Constituent Input in the Process of Developing the Third Edition of the Civil Engineering Body of Knowledge (CEBOK3)

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Abstract

A careful and inclusive process was used to determine the skills, knowledge, and attitudes that future civil engineers should possess, as articulated in an updated edition of the American Society of Civil Engineers (ASCE) Civil Engineering Body of Knowledge (CEBOK3). A key component was obtaining input from various constituents at multiple points in the process. This paper focuses on three structured surveys that were developed and deployed in winter 2017, fall 2017, and spring 2018. The first survey focused primarily on the importance of the 24 outcomes in the CEBOK2 and additional potential outcomes. The second survey was a pre-draft of CEBOK3 rubrics for the cognitive domain of 21 outcomes and affective domain for 7 outcomes; respondents rated the minimum level of achievement appropriate for all civil engineers as they enter into the practice of civil engineering at the professional level. The final survey on the draft CEBOK3 allowed individuals to provide feedback on those among the 21 outcomes that held the most personal interest. The paper describes the survey development, distribution, and responses for each of the three surveys. Discussion will focus on how the survey helped inform the process of preparing a BOK that was inclusive of the ASCE membership and other stakeholders.

Introduction

A definable body of knowledge (BOK) is a core attribute of a profession [1,2]. However, establishing the appropriate content of a BOK is not an easy task. ASCE first defined a BOK for civil engineering in 2004 [3]. The goal was to determine the core knowledge, skills, and attitudes (KSA) that were necessary for all civil engineers at the point they were qualified to enter the practice of civil engineering at the professional level. There are a number of challenges inherent in this goal. First, there are a broad diversity of career paths in civil engineering, crossing a range of specializations and application areas. Each individual is likely to require KSA beyond the core to be successful in their work. In addition, a career is a lifelong journey of learning. Professions are grounded in formal education, but professionals develop discretionary judgement resulting from practical experience. Further, advances in technology and the nature of civil engineering work mean that the BOK for the profession continuously evolves and grows.

Recognizing this, a vision was crafted to review the Civil Engineering Body of Knowledge (CEBOK) on a regular eight-year cycle [4]. The process to update the CEBOK began in summer 2016, with a request for volunteers to serve on a task committee (CEBOK3TC) to evaluate whether an update to the second edition of the CEBOK from 2008 (CEBOK2) [5] was needed, and if so execute the update. Given the large number of highly qualified individuals who volunteered a pre-workshop was held to both inform potential CEBOK3TC members and gather the thoughtful input from a range of stakeholders. Ultimately, a core of 16 individuals were enlisted to serve on the CEBOK3TC, supported by 70 corresponding members and two ASCE staff (these individuals are listed in Appendix C of the CEBOK3 [6]). Despite the range of expertise among those participating in crafting an update to the CEBOK, plans were in place from the beginning to try to engage an even broader array of stakeholders in the process. Given

the complexity of professions, it is clear that perspectives may differ on the specific KSA that define the BOK. Engaging an array of voices was considered a crucial step in revising the BOK.

The purpose of this paper is to provide a record of the process used to gather constituent input into the development of the CEBOK3. This both informs the CE community and can serve as information for future efforts to update the CEBOK. The following sections of the paper present the survey development, distribution, and responses for each of the three surveys in turn. The paper elaborates on information provided in the ASCE CEBOK3 Appendix D [6].

CEBOK2 Survey, Winter 2017

Survey 1 Development

The process of acquiring input from outside constituencies into the development of the CEBOK3 began early. A subcommittee of the CEBOK3TC focused on "outreach to other constituencies" had a conference call November 2, 2016. They continued their work over the following weeks, developing an online survey via multiple iterations. The goal of the survey was to get feedback from a diversity of stakeholders in the civil engineering community on the existing CEBOK2 and potential new outcomes that were identified via a rigorous literature review process by the CEBOK3TC [7]. New outcomes would reflect the evolution of civil engineering practice in the ten years since the CEBOK2 was developed.

The first section of the survey asked individuals to consider each of the 24 outcomes in the CEBOK2 (2008) in turn. A link to the rubric and the full CEBOK2 was provided. The survey then asked individuals to rate the importance of the outcome using a 5-point Likert-type scale of: 1 = not important; 2 = minor importance; 3 = neutral; 4 = moderately important; 5 = very important. Then the survey asked individuals to rate the quality of the rubric and description of the outcome using a 5-point scale of: 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.

The second part of the survey asked individuals to consider ten potential outcomes that were under consideration for incorporation into the CEBOK3. These ten topics were selected based on a literature review that included the bodies of knowledge of other engineering disciplines, visioning documents from other groups, and reports and papers on engineering education and the profession [7]. Individuals 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. This left it open for interpretation on what was intended. For example, Research Skills could mean many different things to different people. Respondents were therefore asked to provide a brief, open text format, definition for any among the 10 potential outcomes they had rated at 4 or higher. An 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, individuals were asked, "Should ASCE consider addressing post-licensure professional development and career advancement, e.g., certification, in the BOK3?"

Three response options were provided: yes, no, not sure/need more information. An open-ended follow-on question asked respondents to discuss "how should post-licensure professional development and career advancement be addressed, and to what extent?"

The final section of the survey related to demographic items. The standard demographics used on typical ASCE surveys were used, which included: ASCE member or not, highest level of education attained, years of experience in the civil engineering profession (post-college), whether or not the individual is a licensed P.E., current professional grade as an engineer, and employment sector.

Survey 1 Distribution

The survey was created in SurveyMonkey. Pilot testing was conducted by members of the CEBOK3TC to ensure that the survey was easy to follow and functioned as desired. Email invitations were sent to key constituencies within the ASCE membership including civil engineering department heads, 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. Members of the CEBOK3TC invited their colleagues and/or the professional advisory board at their institution to take the survey (individuals who may or may not have been ASCE members). In addition, notices were placed in several ASCE publications, such as daily "Smart Brief" emails, *ASCE News*, and the "Leadership Letter" from the ASCE Executive Director. Participants were invited to take the CEBOK2 constituent survey from January 23 to March 20, 2017.

Survey 1 Respondents

Demographics of the 303 survey respondents are summarized in Table 1. The membership of ASCE is over 150,000; therefore, the survey response rate is very low (well below 1%). The largest percentage of the respondents were licensed professional engineers, had more than 25 years of civil engineering experience, had earned doctoral degrees, and were employed in academia / universities. The results were analyzed to determine if there were differences between the responses of those employed in academia (academics) versus those employed outside academic (practitioners / non-academics). Non-parametric Mann-Whitney U tests were conducted, which are robust to non-normal data and appropriate for the ordinal data generated from the Likert-type response scale. While other demographic characteristics may have had different response patterns (e.g. professional grade, level of education), additional comparisons were not made.

