Commentary

On the ABET Program Criteria for Civil and Similarly Named Programs

Effective for 2016-2017 Accreditation Cycle

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A. Purpose of the Commentary

This document was prepared by the Civil Engineering Program Criteria Task Committee as charged by the ASCE Committee on Accreditation. This document provides guidance to civil engineering program evaluators and to civil engineering program faculty by clarifying and amplifying the Civil Engineering Program Criteria to be utilized in association with the Criteria for Accrediting Engineering Programs of the Engineering Accreditation Commission of ABET (EAC/ABET). Nothing in this Commentary is intended to add to, detract from, or modify the EAC/ABET General Criteria for Baccalaureate Level Programs and the General Criteria for Masters Level Programs (hereafter referred to collectively as the “EAC/ABET General Criteria”).

In the spirit of the EAC/ABET General Criteria, this Commentary does not attempt to prescribe a single approach to satisfying the criteria; rather, it emphasizes the educational institution’s freedom to innovate within the framework of an outcomes-based assessment process.

Program evaluation is an inherently subjective process. This Commentary should help evaluators make subjective judgments in a manner that is consistent with the Criteria for Accrediting Engineering Programs of the EAC/ABET. Evaluators are encouraged to use this document as a resource to aid the decision-making process, not as a set of rigid rules to be followed without some flexibility. Ultimately, decisions about compliance with the criteria must be based principally on the evaluator’s professional judgment with input from and concurrence of the visit team, and appropriate program documentation.

This Commentary should assist civil engineering program faculty in better understanding of the Civil Engineering Program Criteria and what must be included in the curriculum relative to the Program Criteria to achieve EAC/ABET accreditation. Additionally, qualifications required of the faculty are included.

There is no ABET policy requiring the measurement and assessment of learning achievement by the graduate of any of the Civil Engineering Program Criteria. However, program faculty must demonstrate each item in the Civil Engineering Program Criteria is taught within the curriculum to the intended levels of achievement, which can be shown or described in course syllabi, assignments, and student work.

Throughout this commentary references are made to Bloom’s Taxonomy. Bloom’s Taxonomy is not a part of the Civil Engineering Program Criteria. However, the authors of the criteria and this commentary utilized Bloom’s Taxonomy in selecting the verbs used to describe intended levels of achievement. Consequently, references to the taxonomy are made to provide guidance in interpreting the language used. A brief discussion of the taxonomy included in Appendix I of this commentary.

The information presented in this Commentary reflects the best collective judgment of its authors and reviewers. It is subject to continual review and revision, to reflect input from constituencies and lessons learned from accreditation practice.
B. The Civil Engineering Body of Knowledge (BOK)

For almost two decades, ASCE has been involved in an ambitious effort to better prepare civil engineering professionals to meet the technological, environmental, economic, social, and political challenges of the future. This “Raise the Bar” initiative attained an important milestone in October 1998, when the ASCE Board of Direction formally adopted Policy Statement 465. The most recent version of this policy states in part:

_The ASCE supports the attainment of an engineering body of knowledge for entry into the practice of civil engineering at the professional level, . . ._

In conjunction with the implementation of Policy Statement 465, ASCE initiated a comprehensive project to define the profession’s body of knowledge (BOK). In 2004 this effort came to fruition with ASCE’s publication of the first edition of the *Civil Engineering Body of Knowledge for the 21st Century* —a report describing the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level. The second edition of this report, published in 2008 and referred to as “BOK2” (download from www.asce.org/civil_engineering_body_of_knowledge/), proved enormously valuable in guiding the subsequent implementation of Policy Statement 465. The conceptual framework includes three key characteristics: (1) the civil engineering BOK is defined in terms of 24 outcomes, (2) the outcomes have clearly defined levels of achievement, and (3) expected levels of achievement are separately specified for baccalaureate-level education, master’s-level education, and pre-licensure experience. This conceptual framework is depicted by the “outcome rubric” extracted from Appendix I of BOK2 and included in Appendix II of this document. Having published its BOK, ASCE determined changes to the accreditation criteria constitute the most viable instrument for affecting the broad-based curriculum reform required for BOK implementation.

In conjunction with the development of the BOK and related Civil Engineering Program Criteria, ASCE identified the need to clearly establish the expected level of achievement associated with each BOK outcome. This distinction is particularly important to ASCE because the civil engineering BOK differentiates the knowledge, skills, and attitudes gained through education from those gained through experience. Given that both education and experience contribute to the attainment of most outcomes, it is critical to define the different level of achievement expected from each source. ASCE addressed this issue by adopting Bloom’s Taxonomy as the basis for defining levels of achievement. Bloom’s Taxonomy is a well-established framework for defining educational objectives in terms of the desired level of cognitive development. It is further described and explained in Appendix I of this document, extracted from Appendix F of BOK2.
C. ABET Engineering Accreditation Criteria

The ABET criteria for accrediting engineering programs are published each year for evaluations during the upcoming accreditation cycle. The criteria are divided into three sections: General Criteria for Baccalaureate Level Programs, General Criteria for Masters Level Programs, and Program Criteria. The ABET “Program Criteria for Civil and Similarly Named Engineering Programs” is provided below. In addition to the Civil Engineering Program Criteria, the EAC/ABET General Criterion 3 Student Outcomes and General Criterion 5 Curriculum are provided in this section for reference and because of the relationship between these parts of the EAC/ABET General Criteria and the Civil Engineering Program Criteria.

Program Criteria for Civil and Similarly Named Engineering Programs

These program criteria apply to engineering programs that include "civil" or similar modifiers in their titles.

1. Curriculum

The curriculum must prepare graduates to apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science; apply probability and statistics to address uncertainty; analyze and solve problems in at least four technical areas appropriate to civil engineering; conduct experiments in at least two technical areas of civil engineering, and analyze and interpret the resulting data; design a system, component, or process in at least two civil engineering contexts; include principles of sustainability in design; explain basic concepts in project management, business, public policy, and leadership; analyze issues in professional ethics; and explain the importance of professional licensure.

2. Faculty

The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience. The program must demonstrate that it is not critically dependent on one individual.
Extracts for the EAC/ABET General Criteria for Baccalaureate Level Programs

The EAC/ABET General Criteria for Baccalaureate Level Programs include the following:

1. Students
2. Program Educational Objectives
3. Student Outcomes
4. Continuous Improvement
5. Curriculum
6. Faculty
7. Facilities
8. Institutional Support

The Civil Engineering Program Criteria have both explicit and implicit relationships with many aspects of Criterion 3 Student Outcomes and Criterion 5 Curriculum. These two criteria are provided here for ease of reference.

**Criterion 3. Student Outcomes**

The program must have documented student outcomes that prepare graduates to attain the program educational objectives.

Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
**Criterion 5. Curriculum**

The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program and institution. The professional component must include:

(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences

(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs

(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

One year is the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation.
D. Understanding the CE Program Criteria

Program evaluation is an inherently subjective process. A common statement in the accreditation criteria is “the program must demonstrate...”, which indicates the burden for demonstrating compliance with the criteria belongs to the program, not the program evaluator. There are innumerable methods available to demonstrate facets of the General and Program Criteria. The program evaluator judges whether the submitted material adequately demonstrates what is claimed.

With this consideration, the following sections should assist both civil engineering program faculty and program evaluators to better understand the Civil Engineering Program Criteria. In addition, for each provision or part of the Program Criteria, a brief background on each criterion is provided. That is, the following sections provide both faculty and program evaluators with an understanding of both “what” is intended by each criterion and “why” the provision is included in the Program Criteria.

It is important to note the Program Criteria include only curricular and faculty requirements. There is no requirement for programs to assess student achievement of the Civil Engineering Program Criteria. The program, however, must clearly demonstrate each curricular item in the Civil Engineering Program Criteria is included within the curriculum, and that the faculty experience and composition meet the faculty requirement of the Civil Engineering Program Criteria.

While Bloom’s Taxonomy is not an explicit part of the accreditation criteria, the Civil Engineering Program Criteria utilizes Bloom’s verbs to describe the intended levels of achievement. Accordingly, references to Bloom’s Taxonomy are made to provide guidance in interpreting the criteria. A brief discussion of the Bloom’s Taxonomy is included in Appendix I.
D-1. Math and Science

The curriculum must prepare graduates to apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science.

