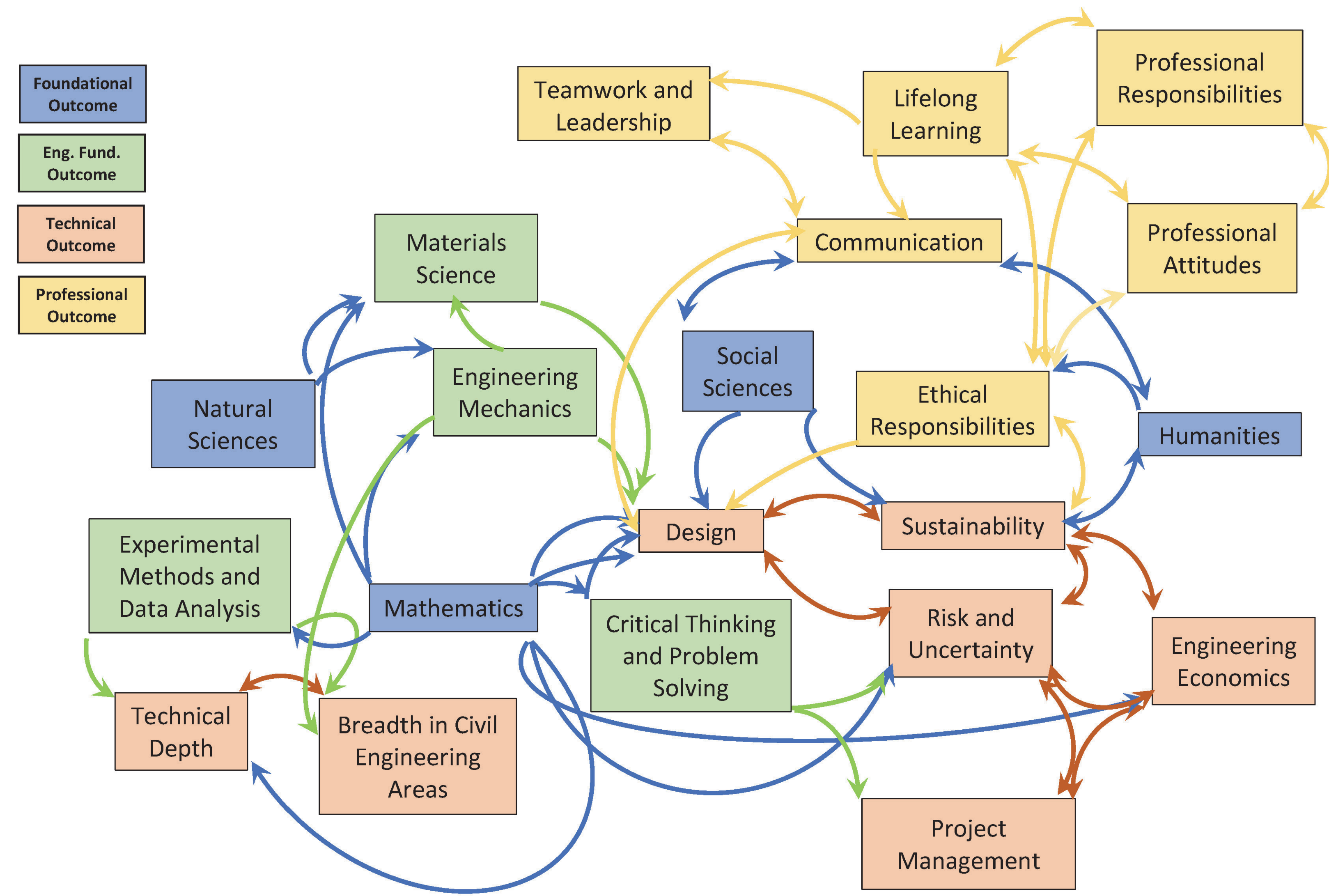
APPENDIX G

Outcomes Relationship Map

Once the CEBOK3TC completed the outcome descriptions, which include understanding the outcome, rationale for including the outcome, levels of achievement and suggested pathways for fulfillment, for each of the 21 outcomes, the interdependencies of the outcomes, although present, were not clearly evident. The CEBOK3TC felt these interdependencies should be highlighted in the published version of the CEBOK3 to reinforce the concept that the CEBOK3 is not just a collection of standalone outcomes but rather a compendium of interrelated knowledge, attributes, and attitudes that are necessary for entry into the practice of civil engineering at the professional level. Figure G-1 is a graphical representation of the outcome interdependencies that were discovered in a crosswalk across outcomes. Figure G-1 may not capture all the interdependencies, but it does describe those that are discussed in the description of the outcomes in Chapter 2.

@seismicisolation
@seismicisolation

Figure G-1. Outcomes Relationship Map.



@seismicisolation

APPENDIX H

CEBOK3 with CEBOK2 Comparison

Appendix H presents a side-by-side comparison of CEBOK3 with CEBOK2 for each of the outcomes and includes a summary of changes. The comparisons are listed in order of the CEBOK3.

Comparison Tables

The bold box in the table defines the level of achievement necessary for entry into the practice of civil engineering at the professional level. The components of the typical pathway are annotated in parentheses for both CEBOK3 and CEBOK2. 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).
- 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.

In the CEBOK2, the path to fulfillment, as it was referred to, included the following three components:

- Bachelor's degree (B): a baccalaureate degree in civil engineering (analogous to UG).
- 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 (analogous to PG).
- Experience (E): appropriate experience based on broad technical and professional practice guidelines that provide sufficient flexibility for a wide range of roles in engineering practice (analogous to ME).

@seismicisolation

The CEBOK3TC changed the terminology from “paths to fulfillment” in CEBOK2, which may imply set specified paths to “typical pathway for fulfillment” to recognize that the pathway is one of many possible pathways. The individual pathways were also renamed to provide clarity, and the self-developed pathway was added primarily as a result of introducing the affective domain for some of the outcomes. Although formal education and mentored experience are appropriate and can be used to develop the knowledge and skills defined in the cognitive domain, the task committee considered the need for personal commitment by each civil engineer to develop some of the outcomes, particularly the value systems that are required for the affective domain.

Outcomes Combined and Outcomes Separated

For CEBOK3, the Teamwork and Leadership outcome was combined from the two separate Teamwork and Leadership outcomes in CEBOK2. The Professional and Ethical Responsibility outcome in the CEBOK2 was split into two separate outcomes, Professional Responsibilities and Ethical Responsibilities, in the CEBOK3. These changes are addressed in this appendix under the specific outcomes.

Outcomes from CEBOK2 Not in CEBOK3

As a result of the comprehensive literature review and the results of the three constituent surveys, many of the topics in the CEBOK2 were modified significantly, and four outcomes were removed as separate outcomes. Although not explicitly incorporated into the Professional Responsibilities outcome in CEBOK3, the CEBOK2 outcomes Contemporary and Historical Perspectives, Public Policy, and Globalization are related to the Professional Responsibilities outcome and are included as topics important to the profession.

The Business and Public Administration outcome from CEBOK2 was also removed from CEBOK3; however, many of the critical concepts in that outcome are incorporated into the Engineering Economics, Teamwork and Leadership, and Professional Responsibilities outcomes. The Engineering Economics outcome addresses many business fundamentals topics in CEBOK2, and the Teamwork and Leadership outcome addresses team dynamics and organizational effectiveness. The Professional Responsibilities outcome specifically addresses legal issues, which were a key component of the Business and Public Administration outcome in CEBOK2.

Outcomes New in the CEBOK3

One new outcome was introduced in the CEBOK3, and two other new topics were combined with two other outcomes. The Engineering Economics outcome is a new outcome in the CEBOK3. Critical thinking is now explicitly included with problem solving in the Critical Thinking and Problem Solving outcome. Data analysis was fully included with conducting experiments in the Experimental Methods and Data Analysis outcome. Finally, Bloom’s Taxonomy for the Affective Domain has been in introduced in the CEBOK3 for the Sustainability outcome and all the professional outcomes—Communication, Teamwork and Leadership, Lifelong Learning, Professional Attitudes, Professional Responsibilities, and Ethical Responsibilities.

