Commentary

On the ABET Program Criteria for Civil and Similarly Named Programs

Effective for 2019-2020 Accreditation Cycle

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A. Purpose of the Commentary

This Commentary was prepared by the Civil Engineering Program Criteria Task Committee as charged by the ASCE Committee on Accreditation. It provides guidance to civil engineering program evaluators (hereafter "PEVs")and to civil engineering program faculty by clarifying and amplifying the Civil Engineering Program Criteria (hereafter "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 "General Criteria"). In the spirit of the General Criteria, this Commentary does not attempt to prescribe a single approach for compliance; rather, it emphasizes the institution's freedom to innovate within the framework of an outcomes-based assessment process.

Program evaluation is an inherently subjective process. This Commentary aims to help PEVs make subjective judgments in a manner that is consistent with EAC/ABET procedures. It is not a set of rigid rules to be followed without some flexibility. Ultimately, recommendations about compliance with the criteria are based on the PEV's judgment with input from and concurrence of the evaluation visit team.

This Commentary should assist program faculty in better understanding of what must be included in the curriculum relative to the Program Criteria. Additionally, qualifications required of the faculty are included. This document may be used by stakeholders other than faculty, e.g., industry advisory boards, administration, donors, employers, and constituencies. Herein, the term "faculty" is used to represent the reader for simplicity.

ABET policies do not require the measurement and assessment of learning achievements for the Program Criteria. However, program faculty must demonstrate each item in the Program Criteria is addressed within the curriculum to the intended levels of achievement and rigor. Course syllabi, assignments, and student work are often used as artifacts for documentation.

Bloom's Taxonomy is referenced throughout here. It is not a part of the Program Criteria; however, Bloom's Taxonomy verbs are used to describe intended levels of achievement. A brief discussion of the taxonomy included in Appendix I.

The information presented herein reflects the best collective judgment of its authors and reviewers. It is periodically reviewed and revised 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" (see: www.asce.org/civil_engineering_body_of_knowledge/), proved to be valuable in guiding the subsequent implementation of Policy Statement 465. The conceptual framework includes three key characteristics, the:

(1) civil engineering BOK is defined in terms of 24 outcomes,

(2) 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 framework is depicted by the "outcome rubric" extracted from Appendix I of BOK2 and included in Appendix II herein. Having published the 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 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 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. In addition to the Civil Engineering Program Criteria, the EAC/ABET General Criterion 3 Student Outcomes and General Criterion 5 Curriculum are provided for convenience.

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 support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering.

Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

3. an ability to communicate effectively with a range of audiences

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Criterion 5. Curriculum

The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The program curriculum must provide adequate content for each area, consistent with the student outcomes and program educational objectives, to ensure that students are prepared to enter the practice of engineering. The curriculum must include:

(a) a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program.

(b) a minimum of 45 semester credit hours (or equivalent) of engineering topics appropriate to the program, consisting of engineering and computer sciences and engineering design, and utilizing modern engineering tools.

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

(d) a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.

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 PEV. Many methods are available to demonstrate facets of the General and Program Criteria. The PEV judges whether the submitted material adequately demonstrates what is claimed and whether is demonstrates compliance.

With this consideration, the following sections aim to assist both faculty and PEVs to better understand the Program Criteria. In addition, for each part of the Program Criteria, a brief background on each criterion is provided to provide background about "what" is intended and "why" the provision is included.

Program Criteria include only curricular and faculty requirements; programs are not required to assess or evaluate student achievements related to the Program Criteria. The program, however, must clearly demonstrate each curricular item in the Program Criteria is included within the curriculum, and additionally, that the faculty experience and composition meet the faculty Program Criteria requirement as well.

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

Understanding the Criterion

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 addressed within the curriculum and that all students must take the necessary courses to graduate. Additionally, while the General Criterion 5(a) requires 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences, 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 inclusive, hence 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, the program must 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 course that is part of a sequence for which a 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 the breath 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. Courses such as thermodynamics, computer science or materials science do not meet this requirement and this is a long-term norm.