Changes from the Previous Edition of the Civil Engineering Program Criteria

| The curriculum program must prepare graduates to apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science, consistent with the program educational objectives |

Understanding the Criterion

To comply with this provision of the Civil Engineering Program Criteria, the program must demonstrate its curriculum content is sufficient to prepare graduates to apply concepts and principles from mathematics and science to solve relatively straightforward problems. This must include mathematics through differential equations, calculus-based physics, chemistry, and one additional area of basic science. The program should present sufficient information and document that these subject areas are adequately covered within the curriculum and that all students must take the necessary courses in order to graduate. Additionally, while the EAC/ABET General Criterion 5(a) requires one year of a combination of mathematics and science, it does not have separate requirements for a minimum number of credit hours or courses in any of these subject areas.

For the additional area of basic science, programs may include areas such as biology, ecology, geology or meteorology, all areas of significant interest and increasing importance for civil engineers. This list is not all-inclusive, and it is not necessary all students within a particular program’s curriculum take the same additional area of science. However, for topics other than those listed above, it is the program’s responsibility to demonstrate the selected area(s) of science provides breadth beyond physics and chemistry. In general, an advanced course in physics or chemistry (i.e., a physics or chemistry course that is part of a physics or chemistry sequence for which a basic-level physics or chemistry course serves as a prerequisite) would not fulfill this requirement because such a course would provide additional depth rather than additional breadth. Still, programs should have a degree of flexibility in choosing basic science courses that meet this breadth requirement. Courses such as geo-physics, seismology, organic or bio-chemistry that are not part of a standard physics or chemistry sequence might be appropriate, especially if they can be tied to student outcomes and program’s curricular emphasis. Likewise, a course primarily engineering science in
content would not fulfill this requirement. It has been long established that courses such as thermodynamics, computer science or materials science do not meet this requirement.

**Background/Rationale**

The EAC/ABET General Criterion 3(a) requires “an ability to apply knowledge of mathematics, science, and engineering.” Additionally, the EAC/ABET General Criterion 5(a) requires “one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences.” ABET defines one year as “the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation.” Refer to Appendix I or www.abet.org for addition information on the EAC/ABET General Criteria.

The Second Edition of the Civil Engineering Body of Knowledge includes two outcomes related to this provision of the Civil Engineering Program Criteria: Outcome 1 – Mathematics and Outcome 2 – Natural Sciences (see Appendix II). Mathematics through differential equations, calculus-based physics, and chemistry are considered part of the technical core of civil engineering and, thus, are explicitly required by the Civil Engineering Program Criteria.

The requirement for “one additional area of basic science” comes from the Second Edition of the Civil Engineering Body of Knowledge and reflects an increasing emphasis on biological systems, ecology, sustainability, and nanotechnology within the practice of civil engineering. The intent is for civil engineering graduates to develop greater breadth in the basic sciences beyond the technical core subjects of physics and chemistry. While the BOK2 defines the additional area of science as a “natural science,” ABET defines “basic science” as biological, chemical, and physical sciences. This definition of a basic science is consistent with the goals of the BOK2 and is, therefore, adopted for use in the Civil Engineering Program Criterion.

The phrase “consistent with the program objectives” was removed from the criteria because the words do not add anything meaningful to the criteria. Program objectives are very broad, describing graduates’ abilities three to five years after graduation. It would be difficult to envision an example of a basic science that would be inconsistent with program objectives.

According to Bloom’s Taxonomy (see Appendix I), the verb “apply,” which is used in the EAC/ABET General Criterion 3(a) and in this provision of the Civil Engineering Program Criteria, denotes the expected level of achievement is Bloom’s Level 3, or “application level.” Both the Civil Engineering BOK2 Outcome 1 – Mathematics and Outcome 2 – Natural Sciences are also at Bloom’s Level 3 of achievement. Therefore, this provision of the Civil Engineering Program Criteria agrees with the targeted level of achievement for math and science as conveyed in the Second Edition of the Civil Engineering Body of Knowledge.
D-2. Probability and Statistics

The curriculum must prepare graduates to apply probability and statistics to address uncertainty

Changes from the Previous Edition of the Civil Engineering Program Criteria

The curriculum program must prepare graduates to apply probability and statistics to address uncertainty

Understanding the Criterion

Probability and statistics are related but separate areas of study. Probability is used to quantify the likelihood, or uncertainty, an event will occur, whereas statistics models or characterizes the dispersion of data or relationships between data sets. The intent of this provision of the Civil Engineering Program Criteria is not to require a specific course or set of courses a curriculum must include, nor is it to define specific topics within probability or statistics that must be included. Rather, the provision is meant to prepare graduates to deal with real-world uncertainties in design and planning. That is, the intent is to provide students with a foundation on which they, as future professionals, can manage risk and uncertainty.

To comply with this provision of the Civil Engineering Program Criteria, the program must demonstrate its curriculum content is sufficient to prepare graduates to apply concepts and principles from probability and statistics to address uncertainty in data, measurements, or calculations. This may include a specific course in probability and statistics, but such a course is not required to meet this provision of the program criteria. The relevant concepts from probability and statistics may be integrated into one or more engineering courses. The key element is for the curriculum to include the opportunity for students to apply these concepts to address uncertainties.

One possible way to integrate probability and statistics concepts into an engineering course and address uncertainties is to include them in laboratory courses that require students to analyze and interpret the resulting data (see Section D-4 on Civil Engineering Experiments). That is, this provision of the program criteria may be met if the analysis and interpretation of the data explicitly addresses uncertainty by, for example, defining potential sources of experimental errors and estimating the cumulative effect of the errors in characterizing the resulting data.
**Background/Rationale**

This is a new provision to the Civil Engineering Program Criteria, and there is not a specific corresponding provision in the EAC/ABET General Criteria. Probability and statistics, however, may be considered part of the mathematics requirement included in the EAC/ABET General Criterion 5(a). Refer to Section B or www.abet.org for addition information on the EAC/ABET General Criteria.

While the probability and statistics provision is referred to new to the Civil Engineering Program Criteria, it was actually part of the program criteria until 2006-2007. At that time, the provision required “graduates have: proficiency in ... probability and statistics...” The provision was removed primarily for two reasons. First, probability and statistics was not included explicitly in the first edition of the Civil Engineering Body of Knowledge. Second, while still recognizing the importance of subject matter, there was a belief that even without the provision most programs would continue to include probability and statistics.

As the Second Edition of the Civil Engineering Body of Knowledge was being prepared, there was broad support for including an outcome related to risk and uncertainty. Based on that input, the BOK now contains Outcome 12 – Risk and Uncertainty (see Appendix II), which includes the following outcome statement at the baccalaureate level: “apply principles of probability and statistics to solve problems containing uncertainties.” While the BOK Outcome 12 is titled Risk and Uncertainty, risk is not explicitly included in outcome statements at the undergraduate level. Adding risk in addition to uncertainty would be exceeding the requirements stated in the BOK2.

Since probability and statistics concepts are integral to most civil engineering subjects and since they are included in the BOK2, the subject matter was reintroduced into the Civil Engineering Program Criteria. Moreover, graduates are required to be able to analyze and interpret data from experiments, which implies some background in probability and statistics. It is entirely feasible for appropriate coverage of probability and statistics to occur in the associated engineering courses, rather than in a separate course in probability and statistics.

According to Bloom’s Taxonomy (see Appendix I), the verb “apply” denotes the expected level of achievement is Bloom’s Level 3, or “application level.” Both this provision of the Civil Engineering Program Criteria and the related BOK2 outcome use the same verb “apply,” therefore this program criterion is consistent with the BOK2.
D-3. Breadth in Civil Engineering

The curriculum must prepare graduates to analyze and solve problems in at least four technical areas appropriate to civil engineering.

Changes from the Previous Edition of the Civil Engineering Program Criteria

The curriculum must prepare graduates to apply knowledge of analyze and solve problems in at least four technical areas appropriate to civil engineering.