@seismicisolation

Mathematics

Table H-1. Mathematics: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of mathematics, including differential equations and numerical methods. (UG)	**Define** key factual information related to mathematics through differential equations. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of mathematics, including differential equations and numerical methods. (UG)	**Explain** key concepts and problem-solving processes in mathematics through differential equations. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering problems. (UG)	**Solve** problems in mathematics through differential equations and **apply** this knowledge to the solution of engineering problems. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of mathematics to solve civil engineering problems.	**Analyze** a complex problem to determine the relevant mathematical principles and then **apply** that knowledge to solve the problem.
5 Synthesize (put learned material together to form a new whole)	**Develop** mathematical models to solve civil engineering problems.	**Create** new knowledge in mathematics.
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** mathematical models used to solve civil engineering problems.	**Evaluate** the validity of newly created knowledge in mathematics.

Summary of Changes

The two primary changes to the Mathematics outcome are introducing the phrase *concepts and principles* and the topic of numerical methods. Concepts and principles is used throughout the CEBOK3 for commonality and is defined as the relationship and combination of general ideas and theories with rules and methods related to specific situations or classes of problems. Numerical methods is an area of mathematics and computer science focused on the development and use of algorithms for obtaining approximate solutions to complex mathematical problems and was added because it forms the basis for modern mathematical, science, and engineering software.

No changes are made to the level of achievement or typical pathway. Other changes are mostly editorial. For example, the phrase "mathematics, including differential equations" used in the CEBOK3 is operationally the same as "mathematics through differential equations." This change was made recognizing that differential equations is the highest level of mathematics expected in the CEBOK, yet some civil engineering programs may require additional mathematics, and by including differential equations in the rubric, calculus (as well as other lower-level math topics) is functionally included as well because of established college math sequences.

@seismicisolation
@seismicisolation

Natural Sciences

Table H-2. Natural Sciences: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences. (UG)	**Define** key factual information related to calculus-based physics, chemistry, and one additional area of natural science. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of chemistry, calculus-based physics, and at least one other area of the natural sciences. (UG)	**Explain** key concepts and problem-solving processes in calculus-based physics, chemistry, and one additional area of natural science. (B)
3 Apply (use learned material in new and concrete situations)	**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)	**Solve** problems in calculus-based physics, chemistry, and one additional area of natural science and **apply** this knowledge to the solution of engineering problems. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of natural sciences to solve civil engineering problems.	**Analyze** complex problems to determine the relevant physics, chemistry, and/or other areas of natural science principles and then apply that knowledge to solve the problem.
5 Synthesize (put learned material together to form a new whole)	**Integrate** appropriate concepts and principles of natural sciences to solve civil engineering problems.	**Create** new knowledge in physics, chemistry, and/or other areas of natural science.
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving concepts and principles of natural sciences.	**Evaluate** the validity of newly created knowledge in physics, chemistry, and/or other areas of natural science.

Summary of Changes

The minor changes in the Natural Sciences outcome are reflected in the more concise language. The phrase "and one additional area of the natural sciences" was replaced with "at least one other area of the natural sciences" to be less prescriptive and less limiting. The word "key" was removed from Levels 1 and 2 to remove the ambiguity and need to determine and classify factual information as key. In Level 3, the verb order was changed to provide a logical, progressive order of applying concepts to solve. The action verb is "apply," which results in the solution of problems.

The explanation includes more solid justification for calculus-based physics and emphasizes the importance and significance of a theoretical, first principles–based knowledge of the natural sciences on which civil engineers rely to solve complex problems.

In Level 4, the specific areas of the natural sciences are eliminated requiring the broader selection and application of concepts and principles. Significant changes also appear in Levels 5 and 6 where the focus shifted from creating and evaluating new knowledge in natural sciences, which would be unlikely for most civil engineers, to integrating appropriate concepts and evaluating solutions involving concepts and principles of the natural sciences.

@seismicisolation
@seismicisolation

Social Sciences

Table H-3. Social Sciences: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of social sciences. (UG)	**Define** key factual information from more than one area of social sciences. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of social sciences. (UG)	**Explain** key concepts from at least one area of the social sciences and their relationship to civil engineering problems and solutions. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of social sciences relevant to civil engineering. (UG)	**Demonstrate** the incorporation of social sciences knowledge into the professional practice of engineering. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of social sciences to solve civil engineering problems.	**Analyze** a complex problem incorporating social science knowledge and then apply that knowledge in the development of a solution to the problem.
5 Synthesize (put learned material together to form a new whole)	**Integrate** appropriate concepts and principles of social sciences to solve civil engineering problems.	**Create** new knowledge in social sciences.
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving concepts and principles of social sciences.	**Evaluate** the validity of newly created knowledge in social sciences.

Summary of Changes

The description of the Social Sciences outcome changed significantly but did not substantially change the focus from CEBOK2 to CEBOK3. The word "key" was removed from Levels 1 and 2 to remove the ambiguity and need to determine and classify factual information as key. Also, the restrictions for "more than one area" and "at least one area" were removed to avoid being overly prescriptive. Levels 1 and 2 also refer to concept and principles in general without the specific requirement for them to be related "to civil engineering problems and solutions" as specified in CEBOK2 for Level 2. The relevance to civil engineering becomes important at the application level. The verbs in Levels 1 and 3 were also changed to better describe the intended outcome.

Significant changes appear in Levels 4, 5, and 6; however, these are beyond the level of achievement required at the point of entry into the practice of civil engineering at the professional level. These changes shifted the focus from creating and evaluating new knowledge in social sciences, which would be unlikely for most civil engineers, to integrating appropriate concepts and evaluating solutions involving concepts and principles of the social sciences.

@seismicisolation

Humanities

Table H-4. Humanities: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Recognize** relationships between the humanities and the practice of civil engineering. (UG)	**Define** key factual information from more than one area of the humanities. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** relationships between the humanities and the practice of civil engineering. (UG)	**Explain** key concepts from at least one area of the humanities and their relationship to civil engineering problems and solutions. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** aspects of the humanities to the solution of civil engineering problems. (UG)	**Demonstrate** the importance of the humanities in the professional practice of engineering. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Illustrate** aspects of the humanities in the solution of civil engineering problems.	**Analyze** a complex problem informed by issues raised in the humanities and **apply** these considerations in the development of a solution to the problem.
5 Synthesize (put learned material together to form a new whole)	**Integrate** aspects of the humanities into the solution of civil engineering problems.	**Create** new knowledge in humanities.
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the integration of the humanities into the solution of civil engineering problems.	**Evaluate** the validity of newly created knowledge in humanities.

Summary of Changes

The changes to this outcome were made primarily to improve the practicality of the outcome rubric, including consideration of the progression of cognitive development and conciseness of the rubric. This was done by changing the phrases "define key factual information," "explain key concepts," and "demonstrate the importance" to "recognize relationships," "explain relationships," and "apply aspects." Overall, the expectation expressed in this outcome has not changed. Rather, the expectation is more clearly communicated and communicated in a manner that does not imply some specific key facets of the humanities must be included in the education of a civil engineer. These changes provide more flexibility to both academic programs and individual civil engineering students based on specific priorities and interests of both civil engineering academic programs and students.

Significant changes appear in Levels 4, 5, and 6; however, these are beyond the level of achievement required at the point of entry into the practice of civil engineering at the professional level. These changes shifted the focus from creating and evaluating new knowledge in the humanities, which would be unlikely for most civil engineers, to integrating appropriate concepts and evaluating solutions involving concepts and principles of the humanities.

@seismicisolation

Materials Science

Table H-5. Materials Science: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of materials science. (UG)	**Define** key factual information related to materials science within the context of civil engineering. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of materials science. (UG)	**Explain** key concepts and problem-solving processes in materials science within the context of civil engineering. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of materials science to solve civil engineering problems. (UG)	**Use** knowledge of materials science to **solve** problems appropriate to civil engineering. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of materials science to solve civil engineering problems.	**Analyze** a complex problem to determine the relevant materials science principles, and then apply that knowledge to solve the problem.
5 Synthesize (put learned material together to form a new whole)	**Develop** new applications in materials science to solve civil engineering problems.	**Create** new knowledge in materials science.
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving new applications in materials science.	**Evaluate** the validity of newly created knowledge in materials science.