Background/Rationale

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 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 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 Bloom's Taxonomy verb "apply," which is used in the General Criterion 3(1 & 2) and in this provision of the Program Criteria, denotes the expected level of achievement is Bloom's Level 3, or "application level." Both the BOK2 Outcome 1 – Mathematics and Outcome 2 – Natural Sciences are also at Bloom's Level 3 of achievement. Therefore, this provision of the Program Criteria agrees with the targeted level of achievement for math and science as conveyed in the BOK2.

D-2. Probability and Statistics

The curriculum 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. Program Criteria does not 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 understand real-world uncertainties in engineering practice with the aim of managing risk.

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. As an example, probability and statistics may be integrated into an engineering course, perhaps laboratory courses that require students to analyze and interpret the resulting data, perform error analysis, and so forth (see Section D-4 on Civil Engineering Experiments).

Background/Rationale

Because probability and statistics concepts are integral to most civil engineering subjects and included in the BOK2, the subject matter was reintroduced into the 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.

Bloom's Taxonomy's verb "apply" denotes the expected level of achievement is Bloom's Level 3, or "application level."

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

Understanding the Criterion

The field of civil engineering involves many traditional technical areas of specialization. Generally recognized civil engineering technical areas include, but are not limited to:

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

New specialty areas will emerge as civil engineering evolves. Therefore enforcement of this provision must not constrain curricular innovation or a program's ability to respond to future opportunities or needs. The program (not the PEV) must demonstrate the technical area or areas are "appropriate to civil engineering," in sufficient detail that a well-reasoned judgment can be discerned. This judgment must consider the balance of the desirability of curricular innovation against the need for relevant technical breadth.

In response to emerging societal needs, civil engineering programs may need to develop non-standard technical areas. These breadth areas should be supported by constituent and stakeholder feedback, and connected to the Program Educational Objectives. Possible justifications for a non-standard technical areas might include the following:

- ASCE has an institute or technical division, publishes a journal, or sponsors specialty conferences in the technical area.
- A national or international civil engineering-related professional society has an institute or technical division, publishes a journal, or sponsors specialty conferences in the technical area.
- Civil engineering consulting or contracting firms that specialize in the technical

area.

- A technical area is aligned with an applicable grand challenge from the National Academy of Engineering (NAE), or other initiatives by national or international engineering organizations
- There is an applicable and established program in a technical area within a government agency to identify emerging areas of societal need. Examples could include programs with the Department of Commerce, Department of Transportation, Department of Energy, Department of Homeland Security, Department of Defense, National Science Foundation, and National Institutes of Health.

This list is not inclusive as 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 Program Criteria with the intent is to ensure every civil engineering graduate has sufficient relevant technical breadth. The Program Criteria may be used to support the General Criterion 3 an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

The primary change from previous editions of the breadth provision of the Program Criteria is replacing "apply knowledge of" with "analyze and solve problems" to make this provision of the program criteria consistent with BOK2. The Bloom's Taxonomy 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, 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.

D-4. Civil Engineering Experiments

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

Understanding the Criterion

The General Criterion 3(6) requires "an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions." The emphasis of this provision of the 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 may be demonstrated by demonstrating that graduates have sufficient exposure to laboratory experiences and that all students must obtain that level of exposure in order to graduate.

The criterion requires the experimental experience in at least two technical areas of civil engineering. As noted with the provision requiring breadth in civil engineering, at least seven generally recognized civil engineering technical areas are available. Experimentation in new or emerging technical areas are appropriate. 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:

- Understand the objectives and procedures associated with an experiment
- Conduct an experiment, including setup, measurement and data collection
- Observe and document error and uncertainties in data collection procedures
- Analyze data
- Interpret experimental results, with appropriate conclusions and recommendations, and
- Apply experimental procedures and analysis of results consistent with a real-world civil engineering problems or situations

A trend in engineering curriculum involves the use of "virtual laboratories." Here computer simulations aim to replicate the hands-on experiences of conventional physical labs. In general, such curricular innovations are encouraged, and the PEV should consider their effectiveness with openness. An evaluation of a virtual laboratory experience should consider such factors as the:

- Extent to which the subject matter lends itself to accurate simulation,
- Extent to which the simulation replicates the actual physical experiences of setup, measurement, errors, and data collection,
- Nature of student interaction with the simulation, and,
- Students' abilities acquired through the simulation.

Background/Rationale

The General Criterion 3(6) requires "an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions." The Program Criteria differs from General Criterion 3(6) because there is no mention of an ability to "develop experiments," however an additional requirement of student exposure to experiments "in at least two technical areas of civil engineering" is necessary.

