AC 2007-432: ASEE 2007 ABSTRACT--CE BOK--FRIDLEY.DOC

Kenneth Fridley, University of Alabama

Kenneth J. Fridley is professor and head of the Department of Civil, Construction, and Environmental Engineering at the University of Alabama. He is active in numerous technical and professional committees, including the ASCE Body of Knowledge II Committee.

Richard Anderson, Somat Engineering, Inc.

An Aspirational Vision of Civil Engineering in 2025—Defining the Body of Knowledge

Abstract

The ASCE Policy 465 states "The American Society of Civil Engineers supports the attainment of a Body of Knowledge (BOK) for entry into the practice of civil engineering at the professional level." To promulgate an aspirational vision, support Policy 465, and be successfully implemented, the civil engineering BOK must specifically define the knowledge, skills, and attitudes of the future civil engineer. This paper describes the inclusive process being used to develop the second edition of the BOK expected for the future practice of civil engineering. The second edition of the BOK (BOK2) builds on the first edition of the BOK, which was released in 2004. The BOK2 is the foundation on which tomorrow's civil engineering accreditation criteria and individual program curricula will be constructed. A strong effort is being made to assess existing and evaluate possible new outcomes for inclusion in the second edition of the BOK. In keeping with current educational pedagogy, an outcomes-based model has been adopted utilizing the well-established Bloom's Taxonomy. The six-levels of Bloom's Taxonomy, along with its use of readily-understood verbs, are used to clearly define the desired levels of achievement for each technical and professional outcome. The resulting BOK outcome rubric is outlined in the paper.

Introduction

"The American Society of Civil Engineers supports *the attainment of a Body of Knowledge* for entry into the practice of civil engineering at a professional level."

This seemingly benign statement is the lead-in sentence of the ASCE Policy Statement 465 Academic Prerequisites for Licensure and Professional Practice. However, this sentence and, more precisely, Policy Statement 465 provide the civil engineering profession an extraordinary opportunity to define civil engineering and the future of the civil engineering profession by defining the Body of Knowledge, or BOK, for future entry into the profession. This paper describes the inclusive process being used to develop the BOK expected for the future practice of civil engineering and provide a preview of the resulting BOK outcome rubric.

Background and Rationale

The 1995 Civil Engineering Education Conference[1] resulted in several recommendations to enhance the education and academic preparedness of civil engineers. One such recommendation became what is now referred to by many as simply "Policy 465". First adopted by the ASCE Board of Direction in 1998, Policy 465 was revised in 2001[2] and most recently in 2004, the crux of the statement lies in *defining* the "Body of Knowledge for entry into the practice of civil engineering." The BOK is defined in the policy as "the necessary depth and breadth of knowledge, skills, and attitudes required of an individual entering the practice of civil engineering at the professional level in the 21st Century."

In January 2004, the Body of Knowledge Committee of the Committee on Academic Prerequisites for Professional Practice (CAP[3]) released the report[3] "Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future" (a copy of which can be found at www.asce.org/raisethebar). As the name implies, this report provided a definition to the BOK necessary for entry into the professional practice of civil engineering. Fifteen outcomes were defined in the first edition of the BOK and include seven technical and eight professional outcomes as shown in Table 1.

Table 1. First Edition BOK Outcomes.

Technical	Professional
1. Apply knowledge of math, science and engineering. 2. Apply knowledge in a specialized area related to civil engineering. 3. Design and conduct experiments as well as to analyze and interpret data. 4. Design a system, component or process to meet desired needs. 5. Identify, formulate and solve engineering problems. 6. Use techniques and modern engineering tools necessary for engineering practice. 7. Understand the elements of project management, construction, and asset management.	8. Function on multidisciplinary teams. 9. Understand professional and ethical responsibilities. 10. Communicate effectively. 11. Know contemporary issues. 12. Understand the impact of engineering solutions in a global and societal context. 13. Recognize the need for and engage in lifelong learning. 14. Understand business, public policy and administration fundamentals. 15. Understand the role of a leader and leadership principles and attitudes.

The first edition of the BOK utilized three levels of competency: recognition, understanding, and ability. These ill-defined and somewhat coarse levels of competencies (i.e., three levels) were found to be limiting as stakeholders, including the Curriculum Design Committee of CAP[3], began to review and implement the recommendations in the BOK report. Accordingly, CAP[3] formed the Levels of Achievement (LOA) Subcommittee to resolve this issue. The LOA Subcommittee issued a report[4] wherein the 15 outcomes defined in the BOK were recast using Bloom's Taxonomy[5]. By adopting Bloom's Taxonomy, the three levels of competencies became six levels of achievement with relatively distinct definitions for each level (see Table 2). With having the level of competency (achievement) issue addressed, the Curriculum Design Committee proceeded with its charge from CAP[3] to determine the current status of civil engineering education in relation to the formal educational component of the BOK. Their effort, however, led to the conclusion that, as stated in Policy 465, "This Body of Knowledge exceeds today's typical civil engineering baccalaureate degree, even when coupled with the practical experience gained prior to licensure."