Summary of Changes

The Materials Science outcome description is not substantially changed from CEBOK2. The use of the term “key” has been removed from Levels 1 and 2, which removes the responsibility for identifying and defining which concepts and principles are in fact key to solving civil engineering problems. Notably, the reference to “civil engineering problems” has also been removed from the first two levels of achievement. By removing this language, it is suggested that achievement Levels 1 and 2 can be accomplished in a general engineering context. For example, it is fairly common that materials science concepts are introduced at the undergraduate level in a course that is common to multiple engineering programs of study. At Level 3 the verb “apply” has been used to replace the double-barreled verbs of “use” and “solve.” The term “apply” is inclusive of both “use” and “solve.” Individuals are expected to meet the materials science outcome, in both the CEBOK3 and CEBOK2, during their undergraduate education.

Significant changes appear in Levels 4, 5, and 6; however, these are beyond the level of achievement required at the point of entry into the practice of civil engineering at the professional level. These changes focus on making the outcome statements more relevant to civil engineering.

@seismicisolation

Engineering Mechanics

Table H-6. Engineering Mechanics: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of solid and fluid mechanics. (UG)	**Define** key factual information related to solid and fluid mechanics. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of solid and fluid mechanics. (UG)	**Explain** key concepts and problem-solving processes in solid and fluid mechanics. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of solid and fluid mechanics to solve civil engineering problems. (UG)	**Solve** problems in solid and fluid mechanics. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of solid and/or fluid mechanics to solve civil engineering problems.	**Analyze** and **solve** problems in solid and fluid mechanics. (B)
5 Synthesize (put learned material together to form a new whole)	**Develop** new methods in solid and/or fluid mechanics to solve civil engineering problems.	**Create** new knowledge in mechanics.
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to civil engineering problems involving new methods in solid and/or fluid mechanics.	**Evaluate** the validity of newly created knowledge in mechanics.

Summary of Changes

This outcome was retitled from "Mechanics" in the CEBOK2 to "Engineering Mechanics" in CEBOK3. Although the Level 1 and Level 2 statements are similar between CEBOK2 and CEBOK3, the revised Level 3 in CEBOK3 is, in general, equivalent to the CEBOK2 Level 4 statement. In CEBOK3 the Level 3 requirement is "apply concepts… to solve civil engineering problems." This is a more accurate characterization of the application level of Bloom's Taxonomy. Previously, the CEBOK2 Level 4 statement confounded "solve" and "analyze" competencies. Thus, although the achievement level for this outcome appears to be lowered in CEBOK3, actually, it is quite similar to the CEBOK2. In both the CEBOK3 and CEBOK2 individuals are expected to meet the engineering mechanics outcome during their undergraduate education.

Significant changes appear in Levels 5 and 6; however, these are beyond the level of achievement required at the point of entry into the practice of civil engineering at the professional level. These changes focus on making the outcome statements more relevant to civil engineering.

@seismicisolation
@seismicisolation

Experimental Methods and Data Analysis

Table H-7. Experimental Methods and Data Analysis: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** the procedures and equipment necessary to conduct experiments in at least two specialty areas of civil engineering. (UG)	**Identify** the procedures and equipment necessary to conduct civil engineering experiments in more than one of the technical areas of civil engineering. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** the purpose, procedures, equipment, and practical applications of experiments in at least two specialty areas of civil engineering. (UG)	**Explain** the purpose, procedures, equipment, and practical applications of experiments spanning more than one of the technical areas of civil engineering. (B)
3 Apply (use learned material in new and concrete situations)	**Conduct** experiments in at least two specialty areas of civil engineering and **report** the results. (UG)	**Conduct** experiments in one or across more than one of the technical areas of civil engineering according to established procedures and **report** the results. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate experiments and **analyze** the results in the solution of civil engineering problems. (PG)	**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. (M/30)
5 Synthesize (put learned material together to form a new whole)	**Develop** new experimental methods and/or **integrate** the results of multiple experiments for the solution of civil engineering problems.	**Specify** an experiment to meet a need, **conduct** the experiment, and **analyze** and **explain** the resulting data.
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** new experimental methods and/or the results of multiple experiments for the solution of civil engineering problems.	**Evaluate** the effectiveness of a designed experiment in meeting an ill-defined real-world need.

Summary of Changes

The title of the outcome has been expanded in CEBOK3 to place greater emphasis on the data analysis aspect of experiments. Although data analysis in both CEBOK2 and CEBOK3 refers principally to data obtained from conducting experiments, a somewhat wider interpretation is

@seismicisolation
@seismicisolation

implied in CEBOK3 to also include data analysis methods for data gathered from other sources. Otherwise, there is little change from CEBOK2 to CEBOK3 regarding action verbs, levels of achievement, and pathways. In the CEBOK2 at Level 3, the outcome could apply to only one technical area, in other words, “conduct experiments in one or across more than one of the technical areas…” whereas CEBOK3 specifies “at least two specialty areas.” In the CEBOK2 at Level 4, the outcome could also apply to only one technical area. In the CEBOK3 the outcome statement is less prescriptive. In general, the individual descriptions for Levels 1–4 in CEBOK3 are more concise than those in CEBOK2. Significant changes were made in Levels 5 and 6; however, these are beyond the level of achievement required at the point of entry into the practice of civil engineering at the professional level. These changes focus on making the outcome statements more relevant to civil engineering.

@seismicisolation

Critical Thinking and Problem Solving

Table H-8. Critical Thinking and Problem Solving: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** and **define** a complex problem, question, or issue relevant to civil engineering. (UG)	**Identify** key factual information related to engineering problem recognition, problem solving, and applicable engineering techniques and tools. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** the scope and context of a complex problem, question, or issue relevant to civil engineering. (UG)	**Explain** key concepts related to problem recognition, problem articulation, and problem-solving processes, and how engineering techniques and tools are applied to solve problems. (B)
3 Apply (use learned material in new and concrete situations)	**Formulate** a possible solution to a complex problem, question, or issue relevant to civil engineering. (UG)	**Develop** problem statements and solve well-defined fundamental civil engineering problems by applying appropriate techniques and tools. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** a possible solution to a complex problem, question, or issue relevant to civil engineering. (ME)	**Formulate** and **solve** an ill-defined engineering problem appropriate to civil engineering by selecting and applying appropriate techniques and tools. (M/30)
5 Synthesize (put learned material together to form a new whole)	**Develop** a set of appropriate solutions to a complex problem, question, or issue relevant to civil engineering. (ME)	**Synthesize** the solution to an ill-defined engineering problem into a broader context that may include public policy, social impact, or business objectives.
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** a set of solutions to determine the most appropriate solution to a complex problem, question, or issue relevant to civil engineering.	**Compare** the initial and final problem statements, the effectiveness of alternative techniques and tools, and evaluate the effectiveness of the solution.

Summary of Changes

The Critical Thinking and Problem Solving outcome in the CEBOK3 replaced the Problem Recognition and Solving outcome in the CEBOK2. Critical thinking is now explicitly part of this outcome, whereas it was simply implied in CEBOK2. This change is consistent with feedback from the multiple constituent surveys, which revealed a strong preference for critical

@seismicisolation

thinking as explicitly part of an outcome. Moreover, critical thinking and problem solving requires problem recognition and definition, so this aspect, although eliminated from the outcome title, remains in the outcome as is explained in the "Understanding the Outcome" section in Chapter 2.

Another significant change in this outcome is the deliberate shift from "well-defined problems" at Level 3 in CEBOK2 and "ill-defined problems" at Levels 4 and 5 to a "complex problem" for all levels in CEBOK3. This was done to align with the International Engineering Alliance (IEA), "Graduate Attributes and Professional Competencies," in which the most critical distinction between engineers, technologists, and technicians is the class of problems they are called on to solve. Engineers solve complex problems, technologists solve broadly defined problems, and technicians solve well-defined problems (IEA 2013).