The time that individuals spent taking the survey, based on the recorded start and end dates, ranged from 4 to 44 minutes with a median of 10 minutes. The time that individuals invested in taking the survey provides an indication that the care and depth of thought likely varied among respondents.

Table 1. Summary of Survey Respondent Demographics for Surveys

Question	Categories	Survey 1: CEBOK2	Survey 2: Level of Achieve-ment	Survey 3: CEBOK3 Draft
	Total Number of Responses, n	*303*	*141*	*149**
		%	*%*	*%*
Level of Education	Bachelor's	23	34	24
	Masters	35	30	36
	Doctorate	42	36	39
Years of civil engineering experience (post college)	1-5	4	9	11
	6-10	7	13	10
	11-15	5	11	10
	16-20	12	9	16
	21-25	11	9	22
	>25	60	49	31
Licensed P.E.	Yes	84	83	88
	No	16	17	12
Professional Grade	1-3. Engineer-In-Training, Eng Intern, Assistant Eng, Junior Eng, Staff Eng, Engineering Instructor; GS 5-9	3	9	11
	4. Civil Engineer, Associate Engineer, Project Engineer, Resident Engr, Assistant Professor; GS-11	4	11	6
	5. Senior Engineer, Project Manager, Associate Professor; GS-12	20	19	12
	6. Principal Engineer, District Engineer, Engineering Manager, Professor; GS-13	20	23	22
	7. Director, Program Manager, City / County Engr, Division Engr, Dept Head, Vice President; GS-14	31	20	22
	8. Bureau Engineer, Director of Public Works, Dean, President, Owner, CEO; GS-15	10	12	18
	9. Other non-engineer, non-technical, non-science, students	1	1	1
	10. Retired	11	6	8
Current Employer	Academic / university	37	27	27
	Private-practice engineering consulting firm	29	23	42
	Government agency	14	26	16
	Sole proprietor	4	2	8
	Multi-discipline corporation	7	3	1
	Contractor / builder	1	1	2
	Military	1	1	0
	Association / non-profit	1	1	2
	Other (please specify)	6	4	3
ASCE Member	Yes	94	74	NA
	No	6	26	

* not all individuals reported demographics; NA = not asked

Survey 1 Results and Discussion

The survey 1 results are summarized in Table 2 and Figure 1. The survey results were presented and reviewed by the CEBOK3TC during its in-person meeting March 24-25, 2017.

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. There were some outcomes

with different ratings based on the employer of the respondent [8]; overall across the 24 outcomes the average importance rating was 4.12 for academics and similar at 4.17 for non-academics. Outcomes with importance ratings 0.30 or higher by the non-academics versus the academics were: Attitudes (0.54), Business and Public Administration (0.51), Materials (0.43), Public Policy (0.36), Project Management (0.33); Mathematics was the only outcome with an average importance rating 0.3 or higher by academics versus non-academics (0.55). Six of the 24 CEBOK2 outcomes had average importance ratings lower than 4.0 (bold highlighted in Table 2). Four of these were removed as stand-alone outcomes in the CEBOK3. Humanities and Social Sciences are foundational areas that support other outcomes [9] and were therefore retained.

Table 2. Summary of CEBOK2 Survey Results (bold highlights low averages)

Outcome *	Average Importance (1-5)	Average Outcome Description (1-5)	Number write-in comments
Mathematics	4.13 [A]	3.64	25
Natural Sciences	4.17	3.63	21
Humanities	**3.68**	**2.87** [P]	34
Social Sciences	**3.68**	**2.96**	30
Materials Science	4.31 [P]	3.70	3
Mechanics	4.56	3.86	2
Experiments	3.99	3.71	12
Problem Recognition and Solving	4.75	3.75	2
Design	4.73	3.88	21
Sustainability	4.15	**3.26**	25
Contemporary Issues & Historical Perspectives	**3.75**	**3.41**	11
Risk and Uncertainty	4.49	3.55 [P]	19
Project Management	4.18 [P]	**3.02**	35
Breadth in Civil Engineering Areas	4.14	3.69	11
Technical Specialization	4.03	**3.31**	16
Communication	4.73	3.93	13
Public Policy	**3.75** [P]	**3.30** [P]	21
Business and Public Administration	**3.51** [P]	**3.23** [P]	22
Globalization	**3.21**	**3.01**	40
Leadership	4.11	3.63	22
Teamwork	4.60	3.93	15
Attitudes	4.00 [P]	**3.31** [P]	24
Lifelong Learning	4.42	**3.43**	15
Professional and Ethical Responsibility	4.68	3.66 [P]	10

* italicized outcomes were removed as stand-alone outcomes in the CEBOK3

[P] Practitioner / non-academic responses averaged 0.3 or more than academic responses

[A] Academic responses averaged 0.3 or more than practitioner / non-academic responses

At $\leq$0.3 difference between practitioners and academics, Mann-Whitney U tests (two-tailed) found statistically significant differences with $p<.01$ (99% confidence)

The majority of the survey respondents felt that most of the outcomes were not particularly well described; average description quality ratings ranged from a high of 3.9 for teamwork to 2.9 for humanities; 11 of the 24 outcomes had average description quality ratings below 3.5 (highlighted bold in Table 2). Overall across the 24 outcomes the average description quality rating was 3.36 for academics and slightly higher at 3.55 for non-academics. The results indicated that even

though the majority of the outcome topics in the CEBOK2 were perceived as important, the precise nature and requirements for the outcome should be reconsidered for the CEBOK3. The survey takers were asked to explain any ratings of 2 or below among their importance or description quality ratings for the 24 CEBOK2 outcomes; 155 responses were received. The number of these comments that related to particular outcomes are summarized in Table 2. Common themes included: the outcome was important for some but not all (e.g. 'On Globalization, many US based engineers do not work internationally'), the outcome should not be required for all civil engineers at the time of licensure, types of math knowledge that should (not) be specified (e.g. differential equations not needed), sustainability being important but poorly described, etc. Some comments also generally noted that the descriptions were confusing, vague, included buzz words, or were too complex. These comments were considered in the process of drafting the CEBOK3.