Understanding the Criterion

The field of civil engineering involves many traditional technical areas of specialization. Seven generally recognized civil engineering technical areas include:

- Construction engineering
- Environmental/sanitary engineering
- Geotechnical engineering
- Hydraulics/hydrology/water resources engineering
- Structural engineering
- Surveying/measurements
- Transportation engineering

The field of civil engineering continues to evolve, and new specialty areas will continually emerge. It is important the enforcement of this provision of the program criteria not stifle curricular innovation and a program’s ability to respond to future opportunities or needs. If a curriculum’s four technical areas include one or more areas not listed above, the program (not the evaluator) is responsible for demonstrating the technical area or areas are “appropriate to civil engineering.” The program must provide information on which a well-reasoned judgment can be made by the program evaluator. This judgment must balance the desirability of curricular innovation against the need for relevant technical breadth in all civil engineering graduates. The judgment may not be based on the evaluator’s personal view of what civil engineering should or should not be.

Some possible justifications for a non-standard technical area to be included as appropriate to civil engineering might include the following:
• ASCE has an institute or technical division in the technical area.
• ASCE publishes a journal in the technical area.
• ASCE sponsors specialty conferences in the technical area.
• There are civil engineering consulting firms that specialize in the technical area.

Again, this list is not all-inclusive since many other legitimate, well-reasoned justifications are possible.

Note there is no requirement for a minimum number of credit hours or courses in each of the four technical areas, and there is no requirement that all graduates of a given program take courses in the same four areas.

**Background/Rationale**

This is a long-standing provision of the Civil Engineering Program Criteria. The intent of this provision is to ensure every civil engineering graduate has sufficient relevant technical breadth. This provision of the Program Criteria may be used to support the EAC/ABET General Criterion 3 Student Outcomes (a) an ability to apply knowledge of mathematics, science, and engineering, and 3(e) an ability to identify, formulate, and solve engineering problems.

The areas of civil engineering a program chooses to include in its curriculum are intentionally not specified in this provision. The field of civil engineering is evolving, and new specialty areas continually emerge. It is critically important the enforcement of this criterion not stifle curricular innovation. There are, of course, many traditional areas of civil engineering programs can include, such as construction, environmental, geotechnical, structural, surveying, transportation, and water resources.

Again, this provision of the program criteria is not intended to specifically mandate any particular areas of civil engineering because many traditional and legitimate non-traditional or emerging areas are possible. For any non-traditional or emerging area, the program must provide a well-reasoned justification for including the area as one of the four technical areas in fulfilling this provision.

In addition to intentionally not specifying the areas of civil engineering required in a curriculum, the provisions do not require a minimum number of credit hours or number of courses in each of the four technical areas. Also, there is no requirement that all graduates of a given program take courses in the same four areas. A curriculum may be designed to allow students to select a number of areas from a list as defined by the program.

The primary change from previous editions of the breadth provision of the Civil Engineering Program Criteria is replacing “apply knowledge of” with “analyze and solve problems” to make this provision of the program criteria consistent with the Second Edition of the Civil Engineering Body of Knowledge. Following Bloom’s Taxonomy (see Appendix I), the verb “apply” used in previous editions of this provision expected
Bloom’s Level 3, Application. The current provision uses “analyze and solve.” While “solve” is a Bloom’s Level 3 verb, “analyze” is a Bloom’s Level 4, Analysis verb. Therefore, the level of achievement to be included in a curriculum is raised. The requirement to “apply” knowledge is the ability to use learned material in new and tangible situations. This may include the application of such things as rules, methods, concepts, principles, laws, and theories. “Analysis” refers to the ability to break down material into its component parts to understand its organizational structure. This may include identifications of parts, analysis of the relationship between parts, and recognition of the organizational principles involved. Analysis is a higher cognitive level than application because it requires an understanding of both the content and the organizational form of the material. Considering this, most curricula in meeting the previous edition of this provision likely meet the new, higher level provision and the BOK2 breadth outcome.
The curriculum must prepare graduates to conduct experiments in at least two technical areas of civil engineering, and analyze and interpret the resulting data

Changes from the Previous Edition of the Civil Engineering Program Criteria

The curriculum program must prepare graduates to conduct civil engineering experiments in at least two technical areas of civil engineering, and analyze and interpret the resulting data

Understanding the Criterion

The EAC/ABET General Criterion 3(b) requires “an ability to design and conduct experiments, as well as to analyze and interpret data.” The emphasis of this provision of the Civil Engineering Program Criteria is on conducting laboratory experiments or tests in at least two technical areas of civil engineering and then analyzing and interpreting the resulting data. Compliance can be demonstrated by showing graduates have sufficient exposure to laboratory experiences within the curriculum and that all students must obtain that level of exposure in order to graduate.

The criterion requires the program include experimental experience in at least two technical areas of civil engineering. As noted with the provision requiring breadth in civil engineering, there are at least seven generally recognized civil engineering technical areas. In addition, the field of civil engineering is evolving, and new specialty areas will emerge. The program may consider providing experimental experiences in generally recognized civil engineering technical areas as well as new or emerging technical areas of civil engineering practice. Regardless of the specific technical areas, the program must provide experimental experiences in at least two different areas.

To comply with this provision, the experimental experiences should include, but are not limited to the following:

- Understanding of the objectives and procedures associated with an experiment
- The conduct of an experiment, including setup, measurement and data collection
- Observation and documentation of error and uncertainties in data collection procedures
- Critical analysis of data
• Interpretation of the experimental results, with appropriate conclusions and recommendations
• Application of experimental procedures and analysis of results consistent with a real-world civil engineering problems or situations

A growing trend in engineering curriculum development involves the use of “virtual laboratories.” These computer simulations attempt to replicate the hands-on experiences of conventional physical labs. In general, such curricular innovations are encouraged, and the program evaluator must keep an open mind when considering their effectiveness. An evaluation of a virtual laboratory experience should consider such factors as:

• The extent to which the subject matter lends itself to accurate simulation.
• The extent to which the simulation replicates the actual physical experiences of setup, measurement, errors, and data collection.
• The nature of student interaction with the simulation.
• The students’ abilities acquired through the simulation.
• Students’ satisfaction with their abilities gained through the simulation.

Background/Rationale

The EAC/ABET General Criterion 3(b) requires “an ability to design and conduct experiments, as well as to analyze and interpret data.” The Civil Engineering Program Criteria differs from EAC/ABET General Criterion 3(b) in that there is no mention of an ability to “design experiments,” but there is an additional requirement of student exposure to experiments “in at least two technical areas of civil engineering.”

The design of experiments is not emphasized in the Program Criteria because civil engineers generally do not develop experimental procedures; rather, they select and conduct experiments according to published standards, such as the American Society for Testing and Materials (ASTM) specifications and the Standard Methods for the Examination of Water and Wastewater. Nonetheless, it is important to recognize the absence of any reference to experimental design in the Civil Engineering Program Criteria does not relieve a program of responsibility for compliance with the “design experiments” provision of EAC/ABET General Criterion 3(b).

Prior editions of the program criteria required programs to “prepare graduates to conduct civil engineering experiments.” The requirement of including an experimental experience in “at least two technical areas of civil engineering” is new and stems from a perceived reduction in the practical hands-on skills of students entering civil engineering curricula and an apparent trend towards a reduction in laboratory courses from engineering curricula. Additionally, this new breadth of experiments supports and aligns with the BOK2 experiments outcome.

Consistent with Bloom’s Taxonomy (see Appendix I), the verb “conduct” in this provision of the Program Criteria implies the level of achievement for such tasks as experimental
setup, measurement, and data collection is Level 3, Application. The verbs “analyze” and “interpret” imply the level of achievement for processing experimental data is Level 4, Analysis.

With respect to the General Criteria, the verb “design” implies the expected level of achievement is Level 5, Synthesis. Thus the design of experiments must reflect the putting together of parts to form a new whole. However, because the requirement for experiment design occurs only in the General Criteria, there is no requirement for students to design experiments in a civil engineering context. Thus the program would be in full compliance if students’ ability to design experiments were acquired, for example, in a physics, chemistry, or engineering mechanics course.
D-5. Civil Engineering Design

The curriculum must prepare graduates to design a system, component, or process in at least two civil engineering contexts

Changes from the Previous Edition of the Civil Engineering Program Criteria

The curriculum must prepare graduates to design a system, component, or process in at least two more than one civil engineering contexts

Understanding the Criterion

The EAC/ABET General Criterion 3(c) requires “an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.” The Civil Engineering Program Criteria further requires a breadth of the design experience in at least two civil engineering contexts. Therefore, to comply with this provision of the Civil Engineering Program Criteria the program must demonstrate its curriculum content is sufficient to prepare graduates to perform engineering design in at least two areas of civil engineering.