The level of achievement for this outcome is now Level 5 as opposed to Level 4 in the CEBOK2. This outcome requires civil engineers to "develop the most appropriate solution to a complex problem, question, or issue relevant to civil engineering," which as noted in the committee research and the multiple constituent surveys, is an appropriate benchmark for achieving the CEBOK. Another change included the selection of the verbs to describe each of the level of achievements. The verbs in CEBOK3 better align with Bloom's Taxonomy, making them more descriptive for the level of achievement.

In addition, the typical pathway for achievement changed at Level 4 from master's degree or equivalent (M/30) in CEBOK2 to mentored experienced. Although postgraduate education should certainly increase the critical thinking and problem-solving abilities of civil engineers, the CEBOK3TC concluded that mentored experience, which progresses in complexity and level of responsibility, is a more consistent and enduring typical pathway for developing these skills at Levels 4 and 5.

@seismicisolation

Project Management

Table H-9. Project Management: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of project management. (UG)	**List** key management principles. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of project management. (UG)	**Explain** what a project is and the key aspects of project management. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of project management in the practice of civil engineering. (ME)	**Develop** solutions to well-defined project management problems. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** components of a project management plan for a complex civil engineering project.	**Formulate** documents to be incorporated into the project plan. (E)
5 Synthesize (put learned material together to form a new whole)	**Integrate** components into a complete project management plan for a complex civil engineering project.	**Create** project plans.
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** a complete project management plan for a complex civil engineering project.	**Evaluate** the effectiveness of a project plan.

Summary of Changes

The changes to the Project Management outcome were based on two considerations. First, the rubric was revised to reflect aspects of project management that each and every individual civil engineer needs to be successful. Second, revisions were made primarily to improve the practicality of the outcome rubric, including consideration of the progression of cognitive development and conciseness of the rubric. This was done by adopting the standard phrase "concepts and principles" in the first three levels, then "components of a project management plan" and "a complete project management plan" in the higher levels. Also, included in the higher levels is reference to "complex civil engineering projects." Although the level of achievement for this outcome was lowered from analyze to apply, the knowledge and skills required remained the same since "apply concepts and principles of project management in the practice of civil engineering" requires the ability to "formulate documents to be incorporated into the project plan."

Concepts and principles is used in the first three levels in the CEBOK3 to define the relationship and combination of general ideas and theories of project management with rules and methods related to specific situations or classes of problems. The undergraduate curriculum is expected to provide the civil engineer with the knowledge to identify and explain project management concepts and principles. The CEBOK3TC concluded that the application of those concepts and principles will be mentored experience leading to entry into the practice of civil engineering at the professional level.

Significant changes appear in Levels 5 and 6; however, these are beyond the level of achievement required at the point of entry into the practice of civil engineering at the professional level. These changes focus on making the outcome statements more relevant to civil engineering.

@seismicisolation

Engineering Economics

Table H-10. Engineering Economics: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of engineering economics. (UG)	Not included in CEBOK2
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of engineering economics. (UG)	Not included in CEBOK2
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of engineering economics in the practice of civil engineering. (ME)	Not included in CEBOK2
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of engineering economics for the practice of civil engineering.	Not included in CEBOK2
5 Synthesize (put learned material together to form a new whole)	**Integrate** engineering economics analyses in the practice of civil engineering.	Not included in CEBOK2
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the effectiveness of engineering economic analyses in the practice of civil engineering.	Not included in CEBOK2

Summary of Changes

In the CEBOK2, engineering economics was addressed tangentially in the Project Management outcome and the Business and Public Administration outcome. In CEBOK3, engineering economics has been separated out for emphasis and clarity. The addition of the Engineering Economics outcome was strongly supported by the first survey in winter 2017 in which 78% of respondents ranked it as very or moderately important for civil engineering practice. In addition, AAES and the US Dept. of Labor (2016) classifies engineering economics as an industrywide technical competency in its "Engineering Competency Model." Further, increasing emphasis in practice on engineering economic considerations in both the private and public sectors suggests that this knowledge and these skills are essential as civil engineers enter professional practice and that this should be explicitly acknowledged in the CEBOK3.

The outcome title, Engineering Economics, may be also slightly misleading because this outcome, as noted in the "Understanding the Outcome" section in Chapter 2, really involves more than economics for engineering and includes the application of both business principles and economics to engineering projects.

@seismicisolation

Risk and Uncertainty

Table H-11. Risk and Uncertainty: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of probability, statistics, and risk relevant to civil engineering. (UG)	**Recognize** uncertainties in data and knowledge and list those relevant to engineering design. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of probability, statistics, and risk relevant to civil engineering. (UG)	**Distinguish** between uncertainties that are data-based and those that are knowledge-based and **explain** the significance of those uncertainties on the performance and safety of an engineering system. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of probability and statistics to determine risk relevant to civil engineering. (UG)	**Apply** the principles of probability and statistics to **solve** problems containing uncertainties. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate concepts and principles of probability and statistics and **analyze** risk in a complex civil engineering problem. (ME)	**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. (E)
5 Synthesize (put learned material together to form a new whole)	**Integrate** risk analyses into the solutions to complex civil engineering problems.	**Develop** criteria (such as required safety factors) for the ill-defined design of an engineered system within an acceptable risk measure.
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the acceptability of the risks associated with solutions to complex civil engineering problems.	**Appraise** a multicomponent system and **evaluate** its quantitative risk measure, taking into account the occurrence probability of an adverse event and its potential consequences caused by failure.

Summary of Changes

The changes to the Risk and Uncertainty outcome were made primarily to include risk at all levels, have the outcome statements progress in a logical manner consistent with Bloom's Taxonomy, and provide a more explicit link to civil engineering. In the CEBOK2, risk was first mentioned at Level 5, and now risk is included at all levels in the CEBOK3 rubric. In the CEBOK2, the progression of the rubric from lower levels to higher levels seemed to drift, introduced new topics, and was not completely consistent with Bloom's Taxonomy. The CEBOK3 rubric was developed to progress logically and advance from lower levels to higher levels in a manner truer to the Bloom's Taxonomy hierarchy. Finally, in the CEBOK2, the outcome statements for Levels 2, 3, 4, and 6 were all written with two verbs and, thus, embedded multiple aspects at each of these levels. In the CEBOK3, all of the levels but one (Level 4) were written with one verb to add clarity to the outcome.

@seismicisolation

Breadth in Civil Engineering Areas

Table H-12. Breadth in Civil Engineering Areas: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering. (UG)	**Define** key factual information related to at least four technical areas appropriate to civil engineering. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles related to at least four specialty areas appropriate to the practice of civil engineering. (UG)	**Explain** key concepts and problem-solving processes in at least four technical areas appropriate to civil engineering. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles to solve complex problems in at least four specialty areas appropriate to the practice of civil engineering. (UG)	**Solve** problems in or across at least four technical areas appropriate to civil engineering. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** complex problems that cross multiple specialty areas appropriate to the practice of to civil engineering. (ME)	**Analyze** and **solve** well-defined engineering problems in at least four technical areas appropriate to civil engineering. (B)
5 Synthesize (put learned material together to form a new whole)	**Integrate** solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.	**Create** new knowledge that spans more than one technical area appropriate to civil engineering.
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** solutions to complex problems that involve multiple specialty areas appropriate to the practice of civil engineering.	**Evaluate** the validity of newly created knowledge that spans more than one technical area appropriate to civil engineering.

Summary of Changes

The Breadth in Civil Engineering Areas outcome rubric was rewritten to align with the "Graduate Attributes and Professional Competencies" (IEA 2013). The rubric shifts from demonstrating key factual information and solving well-defined problems to applying concepts and principles to analyze complex problems across multiple specialty areas. Complex problems involve conflicting technical issues, have no obvious solutions, involve diverse groups of stakeholders, involve the creative use of engineering principles and research in novel ways, have significant consequences, and extend beyond previous experiences. In addition, the "Understanding the Outcome" section in Chapter 2 updates the list of traditional specialty areas appropriate to civil engineering and expands opportunities for nontraditional areas to align with emerging disciplines.