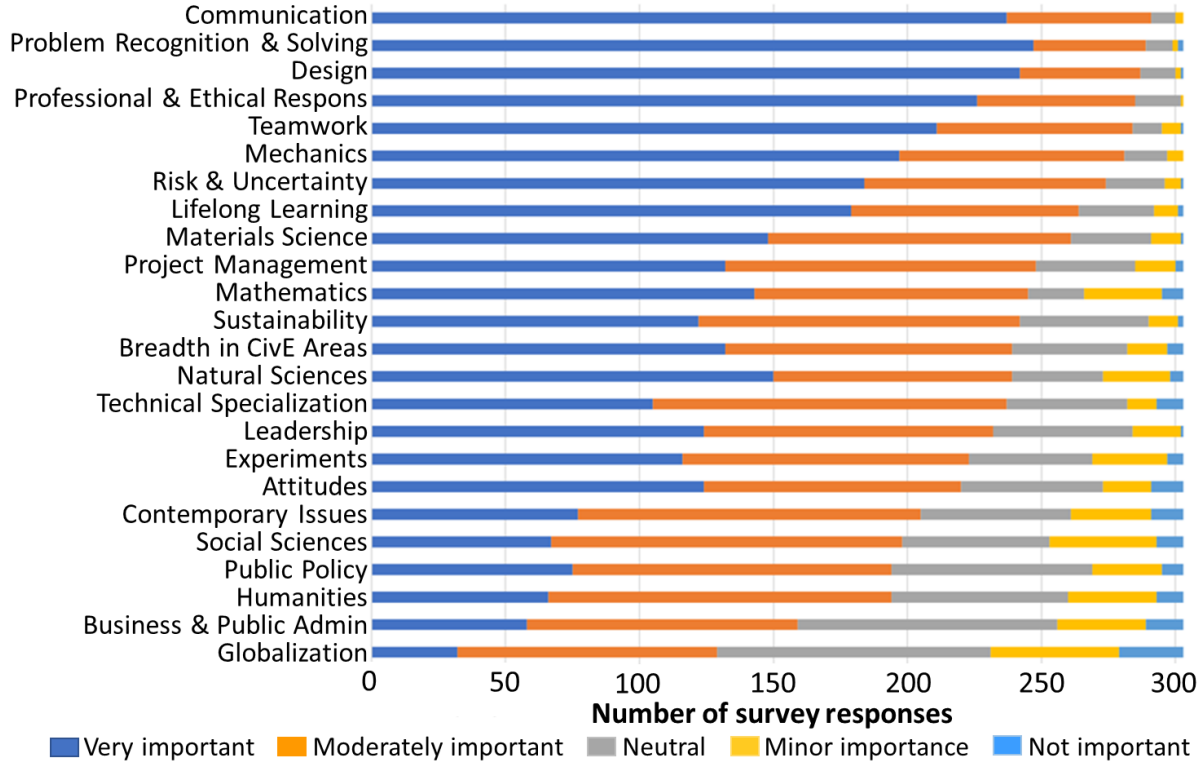

Figure 1. BOK2 outcomes importance, ranked high to low by combined 4+5 survey responses

There were also comments about larger issues. For example, from a practitioner perspective:

> *This survey seems to be geared to making minor tweaks to business as usual, when something more revolutionary is called for.*

> *The list is too long. A low importance score means the skill definition varies so much between industries and companies that what you teach will be useless to a large segment of the trade unless it is so broadly taught as to be meaningless. Either way it is useless to the student and future employer. I look for someone that is a) honest and willing to work, b)*

able to converse with diverse group of people, those not in their peer group and those that do not have the shared interests, and c) curious and interested in learning why things are done the way they are. If they have those traits and a no frills engineering degree they will learn and excel at everything else and there will be a lot less that they have to unlearn.

Perspectives related to academia include:

…it is not feasible for faculty to teach every one of these to any depth within the constraints of a 120 credit hour curriculum or as someone about to be licensed.

Some topics cannot be covered well during limited school time, and while they may be the hallmark of the most successful civil engineers, they are not required at the time of professional registration.

Our students traditionally have been held back by the strictly vocational view of undergraduate engineering education. This speaks to the need to de-constrain undergraduate engineering curricula, to produce more broadly educated individuals who are better positioned to be leaders in civil engineering or whatever professional path they choose.

I am not convinced that we need a BOK. …when I became Department Chair, I became much more heavily involved in recruiting… Civil Engineering is seen as the "old and boring" engineering profession by the students we are trying to recruit. We are disenfranchising the best and brightest, instead of inspiring them.... You would be surprised how many high school students mention having looked at the BOK and decided they would never be able to meet the expectations of this elite club. …. Continuing to refine the "box" that makes everyone like us is causing a significant loss of interest by high school and college students.

These comments reflect the broader concerns about a BOK and how it propagates into issues for education and licensure.

For the 10 outcomes proposed as potential additions to the CEBOK, importance ratings are summarized in Table 3 and Figure 2. The average importance ratings ranged from a high of 4.5 for Critical and Analytical Thinking to a low of 3.2 for Research Skills. Given the predominance of academics among the CEBOK3TC (81%) and corresponding members (64%), the responses from non-academics were particularly of interest to provide a different perspective. Krishnamurthy et al. [8] previously compared the responses of practitioners and academics on the surveys. The ten potential outcomes had an average importance rating by non-academics of 3.85 which was higher than academics at 3.54, and each of the 10 outcomes had a higher average rating by non-academics. The BOK3TC decided that *critical and analytical thinking* could be combined into the existing Problem Recognition and Solving outcome, *interpersonal skills* were encompassed to some degree in Teamwork and Communication, and *safety* into Professional Responsibilities. Engineering Economics was added as a stand-alone outcome in the CEBOK3. *Creativity and innovation* were woven into a number of outcomes including Design,

Sustainability, Professional Attitudes, and Professional Responsibilities. Based on the lower importance of the other outcomes, they were not explicitly added into the CEBOK3.

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 statement or discussion of why these additional outcomes were important. The number of comments pertaining to each of the proposed outcomes is shown in Table 3.