ABET provides the following definition of engineering design in EAC/ABET General Criterion 5 for Curriculum: “Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.”

This definition should form the basis for evaluation of the design-related provisions of the Civil Engineering Program Criteria. Elements to look for in evaluating students design experience include, but are not limited to:

- The engineering design process typically includes both analysis and synthesis. Analysis involves the application of engineering tools and principles to predict the performance of a system, component, or process; synthesis involves the creation of a new system, component or process to meet desired needs. Analysis without synthesis is not engineering design.

- Normally, analysis and synthesis are performed in an iterative cycle. Thus, students should experience some iterative design in the curriculum. It is not, however, necessary for all design experiences to be iterative. Such a requirement would place an unrealistically heavy burden on both faculty and students.
• Engineering design problems are generally ill-defined. As part of their design experience, students should have an opportunity to define a problem, to include determining the problem scope and design objectives.

• Engineering design problems are generally open-ended. They have no single correct answer, rather a range of possible solutions. Nonetheless, the evaluator must recognize, in an academic setting, there are significant practical constraints on a program’s ability to implement open-ended design experiences across the curriculum. The program must strike an appropriate balance between the desirability of open-ended design problems, the limitations of students’ knowledge and experience, and the need to provide students with high-quality feedback on their design computations. It is both typical and appropriate for a design problem to have a relatively narrow range of “correct” solutions. Similarly, the term optimal (or optimally) should be interpreted with caution. While some engineering design problems may have optimal solutions, others (such as ill-defined systems problems) may not have an optimal solution per se. Some engineers might even argue no problems other than the most trivial have true optimal solutions.

• Engineering design does not necessarily involve devising a complete system. The design of a component (e.g., a beam or column) or subsystem (e.g., a roof truss) may constitute an acceptable design experience. Students’ design experience is enhanced, however, if they can also gain an appreciation for the design of large-scale systems.

• Engineering standards and realistic constraints are critical in civil engineering design. The program must clearly demonstrate where standards and constraints are taught and how they are integrated into the design component of the curriculum. In civil engineering, the most common types of standards are consensus standards, codes and regulations. Constraints explicitly cited in EAC/ABET General Criterion 3(c) are economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability considerations. In a civil engineering context, manufacturability is generally interpreted as constructability.

• Engineering design is increasingly interdisciplinary, and requires students to function on multidisciplinary teams. For civil engineering design, a team consisting of (1) representatives from the established sub-disciplines of civil engineering, (2) a more broadly comprised team with representatives from civil engineering, other engineering disciplines, architecture, law, finance, etc., or (3) some combination of the two would be considered multidisciplinary teams.

The program must also demonstrate students have adequate exposure to design, as defined, in at least two civil engineering contexts. The intent of this is for these “civil engineering contexts” to be significantly different from one another.
One unambiguous way to satisfy the criterion for at least two civil engineering contexts is for the program to require its students to experience design in more than one technical area of civil engineering as defined for the Breadth in Civil Engineering criterion (see Section D-3). For example, a program that requires students to design both a reinforced concrete building frame (a structural engineering context) and a deep foundation (a geotechnical engineering context) is probably in compliance. Conversely, a program that requires students to design a reinforced concrete structure and a steel structure may not be in compliance, because the design process for steel and concrete structures is so similar.

**Background/Rationale**

This provision of the Civil Engineering Program Criteria is basically unchanged from previous editions of the criteria. It is intended to assure a breadth of design experiences is included in the curriculum. Consistent with Bloom’s Taxonomy (see Appendix I), the verb “design” implies the expected level of achievement is Level 5, Synthesis. This is also consistent with the ABET definition for engineering design.

Requiring design experiences in at least two civil engineering contexts also builds on the Breadth in Civil Engineering provision (see Section D-3) of the Civil Engineering Program Criteria. The Breadth in Civil Engineering provision requires the curriculum to “prepare graduates to analyze and solve problems in at least four technical areas appropriate to civil engineering,” which implies the expected level of achievement for the four or more areas is Bloom’s Level 4, Analysis. Therefore, it can be inferred for at least two technical areas of civil engineering that the expected level of achievement is raised to Level 5, Synthesis.
D-6. Sustainability in Design

The curriculum must prepare graduates to include principles of sustainability in design

Changes from the Previous Edition of the Civil Engineering Program Criteria

Understanding the Criterion

This is a new provision to the Civil Engineering Program Criteria. Sustainability is included, but not mandated, as one of several possible constraints in the EAC/ABET General Criterion 3(c), which requires “an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.” The Civil Engineering Program Criteria reflects the importance of including sustainability and identifies it as necessary to the design process. Therefore, to comply with this provision of the Civil Engineering Program Criteria the program must demonstrate its curriculum content prepares graduates to include principles of sustainability in design.

There are many definitions of sustainability, and there is not a consensus definition of what constitutes sustainability. This is specifically recognized in the provision’s wording of “… include principles of sustainability” versus “… include the principles of sustainability.” This recognizes there is not a specific set of principles of sustainability that must be included. Rather, the program is allowed the latitude to include principles of sustainability in a context most appropriate for its curriculum.

ASCE defines sustainability as follows: “A set of environmental, economic 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 availability of natural, economic, and social resources.” This definition is comprehensive and recognizes the “triple bottom line” of environmental stewardship, economic growth, and social progress.

The criterion does not require a program to include sustainability in all student design experiences or that it be included in more than one context. The criterion simply requires coverage of sustainability in the curriculum be sufficient so graduates can include key concepts of sustainability in an engineering design, in at least one context.
Background/Rationale

The importance of sustainability is communicated in many ways, and ASCE is a recognized leader in this advancing area. The Civil Engineering Code of Ethics includes as one of the Fundamental Cannons that “Engineers shall...strive to comply with the principles of sustainable development...” The BOK2 also has an outcome specific to sustainability, which states baccalaureate-level students should be able to “apply the principles of sustainability to the design of traditional and emergent engineering systems.” The verb “apply” indicates a level of attainment for sustainability at Bloom’s Level 3 – Application.

While Criterion 3(c) of the EAC/ABET General Criteria lists “sustainability” as one of eight constraints that should be considered in a design, these eight constraints are preceded by the words “such as,” which is commonly interpreted by ABET evaluators as meaning the program complies if it demonstrates students can design within “at least one” of the listed constraints. Criterion 5 states the culminating design experience must include “multiple realistic constraints.” Therefore, considering both EAC/ABET General Criterion 3 and Criterion 5, a program lacking coverage of sustainability complies with the present criteria. However, requiring an additional curricular topic that fully addresses the BOK2 outcome statement was deemed too far-reaching and potentially too difficult for programs to attain without creating a separate course in sustainability. The provision as stated, “to include principles of sustainability in design,” allows a more qualitative approach and lowers the cognitive level of achievement required, yet ensures sustainability is not neglected by simply being part of a larger list of requirements.
D-7. Project Management, Business, Public Policy, and Leadership

The curriculum must prepare graduates to explain basic concepts in project management, business, public policy and leadership

Changes from the Previous Edition of the Civil Engineering Program Criteria

The curriculum program must prepare graduates to explain basic concepts in project management, business, public policy, and leadership

Understanding the Criterion

This provision of the Civil Engineering Criteria includes four components: basic concepts in project management, business, public policy, and leadership. Previously, this provision did not specifically state project management and implied a broader exposure to management, including project management, construction management, and asset management.

Examples of basic concepts in project management include project manager responsibilities, defining and meeting client requirements, risk assessment and management, stakeholder identification and involvement, contract negotiation, project work plans, scope and deliverables, budget and schedule preparation and monitoring, interaction among engineering and other disciplines, quality assurance and quality control, and dispute resolution processes.

Examples of basic business concepts typically applied in the private, government and non-profit sectors include legal forms of ownership, organizational structure and design, income statements, balance sheets, decision (engineering) economics, finance, marketing and sales, billable time, overhead, and profit.

Examples of basic public policy concepts include the political process, formulation of public policy, laws and regulations, funding mechanisms, public education and involvement, government-business interaction, and the public service responsibility of professionals.