Significant changes appear in Levels 5 and 6; however, these are beyond the level of achievement required at the point of entry into the practice of civil engineering at the professional level. These changes shifted the focus to integrating and evaluating solutions to complex problems that involve multiple specialty areas in civil engineering, which is more likely than creating and evaluating new knowledge in civil engineering.

@seismicisolation
@seismicisolation

Design

Table H-13. Design: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Define** engineering design and the engineering design process. (UG)	**Define** engineering design; **list** the major steps in the engineering design process; and **list** constraints that affect the process and products of engineering design. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** engineering design and the engineering design process. (UG)	**Describe** the engineering design process; **explain** how real-world constraints affect the process and products of engineering design. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** the engineering design process to a given set of requirements and constraints to solve a complex civil engineering problem. (UG)	**Apply** the design process to meet a well-defined set of requirements and constraints. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** a complex civil engineering project to determine design requirements and constraints. (ME)	**Analyze** a system or process to determine requirements and constraints. (B)
5 Synthesize (put learned material together to form a new whole)	**Develop** an appropriate design alternative for a complex civil engineering project that considers realistic requirements and constraints. (ME)	**Design** a system or process to meet desired needs within such realistic constraints as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability. (B)
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** design alternatives for a complex civil engineering project for compliance with customary standards of practice, user and project needs, and relevant constraints.	**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. (E)

Summary of Changes

The most significant changes in the Design outcome are the levels of achievement for entry into the practice of civil engineering at the professional level and the typical pathway for fulfillment. The level of achievement changes from Level 6 in the CEBOK2 to Level 5 in the CEBOK3.

@seismicisolation

Based on feedback from the constituent surveys and discussion, the CEBOK3TC determined that Level 6 is more appropriately attained after entry into practice at the professional level. The level of achievement at the completion of an undergraduate program changed from Level 5 in the CEBOK2 to Level 3 in the CEBOK3. The addition of "complex" to Level 3 in CEBOK3 elevates the rigor of that level, and the CEBOK3TC felt that students should only be required to incorporate a defined set of requirements and constraints into a design solution, with the belief that identifying and defining realistic constraints should come through mentored experience.

In CEBOK3 the requirements for all design solutions to consider realistic constraints and meet the requirements of codes and standards is discussed in the "Understanding the Outcome" section in Chapter 2 rather than incorporating the elements requirements and constraints into the rubric itself. Three of the levels in the Design outcome in the CEBOK2 contained multiple action verbs with multiple requirements. The CEBOK3TC sought to create a single requirement, defined by a single action verb, for every level of every outcome. For example, Level 1 in the CEBOK2 contains three action verbs that individually defined specific tasks that constituted some, but perhaps not all, elements of the engineering design process. Level 1 in the CEBOK3 contains a single action verb that requires knowledge of the definition of design and the process of design. Similarly, the multiple action verbs in Levels 2 and 6 were replaced with a single verb and a single requirement. In general, the rubric for the Design outcome in the CEBOK3 focuses on the solution of complex civil engineering problems and provides less specificity, relegating the details of the design process to the "Understanding the Outcome" section in Chapter 2.

@seismicisolation

Depth in a Civil Engineering Area

Table H-14. Depth in a Civil Engineering: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Define** advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering. (UG)	**Define** key aspects of advanced technical specialization appropriate to civil engineering. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** advanced concepts and principles related to a specialty area appropriate to the practice of civil engineering. (UG)	**Explain** key concepts and problem-solving processes in a traditional or emerging specialized technical area appropriate to civil engineering. (M/30)
3 Apply (use learned material in new and concrete situations)	**Apply** advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering. (PG)	**Apply** specialized tools, technology, or technologies to solve simple problems in a traditional or emerging specialized technical area of civil engineering. (M/30)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** appropriate advanced concepts and principles to solve complex problems in a specialty area appropriate to the practice of civil engineering. (PG)	**Analyze** a complex system or process in a traditional or emerging specialized technical area appropriate to civil engineering. (M/30)
5 Synthesize (put learned material together to form a new whole)	**Integrate** advanced concepts and principles into the solutions of complex problems in a specialty area appropriate to the practice of civil engineering. (ME)	**Design** a complex system or process or **create** new knowledge or technologies in a traditional or emerging specialized technical area appropriate to civil engineering. (M/30)
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** advanced concepts and principles in the solutions of complex problems in a specialty area appropriate to the practice of civil engineering.	**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. (E)

@seismicisolation
@seismicisolation

Summary of Changes

This outcome was renamed “Depth in a Civil Engineering Area” in the CEBOK3 from “Technical Specialization” in the CEBOK2 to communicate the expectation for both breadth and depth in civil engineering. As with many other outcomes, the rubric was changed to improve the practicality of the outcome with the term “advanced concepts and principles.” A significant difference between the CEBOK3 and the CEBOK2 is lowering the level of achievement necessary for entry into the practice of civil engineering at the professional level. Similar to the Design outcome, the CEBOK3TC determined that Level 6 is more appropriately attained after entry into practice at the professional level. Also, the phrase “technical area appropriate to civil engineering” was changed to “specialty area appropriate to the practice civil engineering” to be more consistent with the terms used by other learned professions and to provide for the opportunity for “specialty areas” that may not be considered “technical areas.”

@seismicisolation
@seismicisolation

Sustainability

Table H-15a. Sustainability: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of sustainability. (UG)	**Define** key aspects of sustainability relative to engineering phenomena, society at large, and its dependence on natural resources; and relative to the ethical obligation of the professional engineer. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of sustainability. (UG)	**Explain** key properties of sustainability, and their scientific bases, as they pertain to engineered works and services. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of sustainability to the solution of complex civil engineering problems. (UG)	**Apply** the principles of sustainability to the design of traditional and emergent engineering systems. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** the sustainable performance of complex civil engineering projects from a systems perspective. (ME)	**Analyze** systems of engineered works, whether traditional or emergent, for sustainable performance. (E)
5 Synthesize (put learned material together to form a new whole)	**Develop** practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.	**Design** a complex system, process, or project to perform sustainably. **Develop** new, more sustainable technology. **Create** new knowledge or forms of analysis in areas in which scientific knowledge limits sustainable design.
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** practices and requirements to achieve sustainable performance of complex civil engineering projects from a systems perspective.	**Evaluate** the sustainability of complex systems, whether proposed or existing.

Summary of Changes

The language of the sustainability outcomes has been simplified to be less prescriptive and consistent with that of the other outcomes. The term "concepts and principles of sustainability" is broad enough to encompass all the economic, environmental, and social tenets needed to

@seismicisolation

achieve the learning outcomes. Since the publication of the CEBOK2, ASCE has issued ASCE Policy Statement 418, "The Role of the Civil Engineer in Sustainable Development" (ASCE 2016). This policy statement defines sustainability and expounds on the "concepts and principles of sustainability" relevant to civil engineers. The action verb for the Level 1 outcome has changed from "define" to "identify" to frame the acquisition of the knowledge of sustainability as an active choice of the learner. The choice implied in the verb "identify" supports the acquisition of the appropriate attitudes for the affective domain established for sustainability. The "ethical obligation" mentioned in the CEBOK2 Level 1 was further addressed with the addition of the affective domain outcomes. The outcome still recognizes that civil engineers are dealing with "systems of engineered work" by stipulating that the analysis of "complex civil engineering projects" be done from a systems perspective. This perspective indicates a civil engineer should consider not just the sustainability of the individual project and its constituent systems, but how that project impacts the sustainability of the larger systems of which it is a part. The outcome level and pathway did not change for the cognitive domain.

Table H-15b. Sustainability: Comparison of CEBOK3 with CEBOK2 (Affective Domain).