Table 3. Survey 1 Potential Outcomes Proposed for Consideration in the CEBOK

Possible Outcomes	Average importance rating (1 to 5)	Average Rating Not academic – Academic respondents	Number Write-in comments
Critical and Analytical Thinking	4.53	.19	76
Interpersonal Skills	4.12	.47	41
Safety	4.02	.54	47
Engineering Economics	3.98	.28	55
Creativity and Innovation	3.88	.22	34
Information Technology	3.60	.28	29
Legal Aspects	3.54	.50	27
Systems Engineering	3.33	.11	21
Civic Learning / Engagement	3.28	.44	17
Research Skills	3.18	.12	17

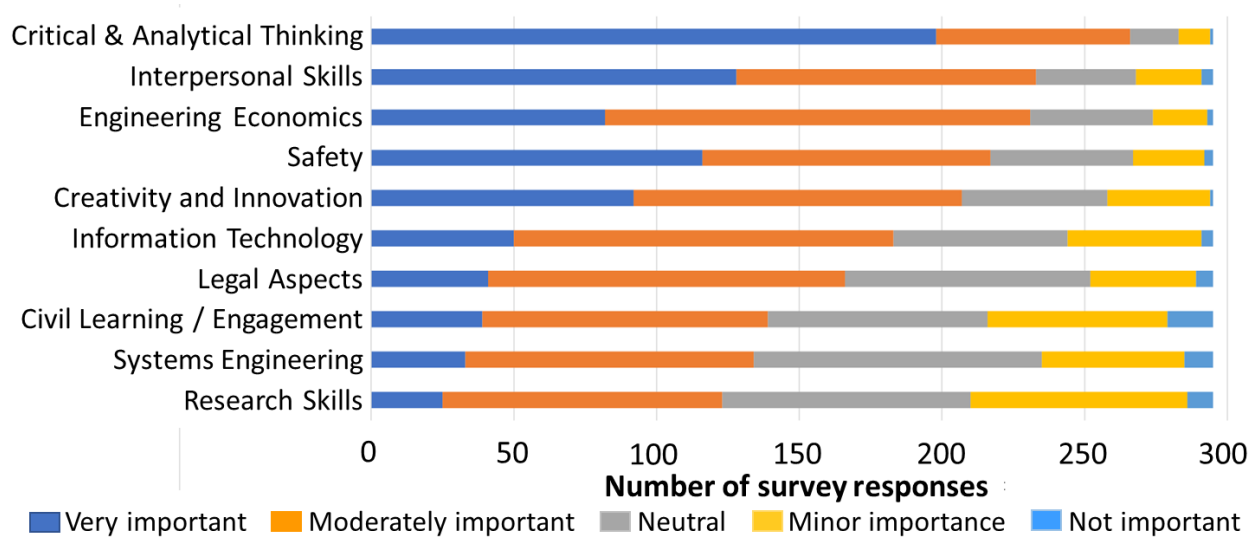

Figure 2. Potential new BOK outcomes importance, ranked high to low by combined 4+5 survey responses

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 these comments related to other aspects, such as already too many outcomes and/or the inter-

relatedness of the outcomes (10 of the comments). Some individuals explained why they felt some of the 10 outcomes were important. Actual "additional outcomes" proposed included public presentations and related communication skills, constructability, modeling, big data, CAD, coding, permitting, procurement, quality assurance / control, foreign language, resilience, and licensure.

In response to the question of whether the CEBOK3 should address post-licensure professional development, the responses were somewhat evenly split among yes, no, and not sure (Table 4). The responses differed by employment sector, with those employed in private-practice engineering consulting firms the most supportive. Highest degree attained also impacted the results, with the most support among those with a Master's degree (48% yes and 21% no) and least support among those with a doctorate degree (21% yes, similar to academic responses as expected since most professors have a PhD). There was not a significant difference among respondents with >25 years of experience in the civil engineering profession versus 1-25 years (data not shown).

Table 4. Percentage of responses to survey question "Should ASCE consider addressing post-licensure professional development and career advancement, e.g., certification, in the BOK3?"

Response	All (n=295)	Employer		
		Academic / university (n=99)	Private-practice engineering consulting firm (n=78)	Government agency (n=39)
Yes	34	20	44	41
No	30	40	21	31
Not sure / need more information	36	39	36	28

A follow-on question asked, "how should post-licensure professional development and career advancement be addressed, and to what extent?" Ninety-six write-in comments were provided, 77 from those who answered yes, 13 from no respondents, and 6 from not sure respondents. Examples from the "yes" respondents included:

> *I believe we are trying to cram too much into the UG curriculum. Many engineers may not need a high level of knowledge in various areas until later in their career. Many skills are better learned through specialized education, through experience, or through mentoring. Many BOK2 topics that are programed in the BS could more effectively be addressed either through extracurricular activities, or later in the engineer's career. For example, how much does an entry level engineer need to know about public policy beyond what they would learn in a high school civics class? By the time someone would need to shape the public policy process they will have years of experience seeing it in action and working through it. The balance between technical topics and soft skills is a tough one. The curriculum has come a long way toward enhancing soft skills since the 1990s. It may be time to allow the pendulum to track back a few degrees by pushing some soft skills in the BS curriculum into the part of the BOK master table.*

Certification should replace the perceived need for an extra year in school- which may or may not be of any use in the workplace. Certification should not be entirely the domain of four year engineering institutions, but could be shared with community colleges and private enterprises.

Need to expand Life Long Learning to over the full career; the need to consistently upgrade, broaden, and learn new emerging skills. Also, strive for specialization exemplified by ASCE's efforts to offer board certification in several disciplines. It demonstrates a level of technical competency the public can trust.

Continuing education requirements can have outcomes associated with them, same as undergraduate program. Again, just be sure that they are not over or under constrained.

Examples from the 'no' respondents included:

I would have a separate publication related to post-licensure professional development and career advancement.

ASCE is already out by themselves on the emphasis on professional licensure compared to other engineering disciplines. Lets stick with that.

Learning is excellent, post-licensure learning is excellent. Certification is not excellent. Certification should not be equated with knowledge or learning.

The charge to the CEBOK3TC from the ASCE board limited the CEBOK3 to consider the KSA one should possess at the point of entry into the practice of civil engineering at the professional level, and not continue to additional certifications or credentials. Individual groups are encouraged to consider these more specialized skills, with proposals in this area from water resources (AAWRE 2005; Kilgore 2015), geotechnical (AGP N.D.), construction engineering (Hildreth and Gehrig 2010), and environmental (AAEE 2009; ABCEP 2018). The CEBOK3TC was also instructed by the board to make the CEBOK3 inclusive of professional progression pathways beyond professional licensure.

The members of the CEBOK3TC were each assigned as primary and secondary reviewers for an average of three of the CEBOK2 outcomes. They were primarily responsible for detailed evaluation of the outcome, including consideration of the survey feedback.