Leadership, which differs from and complements the other components of this criterion, requires broad motivation, direction, and communication skills. Examples of desirable behaviors of leaders, which can be taught and learned, include earning trust, trusting
others, formulating and articulating vision, communication, rational thinking, openness, consistency, commitment to organizational values, and discretion with sensitive information.

Consistent with Bloom’s Taxonomy, the verb “explain” in this criterion implies the expected level of achievement is Level 2 – Comprehension. Graduates must explain some (but not all) of the key concepts in the four areas listed in the provision. It is not necessary for the program to offer one or more courses explicitly devoted to project management, business, public policy, or leadership. Rather, these topics may be integrated into other courses or curricular experiences. Additionally, graduates’ ability to explain generic, business-oriented project management, business, public policy, or leadership concepts such as those acquired from a course or courses offered outside engineering could also represent full compliance with this criterion.

**Background/Rationale**

Narrowing the focus on management in the previous program criteria to project management in the current program criteria recognizes civil engineering work is largely project based. Additionally, to be effectively productive on a project, civil engineers need to know how their work fits into the overall team effort to produce the project. This focus is not intended to diminish any involvement of civil engineers in construction or asset management.

To the extent construction management involves managing a project and not, for example, managing a construction firm or managing construction financing, it could meet the intent of the focus on project management. Similarly, to the extent asset management involves managing a project and not, as examples, managing inventory or managing facilities, it could meet the intent of the focus on project management.
D-8. Professional Ethics

The curriculum must prepare graduates to analyze issues in professional ethics

Changes from the Previous Edition of the Civil Engineering Program Criteria

The curriculum program must prepare graduates to analyze issues in professional ethics

Understanding the Criterion

The EAC/ABET General Criterion 3(f) requires that graduates have “an understanding of professional and ethical responsibility.” Programs could have students achieve an “understanding” of professional and ethical responsibility as required by the EAC/ABET General Criterion 3(f) through seminars or lectures.

However, the provision in the Civil Engineering Program Criteria that graduates “analyze issues in professional ethics” reflects an expectation for a higher level of achievement in professional ethics than required by EAC/ABET General Criterion 3(f). This provision of the Civil Engineering Program Criteria reflects a greater importance of professional ethics by requiring a curriculum to include an opportunity for students to go beyond a simple understanding of ethical responsibility and have students analyze issues in professional ethics.

Consistent with Bloom’s Taxonomy, the verb “analyze” used in this criterion implies the expected level of achievement is Level 4 – Analysis. In this context, for example, analysis implies the ability to determine the fundamental elements of an ethical issue to allow for a close examination and potential resolution. This may be done through a number of mechanisms, such as a compare-and-contrast approach to an ethical issue using case studies, analyzing video scenarios, or first-hand debate of ethical dilemmas.

While there are a wide variety of ways a program may meet this criterion, one possible way to encourage students’ ethical development is to provide developmentally appropriate curricular experiences in multiple contexts at multiple times through the curriculum. It is not necessary to have a separate course in ethics to satisfy this criterion. Students, early in curriculum, may list and explain ethical and professional responsibilities. This could then evolve into having students apply ethical codes and standards to determine an appropriate course of action for a specific circumstance. Analysis of ethical situations could be woven into upper division design problems or into a senior project culminating design.
Another possible way to address this criterion is to include ethical development in selected co- and extra-curricular activities. Having students participate in community service, professional societies, or having co-op or internship opportunities reinforce the in-class learning and may provide “real-world” experiences for students to analyze issues in professional ethics. The recognized difficulty in this approach is documenting that every student participates in a relevant co- or extra-curricular experience.

It is critically important to recognize programs may prepare their graduates to analyze issues in professional ethics in any number of ways. The examples provided here serve only to assist with understanding this new criterion, not prescribe how any program should meet the criterion. Regardless of the program’s specific approach, the curriculum only needs show how it prepares its graduates to analyze issues in professional ethics.

**Background/Rationale**

The Civil Engineering BOK2 Outcome 24 – Professional and Ethical Responsibility states baccalaureate-level civil engineering graduates should be able to “analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action.” The Civil Engineering Program Criteria requirement that graduates “analyze issues in professional ethics” includes most, but not all, of BOK2’s Outcome 24 requirement. Specifically, the BOK2 requirement to include “multiple professional and ethical conflicting interests to determine an appropriate course of action” is a worthy goal for a baccalaureate-level program, but not specifically required by the Civil Engineering Program Criteria.

Seminars or lectures may be ineffective in addressing ethical decision-making and, more importantly, influencing ethical and professional behavior. In fact, professional engineers themselves have reported their ethics education as undergraduates did little to prepare them for the ethical realities they face in their profession. While graduating professionals who behave ethically throughout their careers is ultimately what undergraduate programs and the profession want to achieve, it is unrealistic to place a statement to that effect in the Civil Engineering Program Criteria.
The curriculum must prepare graduates to explain the importance of professional licensure

**Changes from the Previous Edition of the Civil Engineering Program Criteria**

The curriculum program must prepare graduates to explain the importance of professional licensure

**Understanding the Criterion**

To comply with this provision of the Program Criteria sufficient curricular content must be present to address the importance of licensure so all graduates are exposed to and could explain the concept. While professional licensure is not explicitly addressed in the EAC/ABET General Criteria, this long-standing provision in the Civil Engineering Program Criteria is related to and supportive of General Criterion 3 Student Outcome (f) an understanding of professional and ethical responsibility.

Consistent with Bloom’s Taxonomy, the verb “explain” in this criterion implies the expected level of achievement is Level 2 – Comprehension. Graduates should be able to explain the unique nature of civil engineers’ responsibility to the general public and the consequent emphasis on professional licensure in civil engineering professional practice.

**Background/Rationale**

Civil engineers comprise the majority of licensed professional engineers and have responsible charge over projects with direct impact on the everyday lives of the public. ASCE has long recognized this and has actively supported professional licensure, along with life-long learning, as the best assurance the civil engineer is capable of assuring the safety and welfare of the public. In fact, the No. 1 Canon of ASCE’s Code of Ethics is “Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.”

The first engineering licensure law was enacted in 1907 in Wyoming in order to protect the public health, safety, and welfare. Licensure tells the public an engineer has mastered the critical elements of the profession, a symbol of achievement and assurance of quality.
D-10. Faculty Requirements

The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience. The program must demonstrate that it is not critically dependent on one individual.

Changes from the Previous Edition of the Civil Engineering Program Criteria

No changes; faculty requirements remain the same as in the previous edition of the Civil Engineering Program Criteria

Understanding the Criterion

The phrase "courses that are primarily design in content" is intended to apply to the differentiation between engineering science and engineering design courses. Courses in this category would be those, typically in the third and fourth years, where design is a majority percentage of the course. Often, these courses are used to satisfy the General Criteria 3c design outcome and the civil engineering design provision of the Civil Engineering Program Criteria. As an aid to the Program Evaluator in differentiating classes and faculty covered by this criterion, the program may elect to include a listing of all courses primarily design in content or a tabulation indicating the design component of each class, and the faculty members who teach the respective courses.

The next phrase, "qualified to teach the subject matter by virtue of professional licensure, or by education and design experience," describes the minimal EAC/ABET qualifications necessary to teach the design courses. Professional licensure, usually as a Professional Engineer (P.E.), is considered satisfactory evidence of necessary qualifications to teach engineering design. The second half of the requirement, "or by education and design experience," provides an alternative to the demonstration by licensure that a faculty member is qualified to teach design in a specific area. It is recognized by inclusion of this phrase that the appropriate qualifications to teach design in a civil engineering program may not be solely defined by professional licensure. The program must demonstrate to the reasonable satisfaction of the program evaluator that faculty members who teach design courses meet at least one or the other of these qualifications.

Relevant professional licensure may be in a major civil engineering discipline (e.g., structural or environmental engineering). Licensure in a discipline closely related to the
field the faculty member is teaching design may constitute relevant licensure but may not be sufficient for satisfying this requirement. For example, licensure as a professional geologist along with appropriate design experience may be sufficient to satisfy the overall requirement to teach certain design courses, even if not sufficient to satisfy the licensure requirement.

Certifications are available in many disciplines and specialties. These are not professional licensure and cannot be used to fully satisfy this requirement. However, certification can indicate proficiency/expertise in a particular field. Thus, certification may be helpful in demonstrating experience in a specific discipline or specialty.