Table 2. Bloom's Taxonomy[5].

Level of Achievement	Definition	Action Verbs
6. Evaluation	Evaluation is concerned with 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 student 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, plus conscious value judgments based on clearly defined criteria.	appraise; compare & contrast; conclude; criticize; critique; decide; defend; evaluate; judge; justify.
5. Synthesis	Synthesis refers to the ability to put parts together to form a new whole. This may involve the production of a unique communication, a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information). Learning outcomes in this area stress creative behaviors, with major emphasis on the formulation of new patterns or structure.	adapt; anticipate; collaborate; combine; compile; compose; create; design; develop; devise; facilitate; generate; incorporate; integrate; modify; plan; reconstruct; reorganize; revise; structure.
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; break down; correlate; differentiate; discriminate; distinguish; formulate; illustrate; infer; organize, outline; prioritize; separate; subdivide.
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.	administer; apply; articulate; calculate; chart; compute; contribute; determine; demonstrate; establish; implement; prepare; provide; relate; report; show; solve; use.
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.	classify; cite; convert; describe; discuss; estimate; explain; generalize; give examples; paraphrase; restate (in own words); summarize.
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.	define; describe; enumerate; identify; label; list; match; name; reproduce; select; state.

Defining the characteristics of the future engineer is hardly unique to civil engineering. For example, in a separate and independent effort, the National Academy of Engineering (NAE) was also studying the future education of engineers. The NAE's Committee on Engineering Education undertook and completed a two-part project resulting in two seminal reports[6,7]: "The

Engineer of 2020 – Visions of Engineering in the New Century" and "Educating the Engineer of 2020 – Adapting Engineering Education to the New Century".

The first report defines the key attributes, not specific discipline-oriented outcomes, of the future engineer. Specifically, the report states that engineers of the future will, like today, possess strong analytical skills with a foundation of mathematics and science, will exhibit practical ingenuity along with creativity ("thinking outside the box"), and will demonstrate good oral, visual, and written communication skills, including "virtual communication". The NAE report further recognizes that in the future, as in the past, engineers who master the principles of business and management will be rewarded with leadership roles and that, in preparation for this opportunity (and responsibility), engineers must understand the principles of leadership. Engineers will need to exhibit high ethical standards and a strong sense of professionalism, and they need to be lifelong learners. The NAE also recognizes that engineers will need something that cannot be described in a single word or phase but involves dynamism, agility, resilience, and flexibility.

As for the second NAE report which focuses on preparing the future engineer for entry into the profession, the first recommendation states that "The baccalaureate degree should be recognized as the "pre-engineering" degree or "bachelor of arts" in engineering degree, depending on the course content and reflecting the career aspirations of the student."

The common theme and mutual support communicated through ASCE Policy 465 and the NAE reports further reinforce the significance, timeliness, and criticality of the effort. Additionally, one of the first tasks undertaken by the second edition of the BOK (BOK2) Committee was to review the NAE reports and determine support and compatibility between the CE BOK and the NAE vision for the engineer of the future.

The BOK2 Committee

The Second Edition of the Body of Knowledge (BOK2) Committee is balanced and represents a broad cross section of the civil engineering community. A solicitation for membership was distributed (e.g., ASCE News) with over 25 applications received. The ASCE Department Heads Council also nominated four sitting civil engineering department head/chairs. The final committee makeup was governed by maintaining a balance among the large number of constituencies. In addition to the full committee members, the BOK2 Committee has over 60 corresponding members. The BOK2 membership represents a diversity of technical interests and backgrounds and representation of both private and public practice, as well as the civil engineering education community. The BOK2 Committee roster is provided in Appendix A.

The BOK2 Committee Process

The BOK2 Committee was officially formed in late 2005 and held its first face-to-face meeting in January 2006. At that meeting, committee members thoroughly reviewed and discussed the two NAE "The Engineer of 2020" reports as well as the specific outcomes as defined in the BOK and LOA reports. Task groups were then formed to critically review many of the existing outcomes in the BOK as well as some new topics (sustainability, globalization, emerging technologies, history/heritage, attitudes, discover mode, and risk and uncertainty).

Additional face-to-face meetings were held in May 2006 and August 2006, and between these meetings the committee held regular (weekly during many stretches) conference calls and continuous email messaging.