CEBOK3 Pre-Draft Survey, Fall 2017

Survey 2 Development

Based on the survey results and other benchmarking information the CEBOK3TC decided that 21 outcomes should be included in the draft CEBOK3. Among the 24 CEBOK2 outcomes, two were combined (e.g. Teamwork and Leadership), one was split (e.g. Professional and Ethical Responsibilities), and four were removed as stand-alone outcomes although encompassed to some degree within other outcomes (Contemporary Issues & Historical Perspectives; Public Policy; Business and Public Administration; Globalization). Engineering Economics was added

as a new outcome. Each member of the CEBOK3TC was assigned to lead the development of rubrics for one or two outcomes. The CEBOK3TC drafted cognitive rubrics for the 21 outcomes and affective rubrics for 7 outcomes (a so-called pre-draft). It was decided to solicit stakeholder input on where to set the level of achievement that all civil engineers should meet at the time they were qualified for entry into the practice of civil engineering at the professional level.

The first section of the survey provided the cognitive domain rubrics for each of the 21 outcomes in turn, describing the outcome at each of the six levels in Bloom's cognitive taxonomy. 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 individuals to suggest improvements to any of the outcomes, and recommendations for items that may be missing.

The second section of the survey provided a pre-draft of affective domain rubrics for 7 outcomes. Individuals were asked to rate the appropriate affective Bloom's level (from 1 to 5), explain any ratings of "not applicable", suggest improvements to the affective domain outcome statements, and discuss any elements missing from the affective domain.

The final section of the survey contained the same set of demographic items that were used on the first constituent survey.

Survey 2 Distribution

The survey was created in and administered via SurveyMonkey. Similar to the early 2017 survey, invitations were sent to key constituencies, as well as those who had responded to the earlier survey. Because of a brief response period (October 23- November 8), notices were not placed in ASCE publications. There were 141 responses received to this survey between October 23 and November 8, 2017. This is just under half the number of responses received to the first survey, and may indicate that individuals already felt that they had provided input on the BOK and were not interested in participating in an additional survey. The median amount of time individuals were logged in to the survey was 12 minutes. Individuals may have found the task of considering the outcome statements at each level of the cognitive and affective domains more difficult than thinking about the general importance (as was required on Survey 1). The demographics of the survey respondents are summarized in Table 1. The number of survey respondents was reasonably equal across the three levels of education (Bachelor's, Master's, Doctorate). About equal numbers of respondents had 1-25 years and >25 years of civil engineering experience. The largest portion of the survey respondents were employed by government agencies, in contrast to Survey 1 where respondents were predominately academics.

Survey 2 Results and Discussion

The quantitative survey results for the cognitive domain rubrics are summarized in Table 5 and Figure 3. The majority of the 21 outcomes had 1 or more individuals rate the appropriate level of the cognitive domain at all levels, i.e. 1 to 6 of Bloom's taxonomy; individuals could also rate the desired level as N/A (indicating that the outcome should not be included in CEBOK). Only the attitudes outcome had a significant number of N/A responses (n=12); the other outcomes had between 0 to 4 N/A ratings. The majority of the 15 write-in comments that explained why N/A

was selected discussed Professional Attitudes, with a number also discussing Humanities and Social Sciences. Averaging the responses that selected one of the 6 Bloom's cognitive levels, the average ratings ranged from a low of 3.12 for Humanities to a high of 4.78 for Critical Thinking and Problem Solving. The median Bloom's levels ranged from 3 to 5 for all outcomes (Table 5). The mode or most common response for each of the outcomes ranged from level 3 for 11 outcomes to level 6 for three outcomes.

Table 5. BOK3 pre-draft Level of Achievement Survey Results: Cognitive Domain (n=138-141)

Outcome	Cognitive Domain % N/A responses	Average Cognitive Level of Achievement (1 to 6 scale)	Mode level	Median level	Level set in BOK3
Mathematics	0	4.25	4	4	3
Natural Sciences	.7	3.85	3	4	3
Social Sciences	1.4	3.19 [A]	3	3	3
Humanities	2.8	3.12 [A]	3	3	3
Materials Science	.7	3.96	4	4	3
Engineering Mechanics	0	4.18	4	4	3
Experimental Methods and Data Analysis	0	3.96	4	4	4
Critical Thinking and Problem Solving	.7	4.78	6	5	5
Project Management	1.4	3.88	4	4	3
Engineering Economics	.7	3.85	3	4	3
Risk and Uncertainty	.7	3.78	3	4	4
Breadth in Civil Engineering Areas	2.1	3.80	3	4	4
Design	1.4	4.36 [A]	5	4	5
Technical Specialization[+]	0	4.02 [A]	4	4	5
Sustainability	1.4	3.53 [A]	3	3	4
Communication	0	4.11	3, 5	4	5
Teamwork and Leadership	.7	4.00	3	4	5
Lifelong Learning	0	3.93 [P]	3	4	4
Professional Attitudes	8.5	3.88 [P]	3	4	5
Professional Responsibilities	1.4	4.29	6	4	5
Ethical Responsibilities	.7	4.54	6	5	5

[+] Renamed to "Depth in Civil Engineering Areas" in the final CEBOK3

[P] Practitioner / non-academic responses averaged 0.3 or more than academic responses; Mann-Whitney U $p<.01$

[A] Academic responses averaged 0.3 or more than practitioner / non-academic responses; Mann-Whitney U $p<.01$

The average responses across all outcomes from academics of 4.06 was only slightly higher than that among practitioners at 3.93. Five outcomes had average cognitive level ratings that were 0.7 to 0.3 higher among academics than practitioners: Design, Technical Specialization, Sustainability, Social Sciences, and Humanities. Two outcomes had average cognitive level ratings that were 0.4 to 0.3 higher among practitioners than academics: Lifelong Learning and Professional Attitudes. These differences were not found in the importance ratings (Table 2), with the exception of Professional Attitudes which practitioners rated both more important and at a higher level of achievement.

There were 10 contributory responses to the invitation to "provide suggestions or recommendations to improve any of the proposed cognitive domain outcomes." In addition, 25 individuals wrote-in suggestions for things missing from the cognitive domain outcomes, including: computer / information technology skills (programming, AutoCAD, BIM, modeling,

big data), creativity, public policy, legal requirements, licensure, board certification, contracts, business basics, surveying, foreign language, global issues, cultural awareness, and safety.