Faculty members claiming qualifications to teach design by virtue of the education and experience provision should be educated in a field closely related to that in which he/she is teaching design. For instance, the related field may be chemical or mechanical engineering for environmental engineering faculty. Of equal or greater importance than the specifics of his/her education is what the individual has accomplished since obtaining the related education. In the case of an unlicensed faculty member, a relevant question might be whether the person appears to have enough experience to be eligible to be licensed. Design experience can come in many forms and from many types of employment. The most common may be industrial experience working for the private sector. Design experience may come in a sustained period of employment, or it may come incrementally over several years. Generally, design experience repetitious in nature, such as repeatedly designing the same component or type of facility, usually does not provide credit toward licensure beyond the initial performance. The claimant and the program should concisely document the specifics of the claimed experience in design. The specific method for documenting the claimed design experience is left to the program. Simply stated, there is no one correct approach or method to document design experience.

The demonstration by the program that relevant faculty members are qualified by virtue of professional licensure can be as simple as a table with the appropriate information. Information in the table could include the jurisdiction of licensure, discipline (if appropriate), date of initial licensure, and the expiration date of the license.

The program evaluator must also review the class materials to assist in determining if the instructor is qualified to teach the subject matter.

Some jurisdictions explicitly consider the teaching of design courses, or advanced engineering courses in general, as the practice of engineering. Therefore, engineering faculty in those jurisdictions may have a legal obligation for professional licensure, which is beyond the scope of the EAC/ABET accreditation evaluation. Additionally, the legal ramifications of inappropriate or non-existent licensure (practicing engineering without a license) are similarly beyond the scope of the program criteria and this commentary. Those teaching courses with a minority percentage of design in the overall course are not addressed in the program criteria.
A program cannot be critically dependent on a single individual. If a program has only one full-time faculty member able to teach a specific course, it is not necessarily critically dependent on that individual. If a part-time faculty member is able to assist or other reasonable accommodations can be met for an absence or a sabbatical, the criterion is met. A program may be critically dependent on a faculty member if an entire portion of the program is eliminated or seriously degraded if this faculty member departs.

**Background/Rationale**

These requirements for faculty are a long-standing part of the Civil Engineering Program Criteria. General Engineering Criterion 6 for Faculty includes two requirements, one related to the size of the faculty and one related to the qualifications and authority of the faculty to ensure the proper oversight and guidance of the program.

First, the “program must demonstrate that the faculty members are of sufficient number and that have the competencies to cover all curricular areas of the program.” The program criterion adds the requirement that the program not be critically dependent on any one individual. That is, in addition to general criterion assuring adequate levels of student-faculty interactions, advising, mentoring, and other activities, the program criterion assures broader engagement by the program’s faculty. In part, this is also related to the Breadth in Civil Engineering criterion (see section D-3).

Second, the “program faculty must have appropriate qualifications,” which may be “judged by such factors as education, diversity of backgrounds, engineering experience, ... and licensure as Professional Engineers.” The program criteria adds the specific requirement that faculty who teach design courses be qualified to do so by virtue of professional licensure or by education and experience.
Appendix I: Bloom’s Taxonomy

The second edition of the *Civil Engineering Body of Knowledge for the 21st Century* (a.k.a., BOK2, downloadable from www.asce.org/civil_engineering_body_of_knowledge/), explicitly included the use of Bloom’s Taxonomy to define the level of achievement for each outcome. Appendix F of the BOK2 provides an overview of Bloom’s Taxonomy, six Bloom’s levels in the cognitive domain (also referred to as levels of achievement), and a sampling of common Bloom’s verbs associated with each level. Appendix F of the BOK2 is reprinted here for quick reference.
APPENDIX F

Bloom’s Taxonomy

The articulation of BOK learning outcomes and related levels of achievement comes, in part, from the desire to clarify what should be taught and learned. Clarification can be achieved through the use of Bloom’s Taxonomy of Educational Objectives for the cognitive domain, which systematically differentiates outcome characteristics and promotes common understanding for all users of the BOK. The cognitive domain refers to educational objectives that involve the recall and recognition of knowledge and the development of intellectual abilities and skills.

Bloom’s Taxonomy was originally conceived as a technique to reduce the labor of preparing comprehensive examinations through the exchange of test items among faculty at various universities. The goal was to create banks of test items in which each bank attended to the same educational objective. A team of measurement specialists began meeting in 1949 to create the taxonomy of objectives and their first draft was published in 1956. Bloom believed, however, that the original taxonomy went beyond measurement. Among his many ideas was his belief that the taxonomy could serve as a common language for expressing and understanding learning goals or objectives.

Bloom’s emphasis on the use of measurable, action-oriented verbs facilitates the creation of outcome statements that lend themselves to more consistent and more effective assessment. Bloom’s Taxonomy consists of six levels in the cognitive domain, which herein are called levels of achievement. These achievement levels for cognitive development will occur as a result of formal education and experience.

The Levels of Achievement Subcommittee Report details the recommendation to use Bloom’s Taxonomy as the levels of achievement for the BOK. The purpose of this appendix is to define the achievement levels and provide definitions of the active verbs used in the BOK for each level. These definitions are helpful because some of the active verbs can be used at different levels. Moreover, for some outcomes, Bloom’s Taxonomy was not directly applicable and verbs were chosen with specific definitions to convey the progression through the levels of achievement. These special instances are noted in the definitions at each level. The definitions of the verbs were taken from Webster’s Third New International Dictionary, Unabridged. The definition of the levels of achievement were summarized from Bloom’s Taxonomy of Educational Objectives, Stating Objectives for Classroom Instruction, 2nd Edition and from the Levels of Achievement Subcommittee Report.

**Level 1—Knowledge**

Knowledge is defined as the remembering of previously learned material. This may
involve the recall of a wide range of material, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information. Knowledge represents the lowest level of learning outcomes in the cognitive domain.\textsuperscript{e}

Define: to discover and set forth the meaning of.

Describe: to present distinctly by means of properties and qualities.

Identify: to select; to choose something for a number or group.

List: to declare to be.

Recognize: to perceive clearly.

Other illustrative verbs at the knowledge level include: enumerate, label, match, name, reproduce, select, and state.

**Level 2—Comprehension**

Comprehension is defined as the ability to grasp the meaning of material. This may be shown by translating material from one form to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects). These learning outcomes go one step beyond the simple remembering of material, and represent the lowest level of understanding.\textsuperscript{e}

Explain: to make plain or understandable.

Describe: to present distinctly by means of properties and qualities.

Distinguish: to perceive as being separate or different.

Discuss: to present in detail.

Other illustrative verbs at the comprehension level include: classify, cite, convert, estimate, generalize, give examples, paraphrase, restate (in own words), and summarize.

**Level 3—Application**

Application refers to the ability to use learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws, and theories. Learning outcomes in this area require a higher level of understanding than those under comprehension.\textsuperscript{e}

Solve: to find an answer, solution, explanation, or remedy for.

Apply: to use for a particular purpose or in a particular case.

Use: to carry out a purpose or action by means of.

Formulate: to plan out in orderly fashion.

Develop: to make clear, plain, or understandable. Develop is similar to “explain” but at a greater level of detail.

Conduct: the act, manner, or process of carrying out (as a task) or carrying forward.

Report: to give an account of; to give a formal or official account or statement of.

Organize: to put in a state of order.

Function: to carry on in a certain capacity.

Demonstrate: to illustrate or explain in an orderly and detailed way especially with many examples, specimens, and particulars.

Explain: to give the reason for or cause of. Although commonly a level 2 or
level 5 verb when used in the context of outcome 11, contemporary issues and historical perspectives, the verb “explain” conveys the application of broad education to the identification, formulation, and solution of engineering problems.

Other illustrative verbs at the application level include: administer, articulate, calculate, chart, compute, contribute, establish, implement, prepare, provide, and relate.

Level 4—Analysis

Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood. This may include the identification of parts, analysis of the relationship between parts, and recognition of the organizational principles involved. Learning outcomes here represent a higher intellectual level than comprehension and application because they require an understanding of both the content and the structural form of the material.

Analyze: to 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.

Select: to choose something from a number or group.