Affective Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of sustainability in the practice of civil engineering. (UG)	Not included in CEBOK2
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Comply** with the concepts and principles of sustainability in the practice of civil engineering. (UG)	Not included in CEBOK2
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** the benefits of sustainability in the practice of civil engineering. (ME)	Not included in CEBOK2
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Integrate** a commitment to sustainability principles in everyday practice. (SD)	Not included in CEBOK2
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** principles of sustainability.	Not included in CEBOK2

@seismicisolation

Summary of Changes

The addition of the affective domain for the Sustainability outcome is a significant change to the CEBOK. The ASCE Code of Ethics, Canon 1, charges the civil engineer to "strive to comply with the principles of sustainable development in the performance of their professional duties" (ASCE 2017). To meet this charge, a civil engineer must "value" sustainability and "integrate" its principles into their practice. These action verbs are naturally part of the affective domain and have been established as Level 3 and Level 4, respectively. ASCE Policy Statement 418 further clarifies the attitudes and value system a civil engineer should have with respect to sustainability (ASCE 2016). The Code of Ethics and Policy Statement 418 indicate that Level 4 is the desired level of achievement. Although concepts and behavior can be modeled during undergraduate education, the typical pathway to this level acknowledges that valuing sustainability in civil engineering practice will come with mentored experience, which progresses in both complexity and level of responsibility. Finally, to consistently integrate sustainability into one's own practice is a personal choice that must be self-developed.

@seismicisolation
@seismicisolation

Communication

Table H-16a. Communication: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** concepts and principles of effective communication to technical and nontechnical audiences. (UG)	**List** the characteristics of effective verbal, written, virtual, and graphical communications. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of effective communication to technical and nontechnical audiences. (UG)	**Describe** the characteristics of effective verbal, written, virtual, and graphical communications. (B)
3 Apply (use learned material in new and concrete situations)	**Formulate** effective communication to technical and nontechnical audiences. (UG)	**Apply** the rules of grammar and composition in verbal and written communications, properly cite sources, and use appropriate graphical standards in preparing engineering drawings. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** effective communication to technical and nontechnical audiences. (ME)	**Organize** and **deliver** effective verbal, written, virtual, and graphical communications. (B)
5 Synthesize (put learned material together to form a new whole)	**Integrate** different forms of effective communication to technical and nontechnical audiences. (ME)	**Plan**, **compose**, and **integrate** the verbal, written, virtual, and graphical communication of a project to technical and nontechnical audiences. (E)
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the effectiveness of communication to technical and nontechnical audiences.	**Evaluate** the effectiveness of the integrated verbal, written, virtual, and graphical communication of a project to technical and nontechnical audiences.

Summary of Changes

Because effective communication requires a wide variety of competencies, the description of the communications outcome has been simplified to be less prescriptive of communication media and specific skills. In addition, each level within the rubric emphasizes the need to effectively communicate with nontechnical audiences—an important ability for engineers in a technology-driven world with an increasingly science-illiterate population. At Level 4 the action verbs changed from “organize” and “deliver” to “analyze.” This change asserts the need for civil engineers to intentionally analyze the efficacy of their own and others’ communication. The typical pathway to fulfillment has changed so that Levels 1, 2, and 3 are attained at the undergraduate level, with Levels 4 and 5 achieved through mentored experience, which progresses in both complexity and level of responsibility.

@seismicisolation

Table H-16b. Communication: Comparison of CEBOK3 with CEBOK2 (Affective Domain).

Affective Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of effective and persuasive communication to technical and nontechnical audiences. (UG)	Not included in CEBOK2
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Practice** effective and persuasive communication to technical and nontechnical audiences. (UG)	Not included in CEBOK2
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** effective and persuasive communication to technical and nontechnical audiences. (ME)	Not included in CEBOK2
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Display** effective and persuasive communication to technical and nontechnical audiences. (SD)	Not included in CEBOK2
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate** for effective and persuasive communication to technical and nontechnical audiences.	Not included in CEBOK2

Summary of Changes

The addition of the affective domain for the Communication outcomes is a significant change to the CEBOK. To be successful in one's career, a civil engineer must value effective and persuasive communication. The value that a civil engineer places on effective communication is reflected in their efforts to develop and ultimately display effective communication skills. Explicitly acknowledging the importance of persuasive communication and developing the requisite skills is a new emphasis for the Communication outcome in CEBOK3.

@seismicisolation

Teamwork and Leadership

Table H-17a. Teamwork and Leadership: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability (Teamwork)	CEBOK2 Demonstrated Ability (Leadership)
1 Remember (remember previously learned material)	**Identify** concepts and principles of teamwork and leadership, including diversity and inclusion. (UG)	**Define** and **list** the key characteristics of effective intradisciplinary and multidisciplinary teams. (B)	**Define** leadership and the role of a leader; **list** leadership principles and attitudes. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** concepts and principles of teamwork and leadership, including diversity and inclusion. (UG)	**Explain** the factors affecting the ability of intradisciplinary and multidisciplinary teams to function effectively. (B)	**Explain** the role of a leader and leadership principles and attitudes. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** concepts and principles of teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems. (UG)	**Function** effectively as a member of an intradisciplinary team. (B)	**Apply** leadership principles to direct the efforts of a small, homogenous group. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Select** concepts and principles of effective teamwork and leadership, including diversity and inclusion, in the solutions of civil engineering problems. (ME)	**Function** effectively as a member of a multidisciplinary team. (E)	**Organize** and **direct** the efforts of a group. (E)
5 Synthesize (put learned material together to form a new whole)	**Integrate** concepts and principles of effective teamwork and leadership, including diversity and inclusion, into the solutions of civil engineering problems. (ME)	**Organize** an intradisciplinary or multidisciplinary team.	**Create** a new organization to accomplish a complex task.
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** the effectiveness of leaders and teams in the solution of civil engineering problems.	**Evaluate** the composition, organization, and performance of an intradisciplinary or multidisciplinary team.	**Evaluate** the leadership of an organization.

@seismicisolation

Summary of Changes

For the CEBOK3, the two separate CEBOK2 outcomes, the Teamwork outcome and the Leadership outcome, were combined into one outcome, Teamwork and Leadership. This was based in part on IEA's "Graduate Attributes and Professional Competencies," which lists "function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings" as a desired outcome for engineers (IEA 2013). Moreover, although teamwork and leadership could be considered separate skill sets and were separate outcomes in the CEBOK2, additional CEBOK3TC research and feedback from the constituent surveys supported a combined outcome wherein the knowledge, skills, and attitudes associated with each are connected within a single outcome.

The level of achievement also increased from Level 4 for both teamwork and leadership in the CEBOK2 to Level 5 in the CEBOK3; however, with a selection of verbs which better align with Bloom's Taxonomy, the overall level of achievement functionally remained mostly unchanged. This outcome requires each civil engineer to "integrate concepts and principles of effective teamwork and leadership, including diversity and inclusion, into the solutions of civil engineering problems develop the most appropriate solution to a complex problem, question or issue relevant to civil engineering," which is similar to a combination of "function effectively as a member of a multidisciplinary team" and "organize and direct the efforts of a group."

A focus on diversity and inclusion was added to this outcome, which reflects the revision of the ASCE Code of Ethics on July 29, 2017 (ASCE 2017). The updated ASCE Code of Ethics includes Canon 8, "Treat All Persons Fairly." The classification of teams as intradisciplinary and multidisciplinary was eliminated in an effort to maintain the broadest notion of teams as represented in current practice. The typical pathway for achievement did not change from CEBOK2 to CEBOK3 other than the addition of Level 5, which like Level 4, is mentored experience, which progresses in both complexity and level of responsibility.

@seismicisolation

Table H-17b. Teamwork and Leadership: Comparison of CEBOK3 with CEBOK2 (Affective Domain).

Affective Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of teamwork, leadership, diversity, and inclusion. (UG)	Not included in CEBOK2
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Practice** concepts and principles of teamwork, leadership, diversity, and inclusion. (UG)	Not included in CEBOK2
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** the need for teamwork, leadership, diversity, and inclusion. (ME)	Not included in CEBOK2
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Display** effective teamwork and leadership, including support of diversity and inclusion. (SD)	Not included in CEBOK2
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** teamwork, leadership, diversity, and inclusion.	Not included in CEBOK2

Summary of Changes

The addition of the affective domain for the Teamwork and Leadership outcome is a significant change to the CEBOK. A civil engineer must value, internalize, and prioritize teamwork and leadership in the practice of civil engineering. To lead effectively, it is necessary to value diversity, inclusion, and commitment to the roles of team member and leader.