Nearly 30 different educational outcomes have been identified and discussed for possible inclusion in the Second Edition of the Civil Engineering BOK. Recalling that the First Edition of the Civil Engineering BOK included 15 separate outcomes, it is important to know that *this does not* equate to a doubling of the BOK. The committee decided to divide some of the original 15 comprehensive outcomes into separate outcomes, allowing topics previously combined in the first edition of the BOK to be more explicitly defined and to allow, in some cases, for different levels of achievement. Additionally, a task committee has been formed to study how humanities and social sciences should be incorporated into the BOK.

Draft Second Edition BOK Outcomes

The second edition of the BOK builds on the first edition. The draft BOK2, as presented in Table 3, presently includes 6 foundational, 12 technical, and 10 professional practice outcomes, and it should be viewed as a "pre-draft" as the committee continues to deliberate. For example, as mentioned previously, a task committee was established to study and recommend how humanities and social sciences should be integrated into the BOK. In addition to a strong effort being made to assess existing and evaluate possible new outcomes for inclusion in the BOK, the new BOK has also adopted Bloom's Taxonomy to better define and communicate the outcomes. All aspects of this second edition of the BOK are still under review by the committee. In addition to the outcomes, explanations (or commentary) are being developed to add definition and context to each of the outcomes. Also, in addition to the outcomes, the BOK committee will recommend the distribution of how an individual may be expected to develop the knowledge, skills, and attitudes defined in the BOK; that is, what components of the BOK are expected to be part of the undergraduate program of study, the formal post-graduate education, and pre-licensure experience.

The outcomes, associated explanations, and other relevant BOK report content will be made available for public review and comment later this Spring. The aim is for the Second Edition of the Civil Engineering Body of Knowledge Report to be formally released during Engineers' Week in February 2008.

Closing Comments

The BOK2 is envisioned as the foundation on which tomorrow's civil engineering accreditation criteria and program curricula will be constructed. The committee remains on track to release a draft of the Second Edition of the Civil Engineering BOK for public comment in the Spring and to release the formal and final version during Engineers' Week in February 2008 at the National Academy of Engineering.

It is critical that the civil engineering community continues to be engaged and offer their thoughts, suggestions, recommendations, and vision for the future of the profession. The future will come whether we are prepared for it or not. With the broad input and participation of all

constituencies of the profession we will not only be prepared for it, but we may actually be able to positively affect it and position our next generation of civil engineers to lead it.

Table 3. Draft Outcomes for Entry into the Future Practice of Civil Engineering at the Professional Level.

F o u n d a t i o n a l O u t c o m e s	
1. Mathematics	**Solve** problems in mathematics through differential equations and **apply** this knowledge to the solution of engineering problems. (L3)
2. Physics	**Solve** problems in calculus-based physics and **apply** this knowledge to the solution of engineering problems. (Bloom's Level 3)
3. Chemistry	**Use** knowledge of chemistry to **solve** problems appropriate to civil engineering. (Bloom's Level 3)
4. Breadth in basic science	**Use** knowledge of an area of basic science other than mathematics, physics, and chemistry to **solve** problems. (Bloom's Level 3)
5. Humanities	**Formulate** applicable criteria grounded in the humanities and **use** them in the development of a solution to engineering problems appropriate to civil engineering.
6. Social Sciences	**Formulate** criteria from the domain of social sciences and **use** them in the development of solutions to engineering problems appropriate to civil engineering.
T e c h n i c a l O u t c o m e s	
7. Mechanics	**Analyze** and solve problems in solid and fluid mechanics. (Bloom's Level 4)
8. Materials	**Use** knowledge of materials to **solve** problems appropriate to civil engineering. (Bloom's Level 3)
9. Breadth in civil engineering areas	**Analyze** and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering. (Bloom's Level 4)
10. Engineering tools	**Select** and **organize** relevant techniques, skills, and modern engineering tools to solve a well-defined problem. (Bloom's Level 4)
11 Engineering problem recognition and solving	**Analyze** and solve an ill-defined engineering problem appropriate to civil engineering. (Bloom's Level 4)
12. Design	**Evaluate** the design of a complex system, component, or process and **assess** compliance with customary standards of practice, client's needs, and relevant constraints. (Bloom's Level 6)
13. Experiments	**Specify** an experiment to meet a need, conduct the experiment, and analyze and **explain** the resulting data. (Bloom's Level 5)
14. Contemporary issues	**Analyze**, **compare** and **contrast** the economic, environmental, political, and societal impacts of engineering. (Bloom's Level 5)
15. Risk/uncertainty	**Analyze** the loading and capacity, and the effects of their respective uncertainties, for a well-defined design and **illustrate** the underlying probability of failure (or non-performance) for a specified failure mode. (Bloom's Level 4)
16. Sustainability	**Analyze** systems of engineered works, whether traditional or emergent, for sustainable performance. (Bloom's Level 4)
17. Project management	**Formulate** documents to be incorporated into the project management plan. (Bloom's Level 4)
18. Technical specialization	**Evaluate** the design of a complex system or process, or **evaluate** the validity of newly-created knowledge of technologies in a traditional or emerging advanced specialized technical area appropriate to civil engineering. (Bloom's Level 6)