The development 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 development in the Program Criteria does not relieve a program of responsibility for compliance with the "develop experiments" provision of General Criterion 3(6).

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.

Bloom's Taxonomy verb "conduct" 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 "develop" implies the expected level of achievement is Level 5, Synthesis. Thus, the development of experiments must reflect the putting together of parts to form a new whole. However, because the requirement for experiment development occurs only in the General Criteria, there is no requirement for students to develop experiments in a civil engineering context. Thus, the program would be in full compliance if students' ability to develop 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

Understanding the Criterion

The 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 Program Criteria further requires a breadth of the design experience in at least two civil engineering contexts. Therefore, compliance requires this demonstration.

ABET provides the following definition of engineering design in 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 provides the basis for evaluation of the design-related provisions of the Program Criteria. Demonstration elements of students design experience include, but are not limited to:

- 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.
- Analysis and synthesis are often 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.
- 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. No single correct answer exists. Nonetheless, the PEV must recognize, significant practical constraints on a program's ability to implement open-ended design experiences across the curriculum. 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 must be balanced. 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*.

- 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 General Criterion 3(2) public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- 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 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 similar.

Background/Rationale

This provision aims to assure a breadth of design experiences is included in the curriculum. Bloom's Taxonomy verb "design" implies the expected level of achievement is Level 5, Synthesis which is also consistent with the ABET definition for engineering design.

D-6. Sustainability in Design

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

Understanding the Criterion

The Program Criteria reflects the importance of including sustainability and identifies it as necessary to the design process. Therefore, compliance requires demonstration of curriculum content prepares graduates to include principles of sustainability.

Many definitions of sustainability exists without a consensus definition of sustainability. The criterion 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 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.

General Criterion 5 states the culminating design experience must include "multiple constraints." Therefore, considering both 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

Understanding the Criterion

This Program Criterion includes four components: basic concepts in project management, business, public policy, and leadership.

Examples of basic concepts in project management include 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, 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.

The Bloom's Taxonomy verb "explain" 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. The program may not 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(s) offered outside engineering could also represent full compliance.

Background/Rationale

The focus on management 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. 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

Understanding the Criterion

The General Criterion 3(4) requires that graduates have "an ability to recognize ethical and professional responsibilities." Programs demonstrate compliance through a series of seminars or lectures.

However, the Program Criteria that graduates "analyze issues in professional ethics" reflects an expectation for a higher level of achievement in professional ethics than required by General Criterion 3(4). This 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.

Bloom's Taxonomy verb "analyze" implies the expected level of achievement is Level 4 – Analysis. 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 accomplished and demonstrated 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.

One possible way to encourage students' ethical development is to provide appropriate curricular experiences in multiple contexts at multiple locations and times through the curriculum. A separate course in ethics is not required. 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 integrated into upper division design problems or into a senior project.

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.

In summary, professional ethics may be demonstrated in any number of ways. Regardless of the program's specific approach, the curriculum only needs to demonstrate how it prepares its graduates to analyze issues in professional ethics.

Background/Rationale

The 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 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 professionals who behave ethically throughout their careers is ultimately what programs and the profession want to achieve, it is unrealistic to place a statement to that effect in the Program Criteria.

D-9. Professional Licensure

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

Understanding the Criterion

The Program Criteria must 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 General Criteria, this long-standing provision in the Program Criteria is related to and supportive of General Criterion 3 Student Outcome (4) an ability to recognize ethical and professional responsibilities.

Bloom's Taxonomy verb "explain" 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 public. ASCE has long recognized this and has actively supported professional licensure, along with life-long learning, as the best assurance the 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. "

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.

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 of the course. Often, these courses are used to satisfy the General Criteria 3c design outcome and the civil engineering design provision of the Program Criteria. As an aid to the PEV 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 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. 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. Inclusion of this phrase implies 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 PEV 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 licensures 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 because 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 PEV 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 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.” This 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 criterion assures broader engagement by the 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” As outlined above.

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 II: BOK Outcomes Rubric (Second Edition)

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/), is the full outcomes rubric, which includes outcome statements for all six levels of achievement for each and every outcome. Included in the 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 BOK2.