@seismicisolation

Lifelong Learning

Table H-18a. Lifelong Learning: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning. (UG)	**Define** lifelong learning. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** the need for additional knowledge, skills, and attitudes to be acquired through self-directed learning. (UG)	**Explain** the need for lifelong learning and **describe** the skills required of a lifelong learner. (B)
3 Apply (use learned material in new and concrete situations)	**Acquire** new knowledge, skills, and attitudes relevant to civil engineering through self-directed learning. (UG)	**Demonstrate** the ability for self-directed learning. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** new knowledge, skills, and attitudes relevant to civil engineering acquired through self-directed learning. (ME)	**Identify** additional knowledge, skills, and attitudes appropriate for professional practice. (E)
5 Synthesize (put learned material together to form a new whole)	**Integrate** new knowledge, skills, and attitudes acquired through self-directed learning into the practice of civil engineering. (ME)	**Plan** and **execute** the acquisition of required expertise appropriate for professional practice. (E)
6 Evaluate (judge the value of learned material for a given purpose)	**Evaluate** the effectiveness of additional knowledge, skills, and attitudes acquired through self-directed learning.	**Self-assess** learning processes and **evaluate** those processes in light of competing and complex real-world alternatives.

Summary of Changes

In comparing the CEBOK3 to the CEBOK2, significant changes were made to the Lifelong Learning outcome. With respect to the cognitive domain, the level of achievement at the point of entry into the practice of civil engineering at the professional level remained the same at Level 5. However, the outcome statements have been significantly altered. The changes to the Lifelong Learning outcome fall into two distinct categories. First, lifelong learning was specifically identified as "acquiring knowledge, skills, and attitudes." Second, the verbs were changed to better match Bloom's Taxonomy and reflect what is expected to be achieved.

As with the other outcomes, the pathway to achieving lifelong learning was revised. Undergraduate education is identified as the best place to achieve outcome Levels 1–3, because, as students, individuals begin identifying the need for, explaining why, and acquiring additional knowledge that is needed to solve problems. Application of lifelong learning occurs in many

@seismicisolation

culminating design experiences in undergraduate programs. Mentored experience that progresses in both complexity and level of responsibility is the mechanism for achieving Levels 4 and 5 of the outcome.

Table H-18b. Lifelong Learning: Comparison of CEBOK3 with CEBOK2 (Affective Domain).

Affective Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the need for lifelong learning. (UG)	Not included in CEBOK2
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Participate** in lifelong learning opportunities. (UG)	Not included in CEBOK2
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** lifelong learning in the practice of civil engineering. (ME)	Not included in CEBOK2
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Establish** a lifelong learning plan to support one's own professional development. (SD)	Not included in CEBOK2
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate** for lifelong learning in the practice of civil engineering.	Not included in CEBOK2

Summary of Changes

The major innovation to the Lifelong Learning outcome in CEBOK3 is the addition of the affective domain. The affective domain identifies how people understand and learn. Lifelong learning must be driven and valued by the individual, so the addition of the affective domain was highly appropriate because only the individual can truly accomplish self-directed learning. Mentored experiences may guide the individual to identify knowledge, skills, and attitudes needed to advance one's career, but the learning must be accomplished by the individual. Therefore, the mechanism for achieving the expectations of this outcome includes undergraduate education, mentored experience, and self-development.

@seismicisolation

Professional Attitudes

Table H-19a. Professional Attitudes: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Remember (remember previously learned material)	**Identify** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	**List** attitudes supportive of the professional practice of civil engineering. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	**Explain** attitudes supportive of the professional practice of civil engineering. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** knowledge of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (ME)	**Demonstrate** attitudes supportive of the professional practice of civil engineering. (E)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Illustrate** professional attitudes relevant to the practice of civil engineering including, creativity, curiosity, flexibility, and dependability. (ME)	**Analyze** a complex task to determine which attitudes are most conducive to its effective accomplishment.
5 Synthesize (put learned material together to form a new whole)	**Integrate** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	**Create** an organizational structure that maintains/ fosters the development of attitudes conducive to task accomplishment.
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the effectiveness of professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	**Evaluate** the attitudes of key members of an organization and assess the effect of their attitudes on task accomplishment.

Summary of Changes

Based on feedback from the constituent surveys, the title of this outcome was changed from Attitudes in the CEBOK2 to Professional Attitudes in the CEBOK3. The CEBOK3 now explicitly includes the attitudes creativity, curiosity, flexibility, and dependability, whereas the CEBOK2 provided a list of attitudes in the outcome explanation. In terms of levels of achievement, the CEBOK2 called for demonstrating the attitudes at Level 3, whereas the CEBOK3 requires illustrating professional attitudes at Level 4. However, the overall level of achievement functionally remained mostly unchanged because the verb "illustrate," which means to "make clear by giving

@seismicisolation
@seismicisolation

examples" is very similar to the verb "demonstrate," which was defined in CEBOK2 as "to illustrate or explain in an orderly and detailed way especially with many examples…."

Table H-19b. Professional Attitudes: Comparison of CEBOK3 with CEBOK2 (Affective Domain).

Affective Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (UG)	Not included in CEBOK2
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Practice** professional attitudes, relevant to the practice of civil engineering including creativity, curiosity, flexibility, and dependability. (UG)	Not included in CEBOK2
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (ME)	Not included in CEBOK2
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Establish** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability. (SD)	Not included in CEBOK2
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** professional attitudes relevant to the practice of civil engineering, including creativity, curiosity, flexibility, and dependability.	Not included in CEBOK2

Summary of Changes

A significant change to the Professional Attitudes outcomes is the addition of the affective domain. Arguably this outcome represented elements of the affective domain in CEBOK2 since attitudes were defined the CEBOK2 as "the ways in which one thinks and feels in response to a fact or situation." For CEBOK3, an affective domain rubric for the Professional Attitudes was highly appropriate because of the individualized nature of attitudes. In fact, the typical pathway for fulfillment includes not only undergraduate education and mentored experience, but also the new pathway of self-development, which recognized the personal responsibility for professional attitudes.

@seismicisolation

Professional Responsibilities

Table H-20a. Professional Responsibilities: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability (Professional Responsibilities)	CEBOK2 Demonstrated Ability (Professional and Ethical Responsibility)
1 Remember (remember previously learned material)	**Identify** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (UG)	**List** the professional and ethical responsibilities of a civil engineer. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (UG)	**Explain** the professional and ethical responsibilities of a civil engineer. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (ME)	**Apply** standards of professional and ethical responsibility to determine an appropriate course of action. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Illustrate** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (ME)	**Analyze** a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action. (B)
5 Synthesize (put learned material together to form a new whole)	**Integrate** professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation. (ME)	**Synthesize** studies and experiences to foster professional and ethical conduct. (E)
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** the integration of professional responsibilities relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation.	**Justify** a solution to an engineering problem based on professional and ethical standards and **assess** personal professional and ethical development. (E)

@seismicisolation

Summary of Changes

A significant change the CEBOK3 involved the separation of the CEBOK2 outcome Professional and Ethical Responsibility into two BOK3 outcomes, the Professional Responsibilities outcome and the Ethical Responsibilities outcome. Another major change was the explicit listing of specific professional responsibilities including safety, legal issues, licensure, credentialing, and innovation.

Since safety is a critical issue in civil engineering and is specifically recognized as an outcome in the National Society of Professional Engineers (NSPE) BOK (NSPE 2013), the CEBOK3TC decided to specifically include safety among the required professional responsibilities. Likewise, legal issues are an important aspect of civil engineering and were included as an outcome in the NSPE BOK (NSPE 2013). The CEBOK3TC included legal issues under the Professional Responsibilities outcome in the CEBOK3, whereas in the CEBOK2 they were primarily discussed as a part of the Business and Public Administration outcome.