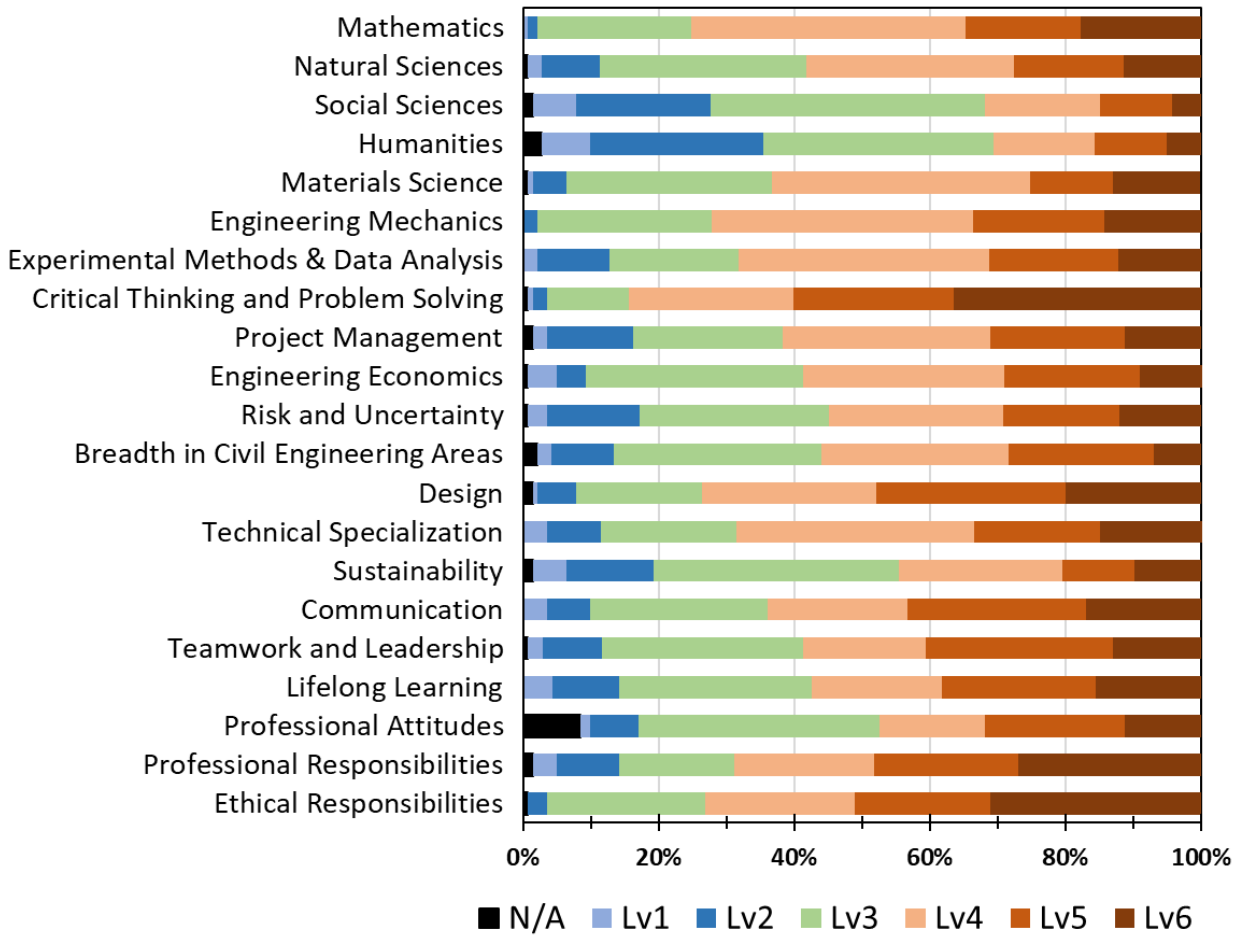

Figure 3. Percentage of survey 2 respondents selecting various cognitive levels of achievement or N/A for each of the 21 CEBOK3 outcomes

The CEBOK3TC proposed that seven outcomes should have affective domain achievement. Survey respondents reviewed the proposed rubrics and rated the minimum level that all civil engineers entering the practice of CE at a professional level should possess; the average of the 1 to 5 Bloom's levels is shown in Table 6. There were 0 to 5 fewer individuals who rated the affective domain compared to the cognitive domain of the same outcome. A higher percentage of the survey respondents rated the affective outcomes as N/A (outcome should not be included in the CEBOK) compared to the cognitive rubric, with the exception of the Professional Attitudes outcome. The highest number of individuals rated four of the affective outcomes at level 4 of the affective rubric (the mode), and level 4 was also the median level for the majority of the outcomes. Six of the affective outcomes were set at an affective level goal of 4 in the CEBOK3, with only Ethical Responsibilities at level 5.

Table 6. BOK3 pre-draft Level of Achievement Survey Results: Affective Domain (n=136-138)

Outcome	Average Affective Level of Achievement (1 to 5 scale)	Affective Domain % NA responses	Mode level	Median level	Level set in BOK3
Sustainability	3.1	3.4	3	3	4
Communication	3.5	1.5	4	4	4
Teamwork and Leadership	3.4	2.2	4	4	4
Lifelong Learning	3.4	2.2	4	3.5	4
Professional Attitudes	3.5	5.8	4	4	4
Professional Responsibilities	3.8	1.4	5	4	4
Ethical Responsibilities	4.1	2.2	5	4	5

A couple of write-in comments opposed the BOK idea in general and/or recommended disconnecting the CEBOK from educational requirements. It is important to acknowledge these perspectives. Two example quotes are:

> *I urge you to sever all links with accreditation. There is a growing body of evidence that this long link between the BOK and accreditation is weighing down the profession in many unanticipated ways. No committee knows the appropriate Body of Knowledge for an individual.*
>
> *In general, while one may deem the BOK to be a valiant effort, it is one that is holding back our profession. It seems that this BOK is being written with the assumption that the people who read it want to be licensed engineers, and that the places that grant degrees in this area need to comprehensively address these topics in some way or otherwise are be considered legitimate programs. This exercise will hold us back unless it is clear that this is a document for an individual to use for their own possible growth -- a self-help document -- and nothing more. The more you make this required, the more vital topics as are listed here will necessarily have to be listed as N/A.*

Based on the survey feedback, changes were made to the rubrics and the explanations of the 21 outcomes.

CEBOK3 Survey, Spring 2018

Survey 3 Development

A survey was conducted to solicit feedback on the draft of the proposed 21 CEBOK3 outcomes, with a goal to get a detailed review of the rubrics and descriptions for each outcome. However, it was believed that the majority of individuals would not want to devote the time needed for a complete review of all 21 outcomes. Therefore, it was decided to structure the survey to allow individuals to review only the outcomes in which they were the most interested. This required the survey to employ a branching structure. The CEBOK3TC also felt that it was important for survey takers to read the entirety of the rubric being evaluated, and therefore embed this within the survey. This more complicated survey architecture could not be accommodated in SurveyMonkey, and therefore the survey was implemented in the Qualtrics platform.