Table 2 (continued)

Professional Outcomes	
19. Communication	**Plan, compose,** and **integrate** the verbal, written, virtual, and graphical communication of a project to technical and non-technical audiences. (Bloom's Level 5)
20. History and heritage	**Explain** contributions of significant individuals, events, and developments that occurred in the history of civil engineering and the impact they have on the profession. (Bloom's Level 2)
21. Globalization	**Analyze** engineering works and services delivered in a global context. (Bloom's Level 4)
22. Professional and ethical responsibility	**Justify** a solution to an engineering problem based on professional and ethical standards; **assess** personal professional and ethical development. (Bloom's Level 6)
23. Public policy	**Apply** public policy process techniques to simple public policy problems related to civil engineering works. (Bloom's Level 3)
24. Business and public administration	**Apply** business and public administration concepts and problem-solving processes. (Bloom's Level 3)
25. Teamwork	**Function** effectively as a member of a multi-disciplinary team. (Bloom's Level 4)
26. Leadership	**Organize** and **direct** the efforts of a group. (Bloom's Level 4)
27. Life-long learning	**Plan** and **execute** the acquisition of required expertise appropriate for professional practice. (Bloom's Level 5)
28. Attitudes	**Demonstrate** attitudes supportive of the professional practice of civil engineering. (Bloom's Level 3)

Bibliography

1. ASCE, 1995 Civil Engineering Education Conference – Summary Report. New York, NY: ASCE, 1995.
2. ASCE Task Committee on the First Professional Degree, Engineering the Future of Civil Engineering. Reston, VA: ASCE, 2001.
3. ASCE Body of Knowledge Committee, Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineering for the Future. Reston, VA: ASCE, 2004.
4. ASCE Levels of Achievement Subcommittee, Levels of Achievement Applicable to the Body of Knowledge Required for Entry Into the Practice of Civil Engineering at the Professional Level. Reston, VA: ASCE, 2005.
5. B. S. Bloom, M. D. Englehart, E. J. Furst, W. H. Hill, and D. Krathwohl, Taxonomy of Educational Objectives, the Classification of Educational Goals Handbook I: Cognitive Domain. New York, NY: David McKay, 1956.
6. National Academy of Engineering, The Engineer of 2020: Visions of Engineering in the New Century. Washington, DC: NAE, 2004.
7. National Academy of Engineering, Educating the Engineer of 2020: Adapting Engineering Education to the New Century. Washington, DC: NAE, 2005.

Appendix A: BOK2 Committee Roster

Members
Richard Anderson (Chair), Kenneth Fridley (Vice-Chair), Stuart Walesh (Editor), Anirban De, Decker Hains, Ronald Harichandran, Peter Hoadley, Manoj Jha, David Lange, Melanie Lawrence, Timothy Lengyel, Daniel Lynch, Robert Mackey, John Mason

Corresponding Members
Carsten Ahrens, Alfredo Ang, Tomasz Arciszewski, C. Robert Baillod, Amitabha Bandyopadhyay, Brian Brenner, Jason Burke, Donald Carpenter, Pascale Champagne, Karen Chou, Larry Esvelt, Robert Ettema, Jeffrey Evans, Howard Gibbs, Ali Haghani, Gerd Hartung Chris Hendrickson, Garabed Hoplamazian, Kenneth Johns, Dinesh Katti, Kenneth Kellogg, William Kelly, Merlin Kirschenman, William Knocke, Kenneth Lamb, James Lee, E Walter LeFevre, Jerry Marley, Paul McMullin, Donald Milks, Adi Murthy, James Nelson, Jr.,John Nelson, James Plemmons, Stephen Ressler, Jerry Rogers, David Ruby, Steven Sanders, Subal Sarkar, David Schwegel, Roger Seals, Jennifer Shannon, Alan Sheppard, Johann Szautner, Y. Cengiz Toklu, Marlee Walton

Ex-Officio Members
Jeffrey Russell (CAP^3 Contact), Thomas Lenox (ASCE Staff Leader), James O'Brien, Jr. (ASCE Staff Member)