Many civil engineers elect to pursue licensure as a professional engineer. Licensure was not specifically included within any of the CEBOK2 outcomes, and the CEBOK3TC concluded that an awareness of the importance of professional licensure and, specifically, knowledge of the licensure process and pre-licensure experience should be included explicitly in CEBOK3. This aspect is now included in the Professional Responsibilities outcome in CEBOK3.

The CEBOK3TC also decided to specify credentialing, which includes specialty certifications and post-licensure certifications, as another aspect of professional responsibilities in the CEBOK3. Because of the ever-increasing role of creativity and innovation in civil engineering as civil engineers face increasingly complex problems, being innovative is also specifically listed as a professional responsibility in the CEBOK3.

Other aspects of professional responsibility that are not specifically listed but are important to the profession include contemporary issues, historical perspectives, and globalization, all of which were separate outcomes in CEBOK2. As stated in the "Rationale" section in Chapter 2 for the Professional Responsibilities outcome: "Each problem that a civil engineer faces is unique due to a combination of technical, safety, historical, environmental, political, and cultural issues. … Civil engineers are expected to have the ability to recognize and discharge their professional responsibilities in engineering situations and make informed judgments, considering the impact of engineering solutions in a global, economic, environmental, societal, and historical context. Determining appropriate solutions to complex problems requires innovation, adherence to standards, and consideration of many nontechnical factors."

@seismicisolation

Table H-20b. Professional Responsibilities: Comparison of CEBOK3 with CEBOK2 (Affective Domain).

Affective Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (UG)	Not included in CEBOK2
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Examine** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (UG)	Not included in CEBOK2
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (ME)	Not included in CEBOK2
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Form judgments** about professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation. (SD)	Not included in CEBOK2
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** professional responsibilities relevant to the practice of civil engineering including safety, legal issues, licensure, credentialing, and innovation.	Not included in CEBOK2

Summary of Changes

Although the CEBOK2 did not include any outcomes in the affective domain, it did include an example affective domain rubric for the Professional and Ethical Responsibility outcome that showed that individuals should reach Level 5 and "display professional and ethical conduct in engineering practice." Furthermore, the path to fulfillment for achieving this level was experience. The CEBOK3 added self-development as a typical pathway and revised the rubric to focus on the professional responsibilities. The CEBOK3TC selected Level 4 as the level of achievement, with a typical pathway consisting of undergraduate education, mentored experience that progresses in complexity and level of responsibility, and self-development.

@seismicisolation

Ethical Responsibilities

Table H-21a. Ethical Responsibilities: Comparison of CEBOK3 with CEBOK2 (Cognitive Domain).

Cognitive Domain Level of Achievement	CEBOK3 Demonstrated Ability (Ethical Responsibilities)	CEBOK2 Demonstrated Ability (Professional and Ethical Responsibility)
1 Remember (remember previously learned material)	**Identify** the ethical responsibilities of a civil engineer. (UG)	**List** the professional and ethical responsibilities of a civil engineer. (B)
2 Comprehend (grasp the meaning of learned material)	**Explain** the ethical responsibilities of a civil engineer. (UG)	**Explain** the professional and ethical responsibilities of a civil engineer. (B)
3 Apply (use learned material in new and concrete situations)	**Apply** appropriate reasoning to an ethical dilemma. (ME)	**Apply** standards of professional and ethical responsibility to determine an appropriate course of action. (B)
4 Analyze (break down learned material into its component parts so that its organizational structure may be understood)	**Analyze** ethical dilemmas to determine possible courses of action. (ME)	**Analyze** a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action. (B)
5 Synthesize (put learned material together to form a new whole)	**Develop** courses of action to ethical dilemmas in complex situations. (ME)	**Synthesize** studies and experiences to foster professional and ethical conduct. (E)
6 Evaluate (judge the value of learned material for a given purpose)	**Assess** courses of resolution to ethical dilemmas in complex situations.	**Justify** a solution to an engineering problem based on professional and ethical standards and **assess** personal professional and ethical development. (E)

Summary of Changes

A significant change in the CEBOK3 involved the separation of the CEBOK2 outcome, Professional and Ethical Responsibility, into two CEBOK3 outcomes, the Professional Responsibilities outcome and the Ethical Responsibilities outcome. One key reason for the separation was to specifically emphasize ethics because of its importance to the individual civil engineer and the civil engineering profession.

The CEBOK3 Ethical Responsibilities outcome focuses explicitly on the ethical responsibilities and expectations of a civil engineer. Both the level of achievement and typical pathway for fulfillment of the outcome changed from the combined CEBOK2 outcome. Based on feedback from the constituent surveys and discussion, the CEBOK3TC determined that Level 6 is more appropriately attained after entry into practice at the professional level.

@seismicisolation

Both typical pathways included undergraduate education and mentored experience, but in the CEBOK3, undergraduate education would typically lead to achievement at Levels 1 and 2, whereas Levels 3, 4, and 5 would be achieved through mentored experience, which progresses in both complexity and level of responsibility. Survey results, specifically focused on feedback from industry professionals and practitioners, supported this revision.

Table H-21b. Ethical Responsibilities: Comparison of CEBOK3 with CEBOK2 (Affective Domain).

Affective Domain Level of Achievement	CEBOK3 Demonstrated Ability	CEBOK2 Demonstrated Ability
1 Receive (be aware of, be willing to receive, and be attentive to a particular phenomenon or behavior)	**Acknowledge** the importance of ethical behavior. (UG)	Not included in CEBOK2
2 Respond (actively participate in an activity, attend to a task, and react to motivation)	**Comply** with applicable ethical codes. (UG)	Not included in CEBOK2
3 Value (attach value to a particular object, phenomenon, or behavior)	**Value** ethical behavior in the practice of civil engineering. (ME)	Not included in CEBOK2
4 Organize (sort values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system)	**Display** ethical behavior in the practice of civil engineering. (ME)	Not included in CEBOK2
5 Characterize (follow a value system that controls behavior that is pervasive, consistent, predictable, and a defining characteristic)	**Advocate for** ethical behavior in the practice of civil engineering. (SD)	Not included in CEBOK2

Summary of Changes

ASCE believes all civil engineers must practice with high ethical standards. The CEBOK2 identified outcomes that would be enhanced by descriptions in both the cognitive domain and the affective domain, including the Professional and Ethical Responsibilities outcome. The affective domain can be characterized as the internalization of values and attitudes. The affective domain rubrics supplement and enrich the cognitive domain rubrics but they do not replace them.

Knowledge of ethical responsibility should be internalized and valued such that the civil engineer commits to the standards of ethical practice. To accomplish this objective, the civil engineer must "acknowledge the importance of ethical behavior" as noted in Level 1 and

@seismicisolation
@seismicisolation

"comply with applicable ethical codes," as noted in Level 2. Early career civil engineers should demonstrate that they "value ethical behavior in the practice of civil engineering" at Level 3, and "display ethical behavior in the practice of civil engineering" at Level 4. Both Levels 3 and 4 should be accomplished through early career, mentored experience, which progresses in both complexity and level of responsibility. Level 5, "advocate for ethical behavior in practice of civil engineering," should be achieved through self-development.

References

AAES (American Association of Engineering Societies) and the US Dept. of Labor. 2016. "Engineering competency model." Accessed August 4, 2018. http://www.aaes.org/model.

ASCE. 2016. "Policy Statement 418—The role of the civil engineer in sustainable development." Reston, VA: ASCE. Accessed August 4, 2018. https://www.asce.org/issues-and-advocacy/public-policy/policy-statement-418---the-role-of-the-civil-engineer-in-sustainable-development/.

ASCE. 2017. "Code of ethics." Reston, VA: ASCE. Accessed August 4, 2018. https://www.asce.org/code-of-ethics/.

IEA (International Engineering Alliance). 2013. "Graduate attributes and professional competencies." Accessed August 4, 2018. http://www.ieagreements.org/about-us/key-documents/.

NSPE (National Society of Professional Engineers). 2013. Professional engineering Body of Knowledge. Alexandria, VA: NSPE.

@seismicisolation

Index

@seismicisolation

@seismicisolation

@seismicisolation

U

@seismicisolation