Organize: to arrange by systematic planning and coordination; to unify into a coordinated functioning whole. Although “organize” is not typically a level 4 verb, it is appropriate for outcomes 8 (problem recognition and solving), 16 (communication), and 20 (leadership). For each of these outcomes, the verb “organize” conveys the appropriate educational objective progression.

Compare: to examine the character or qualities of, especially for the purpose of discovering resemblances or differences.

Contrast: to compare in respect of differences; to examine like objects by means of which dissimilar objects are made prominent.

Illustrate: to make clear by giving examples or instances.

Formulate: to put into a systematized statement or expression.

Deliver: give forth in words; to make known to another. Although the verb “deliver” is not typically a level 4 verb, it is appropriate for outcome 16 (communication) because it conveys the appropriate educational objective progression.

Function: to carry on in a certain capacity. For level 4, the verb “function” is only used for outcome 21 (teamwork) and it has the same definition at level 4 as it does at level 3. In this case, the verb does not convey the educational progression between levels 3 and 4. Rather, the progression is delineated by the movement from an intradisciplinary to a multidisciplinary team.

Direct: to carry out the organizing, energizing, and supervising of, especially in an authoritative capacity; to regulate the activities or course of; to guide and supervise; to assist by giving advice, instruction, and supervision. The verb “direct” may not be considered a typical level 4 verb; however, within the context of outcome 20 (leadership), the verb “direct” conveys the logical educational progression in the outcome.
Identify: to establish the distinguishing characteristic of; to select; to choose something from a number or group. The verb “identify” is also a level 1 verb; however, within the context of outcome 23 (lifelong learning), the verb “identify” conveys the ability to determine the additional knowledge, skills, and attitudes appropriate for professional practice, which is a level 4 task.

Other illustrative verbs at the analysis level include: break down, correlate, differentiate, discriminate, infer, and outline.

**Level 5—Synthesis**

Synthesis refers to the ability to put together to form a new whole. This may involve the production of a unique communication, a plan of operation (research proposal), or a set of abstract relations (scheme for classifying information). Learning outcomes in this area stress creative behaviors and place major emphasis on the formulation of new patterns or structure.

Create: to produce (as a work of art or of dramatic interpretation) along new or unconventional lines; to make or bring into existence something new.

Design: to conceive and plan out in the mind; to create, fashion, execute, or construct according to plan; to originate, draft, and work out, set up, or set forth.

Specify: to tell or state precisely or in detail. Although not usually considered a level 5 verb, when used with outcome 7 (experiments), the verb “specify” refers to the ability to determine which experiment or experiments are required. Drawing from a wide range of possibilities and then specifying the appropriate one(s) is a level 5 task.

Explain: to show the logical development or relationships of. “Explain” is also a level 2 verb when it simply means to make plain or understandable. Showing a logical development or relationships are level 5 tasks.

Synthesize: combine or put together by the composition or combination of parts or elements so as to form a whole; the combining of often varied and diverse ideas, forces, or factors into one coherent or consistent complex.

Relate: to show or establish a logical or causal connection between.

Develop: to open up; to cause to become more completely unfolded so as to reveal hidden or unexpected qualities or potentialities; to lay out (as a representation) into a clear, full, and explicit presentation. “Develop” is also a level 3 verb when—much like the verb “explain”—it means to make clear, plain, or understandable. For outcomes 10 (sustainability), 12 (risk and uncertainty), 17 (public policy), and 19 (globalization) develop requires synthesis.

Plan: to devise or project the realization or achievement of; to arrange the parts of.

Compose: to form by putting together two or more things, elements, or parts; to put together; to arrange in a fitting, proper, or orderly way.

Integrate: to make complete; to form into a more complete, harmonious, or coordinated entity, often by the addition or arrangement of parts or elements; to combine to form a more complete, harmonious, or coordinated entity; to incorporate (as an individual or group) into a larger unit or group.

Construct: to form, make, or create by combining parts or elements; to create by organizing ideas or concepts.
logically, coherently, or palpably; to draw with suitable instruments so as to fulfill certain specified conditions; to assemble separate and often disparate elements.

Adapt: to make suitable (for a new or different use or situation) by means of changes or modifications.

Organize: to arrange or constitute into a coherent unity in which each part has a special function or relation; to arrange by systematic planning and coordination of individual effort; to arrange elements into a whole of interdependent parts.

Execute: to put into effect; to carry out fully and completely.

Other illustrative verbs at the synthesis level include: anticipate, collaborate, combine, compile, devise, facilitate, generate, incorporate, modify, reconstruct, reorganize, revise, and structure.

Level 6—Evaluation

Evaluation concerns the ability to judge the value of material for a given purpose. The judgments are to be based on definite criteria. These may be internal criteria (organization) or external criteria (relevance to the purpose) and the individual may determine the criteria or be given them. Learning outcomes in this area are highest in the cognitive hierarchy because they contain elements of all the other categories as well as conscious value judgments based on clearly defined criteria.

Evaluate: to examine and judge concerning the worth, quality, significance, amount, degree, or condition of.

Compare: to examine the character or qualities of, especially for the purpose of discovering resemblances or differences. This definition is the same as for level 4; however, when used in context with the verb “evaluate” for outcome 8 (problem recognition and solving), the combined action requires evaluation and is a level 6 task.

Appraise: to judge and analyze the worth, significance or status of; especially to give a definitive expert judgment of the merit, rank, or importance of.

Justify: to prove or show to be just, desirable, warranted, or useful.

Assess: to analyze critically and judge definitively the nature, significance, status, or merit of; to determine the importance, size, or value of.

Self-assess: to personally or internally analyze critically and judge definitively the nature, significance, status, or merit of a personal trait. Outcome 23 (life-long learning) uses the verb “self-assess” to convey the concept of introspective reflection.

Other illustrative verbs at the evaluation level include: compare and contrast, conclude, criticize, decide, defend, judge, and recommend.

Cited Sources


c) ASCE Levels of Achievement Subcommittee. 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, September. (http://www.asce.org/raisethebar)


One of the key sections of the second edition of the *Civil Engineering Body of Knowledge for the 21st Century* (downloadable from [www.asce.org/civil_engineering_body_of_knowledge/](http://www.asce.org/civil_engineering_body_of_knowledge/)), is the full outcomes rubric, which includes outcome statements for all six levels of achievement for each and every outcome. Included in rubric are the outcomes envisioned as part of the baccalaureate degree (B), the post-baccalaureate formal education (M/30), and pre-licensure experience (E). The outcomes rubric is included in Appendix I of the BOK2 and is reprinted here for quick reference.
Building on the recommendations of the Levels of Achievement Subcommittee,\(^9\) the BOK2 Committee developed the outcome rubric.\(^{14}\) The rubric communicates the following BOK characteristics:

- The 24 outcomes, categorized as foundational, technical, and professional and, within each category, organized in approximate pedagogical order
- The level of achievement that an individual must demonstrate for each outcome to enter the practice of civil engineering at the professional level
- For each outcome the portion to be fulfilled through the bachelor’s degree, the portion to be fulfilled through the master’s degree or equivalent (approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses in a specialized technical area and/or professional practice area related to civil engineering), and the portion to be fulfilled through prelicensure experience

Key:

- **B** Portion of the BOK fulfilled through the bachelor’s degree
- **M/30** Portion of the BOK fulfilled through the master’s degree or the equivalent
- **E** Portion of the BOK fulfilled through prelicensure experience
- **** Achievement levels beyond minimums needed to enter professional practice
<table>
<thead>
<tr>
<th>Outcome title</th>
<th>Level of cognitive achievement</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1 Knowledge</td>
</tr>
<tr>
<td>1 Mathematics</td>
<td>Define key factual information related to mathematics through differential equations.</td>
</tr>
<tr>
<td>2 Natural sciences</td>
<td>Define key factual information related to calculus-based physics, chemistry, and one additional area of natural science.</td>
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<tr>
<td>3 Humanities</td>
<td>Define key factual information from more than one area of the humanities.</td>
</tr>
<tr>
<td>Outcome title</td>
<td>Knowledge (1)</td>
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<tr>
<td>4 Social sciences</td>
<td><strong>Define</strong> key factual information from more than one area of social sciences.</td>
</tr>
<tr>
<td>5 Materials science</td>
<td><strong>Define</strong> key factual information related to materials science within the context of civil engineering.</td>
</tr>
<tr>
<td>6 Mechanics</td>
<td><strong>Define</strong> key factual information related to solid and fluid mechanics.</td>
</tr>
<tr>
<td>Outcome title</td>
<td>1 Knowledge</td>
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<tr>
<td>7 Experiments</td>
<td><strong>Identify</strong> the procedures and equipment necessary to conduct civil engineering experiments in more than one of the technical areas of civil engineering.</td>
</tr>
<tr>
<td>8 Problem recognition and solving</td>
<td><strong>Identify</strong> key factual information related to engineering problem recognition, problem solving, and applicable engineering techniques and tools.</td>
</tr>
<tr>
<td>Outcome title</td>
<td>Level of cognitive achievement</td>
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<tr>
<td></td>
<td>1 Knowledge</td>
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<tr>
<td>9 Design</td>
<td>Define</td>
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<td>engineering design; list the major steps in the engineering design process; and list constraints that affect the process and products of engineering design.</td>
</tr>
<tr>
<td>10 Sustainability</td>
<td>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.</td>
</tr>
<tr>
<td>Outcome title</td>
<td>1 Knowledge</td>
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</tr>
<tr>
<td>11 Contemporary issues and historical perspectives</td>
<td>Identify economic, environmental, political, societal, and historical aspects in engineering.</td>
</tr>
<tr>
<td>12 Risk and uncertainty</td>
<td>Recognize uncertainties in data and knowledge and list those relevant to engineering design.</td>
</tr>
<tr>
<td>Outcome title</td>
<td>1</td>
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<tr>
<td><strong>13 Project management</strong></td>
<td>List key management principles.</td>
</tr>
<tr>
<td><strong>14 Breadth in civil engineering areas</strong></td>
<td>Define key factual information related to at least four technical areas appropriate to civil engineering.</td>
</tr>
<tr>
<td><strong>15 Technical specialization</strong></td>
<td>Define key aspects of advanced technical specialization appropriate to civil engineering.</td>
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</table>

<table>
<thead>
<tr>
<th>Level of cognitive achievement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td><strong>Knowledge</strong></td>
<td>(B)</td>
<td>(B)</td>
<td>(B)</td>
<td>(E)</td>
<td>(M/30)</td>
<td>(E)</td>
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<tr>
<td><strong>Comprehension</strong></td>
<td>(B)</td>
<td>(B)</td>
<td>(B)</td>
<td>(M/30)</td>
<td>(M/30)</td>
<td>(E)</td>
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<tr>
<td><strong>Application</strong></td>
<td>(B)</td>
<td>(B)</td>
<td>(B)</td>
<td>(M/30)</td>
<td>(M/30)</td>
<td>(E)</td>
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<tr>
<td><strong>Analysis</strong></td>
<td>(B)</td>
<td>(B)</td>
<td>(B)</td>
<td>(M/30)</td>
<td>(M/30)</td>
<td>(E)</td>
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<tr>
<td><strong>Synthesis</strong></td>
<td>(B)</td>
<td>(B)</td>
<td>(B)</td>
<td>(M/30)</td>
<td>(M/30)</td>
<td>(E)</td>
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<tr>
<td><strong>Evaluation</strong></td>
<td>(B)</td>
<td>(B)</td>
<td>(B)</td>
<td>(M/30)</td>
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<td></td>
<td>1 Knowledge</td>
<td>2 Comprehension</td>
<td>3 Application</td>
<td>4 Analysis</td>
<td>5 Synthesis</td>
<td>6 Evaluation</td>
</tr>
<tr>
<td>16 Communication</td>
<td>List the characteristics of effective verbal, written, virtual, and graphical communications.</td>
<td>Describe the characteristics of effective verbal, written, virtual, and graphical communications.</td>
<td>Apply the rules of grammar and composition in verbal and written communications, properly cite sources, and use appropriate graphical standards in preparing engineering drawings.</td>
<td>Organize and deliver effective verbal, written, virtual, and graphical communications.</td>
<td>Plan, compose, and integrate the verbal, written, virtual, and graphical communication of a project to technical and nontechnical audiences.</td>
<td>Evaluate the effectiveness of the integrated verbal, written, virtual, and graphical communication of a project to technical and nontechnical audiences.</td>
</tr>
<tr>
<td>17 Public policy</td>
<td>Describe key factual information related to public policy.</td>
<td>Discuss and explain key concepts and processes involved in public policy.</td>
<td>Apply public policy process techniques to simple public policy problems related to civil engineering works.</td>
<td>Analyze real-world public policy problems on civil engineering projects.</td>
<td>Develop public policy recommendations, and create or adapt a system to a real-world situation on civil engineering work programs.</td>
<td>Evaluate the effectiveness of a public policy in a complex, real-world situation associated with large-scale civil engineering initiatives.</td>
</tr>
<tr>
<td>18 Business and public administration</td>
<td>List key factual information related to business and public administration.</td>
<td>Explain key concepts and processes used in business and public administration.</td>
<td>Apply business and public administration concepts and processes.</td>
<td>Analyze real-world problems involving business or public administration.</td>
<td>Create or adapt a system of business or public administration to meet a real-world need.</td>
<td>Evaluate a system of business or public administration in a complex, real-world situation.</td>
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<td>Outcome title</td>
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<tr>
<td>Describe globalization processes and their impact on professional practice across cultures, languages, or countries.</td>
<td>1 Knowledge</td>
<td>2 Comprehension</td>
<td>3 Application</td>
<td>4 Analysis</td>
<td>5 Synthesis</td>
<td>6 Evaluation</td>
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<tr>
<td>Define and list the key characteristics of effective intradisciplinary and multidisciplinary teams.</td>
<td>20 Leadership</td>
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<tr>
<td>Define leadership and the role of a leader; list leadership principles and attitudes.</td>
<td>21 Teamwork</td>
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<td>Explain the factors affecting the ability of intradisciplinary and multidisciplinary teams to function effectively.</td>
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<td>Analyze engineering works and services in order to function at a basic level in a global context.</td>
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<td>Develop criteria and guidelines to address global issues.</td>
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<td>Evaluate different criteria and guidelines in addressing global issues.</td>
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<td>Organize and direct the efforts of a group.</td>
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<td>Create a new organization to accomplish a complex task.</td>
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<td>Evaluate the leadership of an organization.</td>
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<td>Function effectively as a member of an intradisciplinary team.</td>
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<tr>
<td>Organize an intradisciplinary or multidisciplinary team.</td>
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<td>Evaluate the composition, organization, and performance of an intradisciplinary or multidisciplinary team.</td>
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<tr>
<td>Outcome title</td>
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<tr>
<td><strong>22 Attitudes</strong></td>
<td>List attitudes supportive of the professional practice of civil engineering.</td>
<td>Explain attitudes supportive of the professional practice of civil engineering.</td>
<td>Demonstrate attitudes supportive of the professional practice of civil engineering.</td>
<td>Analyze a complex task to determine which attitudes are most conducive to its effective accomplishment.</td>
<td>Create an organizational structure that maintains/fosters the development of attitudes conducive to task accomplishment.</td>
<td>Evaluate the attitudes of key members of an organization and assess the effect of their attitudes on task accomplishment.</td>
</tr>
<tr>
<td><strong>23 Lifelong learning</strong></td>
<td>Define lifelong learning.</td>
<td>Explain the need for lifelong learning and describe the skills required of a lifelong learner.</td>
<td>Demonstrate the ability for self-directed learning.</td>
<td>Identify additional knowledge, skills, and attitudes appropriate for professional practice.</td>
<td>Plan and execute the acquisition of required expertise appropriate for professional practice.</td>
<td>Self-assess learning processes and evaluate those processes in light of competing and complex real-world alternatives.</td>
</tr>
<tr>
<td><strong>24 Professional and ethical responsibility</strong></td>
<td>List the professional and ethical responsibilities of a civil engineer.</td>
<td>Explain the professional and ethical responsibilities of a civil engineer.</td>
<td>Apply standards of professional and ethical responsibility to determine an appropriate course of action.</td>
<td>Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action.</td>
<td>Synthesize studies and experiences to foster professional and ethical conduct.</td>
<td>Justify a solution to an engineering problem based on professional and ethical standards and assess personal professional and ethical development.</td>
</tr>
</tbody>
</table>