Individuals were provided with a list of the names of the 21 proposed CEBOK3 outcomes and asked to indicate those they wished to review. For the outcomes selected, the survey then

provided the rubric for the outcome that was selected and a link to the detailed explanation (a screenshot for the Mathematics outcome is shown as an example, in the Appendix). The survey taker was asked to rate: (1) the importance of the outcome using a 5-point scale with end anchors (1 = not important; 5 = very important); (2) the quality of outcome name and rubric description using a 5-point scale with end anchors (1 = poorly described, 5 = very well described), and (3) the effectiveness of the explanation using a 5-point scale with end anchors (1 = not effective; 5 = very effective). 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 (in addition to cognitive domain outcomes), both the cognitive and the affective domain rubrics were provided, and individuals were also asked to rate the importance and quality of the affective description.

After completing survey questions about each of the outcomes that an individual initially checked for interest, respondents were asked if they wanted to rate any additional outcomes. The same style of questions were provided for each outcome requested. An open-ended question at the end of the survey invited individuals to "provide any additional feedback on the CEBOK3 draft outcomes." The survey concluded with demographic questions. The same set of demographic items employed in the previous two surveys were used, with the exception that the spring 2018 survey did not ask whether or not the survey-taker was an ASCE member.

Survey 3 Distribution

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 (Committee on Advancing the Profession, Committee on Education, Member Communities Committee, Public Policy Committee, and Committee on Technical Activities), and ASCE Institute leaders. The survey was officially open for responses from March 5 to May 2, 2018, and these responses were considered by the BOK3TC during their in-person meeting May 19-20, 2018.

Survey 3 Respondents

Qualtrics registered 288 responses (individuals who at least started the survey); however, many of those included no useful information. There were 142 fully completed responses and 35 additional responses where 1 or more outcomes were rated. Those who completed the survey rated a median of 7 among the 21 outcomes. Among those who completed the survey, their median amount of time spent (based on the 'duration' reported by Qualtrics) was 15 minutes. The majority of the started surveys answered at least the first question to indicate which outcomes they planned to rate; 48-68% of those outcomes were actually rated. A summary of the demographic information provided by the respondents is provided in Table 1. None of the partially completed responses included responses to the demographic items and others skipped one or more of the demographic items. The most prevalent groups of respondents to this survey included those employed in private consulting firms. Among the three surveys, this survey had the most even distribution of individuals with different years of employment (31% 1-15 years, 38% 16-25 years, 31% >25 years).

Survey 3 Results and Discussion

The quantitative survey results are summarized in Table 7. 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 (n=77-82). The outcome with the fewest ratings was Social Sciences (n=27).

Only three of the 21 outcomes had average importance ratings in the cognitive domain of below 4.0 (indicated in bold in Table 7): Humanities, Social Science, and Project Management; the remaining 18 outcomes had average importance ratings of 4.2 to 4.9. The 7 affective domain outcomes all had average importance ratings above 4.0. The importance ratings for the cognitive and affective domains of the same outcome were generally very similar. The high importance ratings of the outcomes support the idea that the CEBOK3 does not contain inappropriate outcomes. An outcome relationship map in Appendix G of the CEBOK3 illustrates why the foundational outcomes of Social Sciences and Humanities are important, each supporting three outcomes (both support Communication and Sustainability; Social Sciences supports Design and Humanities supports Ethical Responsibilities). The explanation was also revised to strengthen the description of how these foundational outcomes link to civil engineering. In addition, these three outcomes with importance ratings below 4 have a cognitive level of achievement of 3 (apply) which is lower than some of the more important outcomes.

Table 7. Summary of CEBOK3 Draft Survey Responses from Spring 2018

Outcome	n*	Average Cognitive Importance (1 to 5 scale)	Average cognitive rubric description (1 to 5)	Average Affective Importance (1 to 5 scale)	Average affective rubric description (1 to 5)	Average effectiveness of the explanation (1 to 5 scale)
Mathematics	65	4.54	4.23	-	-	4.11
Natural Sciences	47	4.47	4.02	-	-	4.00
Social Sciences	27	**3.78**^{A}	3.85	-	-	3.76
Humanities	40	**3.70**^{A}	3.73	-	-	3.63^{A}
Materials Science	39	4.59	4.05^{P*}	-	-	4.23
Engineering Mechanics	46	4.89	4.26	-	-	4.30
Experimental Methods & Data Analysis	40	4.40	4.25	-	-	4.06
Critical Thinking & Problem Solving	82	4.80	4.46	-	-	4.30
Project Management	65	**3.80**	3.98	-	-	3.94
Engineering Economics	52	4.25	4.00^{P}	-	-	3.96
Risk and Uncertainty	63	4.32^{P}	4.02	-	-	3.87
Breadth in Civil Engineering Areas	64	4.45	4.25	-	-	4.22
Design	65	4.45^{A*}	4.31	-	-	4.22
Technical Specialization	57	4.56	4.50	-	-	4.29
Sustainability	58	4.16^{A}	4.09	4.07^{A}	3.95^{A*}	3.86^{A}
Communication	56	4.68	4.16	4.51	4.07^{A}	4.00^{A}
Teamwork and Leadership	59	4.53	4.22	4.50	4.29	4.29
Lifelong Learning	57	4.33^{A}	4.05^{A}	4.28	4.11^{A}	4.04^{A}
Professional Attitudes	60	4.38	3.81	4.43	3.78	3.78^{P}
Professional Responsibilities	77	4.47^{A}	4.12	4.51	4.00	4.10
Ethical Responsibilities	79	4.75	4.17	4.73	4.25	4.24

* Number of importance ratings for the cognitive outcome; somewhat fewer responses for the rubric description, affective rubric, and the overall effectiveness of the explanation

^{P} Practitioner / non-academic responses averaged 0.3 or more than academic responses

^{A} Academic responses averaged 0.3 or more than practitioner / non-academic responses

* Mann-Whitney U test (two-tailed) $p<.05$

Some differences in the importance ratings between academics and practitioners were found, indicated by superscripts in Table 7. There were six outcomes where the average importance ratings of the outcome in the cognitive domain from the academics were 0.3 points or more than the average among practitioners. However, given the low number of respondents, the difference was only statistically significant for Design (4.93 among 15 academics vs. 4.30 among 50 non-academics). Only the Risk and Uncertainty outcome was rated more important by practitioners than academics. Interestingly, these topics with importance differences were not the same as those identified in the first survey (Table 2) but did mirror the level of achievement results from the second survey for Social Sciences, Humanities, Design, and Sustainability (Table 3). Differences across the surveys could be due to different individuals responding to the surveys and/or changes in how the outcomes were defined and explained. Only one of the outcomes with an affective domain, Sustainability, had a higher average importance rating among academics compared to practitioners.

The quality ratings for the name and cognitive domain rubric descriptions (average 3.73 to 4.46) were higher than the CEBOK2 description ratings (average 2.87 to 3.93). This seems to indicate that the cognitive domain rubrics were generally improved. The affective domain rubric descriptions had average quality ratings similar to the cognitive domain for the same outcomes (average 3.78 to 4.29). Comparatively, the weakest rubric quality ratings were Humanities, Social Sciences, and Professional Attitudes. The descriptions of these outcomes were revised. The average explanation effectiveness ratings ranged from 3.78 to 4.30, with six outcomes below 4.0. There were a few cases where the average quality and effectiveness description ratings differed between academics and practitioners, as shown in Table 7.

Survey takers had the opportunity to provide write-in comments for each outcome they rated, as well as a final open-ended invitation for comments. The number of comments and a summary of key points is provided in Table 8. Per outcome, there was a median of 17 comments (ranging from a low of 8 for experiments and data analysis to a high of 23 for project management. There were also additional comments received via email from 11 individuals. For nearly every outcome some individuals argued that the specified level of achievement for entry into the practice of engineering at a professional level was too high and others argued it was too low. In addition, there was at least one comment / concern with assessment made with respect to all of the outcomes; assessment concerns were considered outside the purview of the CEBOK3. The outcome lead from the CEBOK3TC carefully considered the survey feedback and write-in comments when preparing revisions, primarily in the outcome explanations. In addition, the "technical specialization" outcome was renamed "depth in a civil engineering area" to better reflect the content of the outcome and avoid potential confusion with specialty certifications (which were outside the purview of the CEBOK3).

Table 8. Summary of Write-In Comments on the CEBOK3 Draft Survey

Outcome	n	Summary
Mathematics	18	Level too high or too low; differential equations not needed;
Natural Sciences	17	Pathway does not need to include post graduate education; level too low or too high;
Social Sciences	10	Level too high or too low; needs to be better defined
Humanities	14	Assessment, poor definition, level too high
Materials Science	9	Level too low; engineering materials vs. materials science
Engineering Mechanics	11	Level too low; rubric too prescriptive at lower levels
Experimental Methods & Data Analysis	8	Number of CE areas; pathway to fulfillment; examples; specify experiments
Critical Thinking & Problem Solving	20	Level too low or too high; aim for higher level with undergraduate; more emphasis on problem recognition and definition; define complex problems
Project Management	23	Level too high or too low; ambiguous
Engineering Economics	20	Level too high or too low; specific topics needed; too narrow to be stand alone; increasing importance
Risk and Uncertainty	22	Omits key ideas like big data, uncertainty beyond what can be readily quantified, risk communication
Breadth in Civil Engg Areas	19	Level too low; uncertain why four areas needed vs. other number
Design	14	Should discuss creativity, resilience, and sustainability at lower levels; comments on pathway (undergraduate versus mentored experience); level too high
Technical Specialization	12	Define complex problems; pathway should include mentored experience
Sustainability	20	Level too low or too high; include / distinguish versus resilience (climate change)
Communication	20	Level too high; be more succinct, use direct language, avoid “preachy”
Teamwork and Leadership	16	Level too high (particularly for leadership); affective domain should not be included, affective domain better than cognitive
Lifelong Learning	17	Pathway concerns (undergraduate vs. post-graduate education); oppose mandatory continuing education
Professional Attitudes	18	Which attitudes called out in rubric (others more important, some omitted); creativity and innovation should be stand-alone outcome; unsure these can be taught
Professional Responsibilities	17	Issues with description of safety; innovation comments; service to community or profession?
Ethical Responsibilities	21	Level too low; level 3 should be required for undergraduate education; hard to teach; legal vs. ethical
Overall comments	25	Need better definition of “point of entry into practice of civil engineering at professional level”; clearer distinction between BS graduate and person at licensure; not specific enough; needs to be more simple; needs plainer English

Conclusions

The development of the CEBOK3 involved a concerted effort to acquire broad stakeholder input via three rounds of surveys. Individuals differed in the outcomes they believed should be included in the CEBOK; combining the survey results and judgement of the CEBOK3TC resulted in 21 outcomes. The final product represents a compromise rather than consensus. Some individuals feel that there should be more outcomes and some fewer. In addition, individuals had differing opinions on the appropriate level of the cognitive and affective domains that a civil engineer should possess upon entering the practice of civil engineering at the professional level. The level in the final version of the CEBOK3 is deemed to represent the minimum level that all civil engineers should reach, regardless of specialization area. Most civil engineers will also have deeper knowledge and skills in the outcomes in the CEBOK3 as well as additional attributes. The CEBOK3 includes a recommended path to meet the outcomes, through a combination of

undergraduate education, post-graduate education, mentored experience, and/or self-development. However, this path is not intended to be prescriptive. Some CE Bachelor's degree programs will exceed or not fulfill the outcomes identified as being fulfilled through undergraduate education in the CEBOK3. Some individuals voiced concerns that the CEBOK3 should not set the program-specific criteria for accreditation under ABET. Nor should the CEBOK3 be viewed as setting specific criteria to be vetted for P.E. licensure. Rather, individuals can view the CEBOK3 as recommendations and guidelines. As the civil engineering profession continues to evolve in the future, the CEBOK will be updated accordingly. Civil engineers are encouraged to engage in this effort, so the CEBOK can serve as an effective and evolving guide for individuals, mentors, employers, and educators.

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Appendix. Screen shot from Survey 3

Mathematics

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.*
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. (PG)	**Develop** mathematical models to solve civil engineering problems.	**Assess** mathematical models used to solve civil engineering problems.

Detailed explanation of the mathematics outcome

Please rate the importance of **mathematics** in terms of knowledge needed at entry into the practice of civil engineering at the professional level:

1=not important	2	3	4	5=very important
○	○	○	○	○

Please rate the outcome name and rubric description above of the **mathematics** knowledge needed at entry into the practice of civil engineering at the professional level:

1=poorly described	2	3	4	5=very well described
○	○	○	○	○

If you read the full explanation at the link above, please rate the effectiveness of the explanation:

1=not effective	2	3	4	5=very effective
○	○	○	○	○

For any questions that you rated at 3 or below, please explain the reason for your rating and share any additional comments about the mathematics outcome.