Comparison of BOKI and BOK2 to NAU's Undergraduate Civil Engineering Program

Debra Larson, College of Engineering, Forestry & Natural Sciences,
Northern Arizona University

Introduction

The American Society of Civil Engineering is a promoting change to the path for entering the professional practice of civil engineering. This change is articulated in Policy 465[1], which supports the attainment of a Body of Knowledge (BOK) by way of a fulfillment pathway: bachelor's degree plus a master's degree or thirty semester credits plus experience. This paper presents a review of the two versions of the BOK, BOK1 and BOK2, and a comparison of these versions to the undergraduate civil engineering curriculum at Northern Arizona University (NAU), which is benchmarked to the 2007-2008 ABET Criteria for Accrediting Engineering Programs[2].

BOK1

In January of 2004, the ASCE published the BOK[3] (known as the BOK1) that identified fifteen learning outcomes, of which the first eleven came directly from Criterion 3 of the ABET Criteria for Accrediting Engineering Programs, herein referred to simply as the ABET Criteria. The additional four outcomes addressed technical specialization, project management, construction, asset management, business and public policy and administration, and leadership and its attending attitudes.

In late 2005, an ASCE subcommittee, named the Levels of Achievement subcommittee, produced a report[4] that rewrote the fifteen BOK1 outcomes and framed them within Bloom's cognitive taxonomy. The subcommittee's work represented a major advancement to body of knowledge concept. The fifteen outcomes were restated in terms of action-orientated, measurable verbs and included additional specificity. In example, the broadly stated communication outcome, ABET Outcome (g), was restated to specify communication as covering verbal, written and graphical techniques. Achievement levels per outcome per stages of the fulfillment pathway were made explicit. In example, Outcome 12 - specialized area of civil engineering knowledge – was assigned solely to the master's/30 credits level of the fulfillment pathway. Recently, Outcomes 13 - 15 of the revised BOK1 have been incorporated into the 2008-2009 ABET Criteria[5] within Criterion 9 for civil engineering programs. Specifically, graduates must be able to "explain basic concepts in management, business, public policy, and leadership." In addition, the previous "proficiency" language relating to the four recognized major areas of civil engineering was softened so that programs need only to demonstrate

graduates' abilities to "apply knowledge" in four technical areas appropriate to civil engineering. ASCE adopted the subcommittee's revised BOK1 as the standing BOK1, and it is this version that is used in this paper. The revised BOK1 outcomes for the bachelor's stage of the fulfillment pathway, along with the corresponding level of achievement at graduation and the corresponding ABET Criterion 3 outcome, are provided in Table 1.

Table 1. ASCE's BOK1 Outcomes

BOK1 Outcomes at the Baccalaureate	**Achieve. Level**	**ABET Criteria 3**
1. Graduates can solve problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science.	3: Application	(a)
2. Graduates can design a civil engineering experiment to meet a need; conduct the experiment, and analyze and interpret the resulting data.	5: Synthesis	(b)
3. Graduates can design a complex system or process to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	5: Synthesis	(c)
4. Graduates can function effectively as a member of a multidisciplinary team.	3: Application	(d)
5. Graduates can solve well defined engineering problems in four technical areas appropriate to civil engineering.	3: Application	(e)
6. Graduates can analyze a complex situation involving multiple conflicting professional and ethical interests, to determine an appropriate course of action.	4: Analysis	(f)
7. Graduates can organize and deliver effective verbal, written, and graphical communications.	4: Analysis	(g)
8. Drawing upon a broad education, graduates can determine the global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution.	4: Analysis	(h)
9. Graduates can demonstrate the ability to learn on their own, without the aid of formal instruction.	3: Application	(i)
10. Graduates can incorporate specific contemporary issues into the identification, formulation, and solution of a specific engineering problem.	3: Application	(j)
11. Graduates can apply relevant techniques, skills, and modern engineering tools to solve a simple problem.	3: Application	(k)
12. Specialized area	Not applicable	
13. Graduates can explain key concepts and problem-solving processes used in management.	2: Comprehend	
14. Graduates can explain key concepts and problem-solving processes used in business, public policy, and public administration.	2: Comprehend	
15. Graduates can explain the role of the leader, leadership principles, and attitudes conducive to effective professional practice of civil engineering.	2: Comprehend	

BOK2

Not stopping there, however, ASCE continued in its efforts to further refine the BOK; motivated by questions and suggestions from stakeholders and an interest to further align the BOK with the

newly released 2006 ASCE Vision for Civil Engineering[6]. This work has resulted in the in the BOK2[7] published in 2008. The BOK2 consists of twenty-four outcomes with respective levels of achievement for each stage of the fulfillment pathway from the bachelor's degree through experience. Every outcome, including technical specialization, is targeted for some level of achievement at the bachelor's stage; making this the primary strategy of the fulfillment pathway. Three of the twenty-four BOK2 outcomes are mapped to the master's level. Unlike the BOK1, the BOK2 outcomes do not directly lineup to the eleven ABET Criterion 3 outcomes. ASCE, however, has related, in a general way, nineteen of the twenty-four BOK2 outcomes to Criterion 3, 5, or 9 of the ABET Criteria.

Many of the BOK2 outcomes were developed through disaggregation and specificity of an originating BOK1 outcome or an ABET Criteria requirement. Consider two examples. The BOK1 technical core Outcome 1, which is related to ABET's Outcome (a), is presented as four separated outcomes in the BOK2: two - the mathematics and natural sciences outcomes - are directly identifiable subsets of the BOK1 language, and two – materials science and mechanics outcomes – are newly developed to add specificity to the word "engineering" as it occurs in Outcome (a). The ABET Criterion 5 requirement of a complementary general education component has been addressed by BOK2 by two outcomes specifically applying the humanities and social sciences to professional practice. Relative to the BOK1, other outcomes came into being because the committee added them anew (e.g. historical perspectives, risk and uncertainty) or they were elevated to stand-alone status from their previous standing as being part of a list from which a program could chose to address (e.g. sustainability, globalization). In total, the BOK2 presents an increase of seven new outcomes over the earlier BOK1.

The BOK2 outcomes for the bachelor's stage of the fulfillment pathway, along with the corresponding level of achievement at graduation and the related BOK1 outcomes, are provided in Table 2. The related BOK1 analysis of this table is slightly different than the analysis provided in the BOK2 report[7] of Table H-2. The specific differences lie with BOK2 Outcomes 12 and 14. This author suggests that BOK2 Outcome 12 **is not** related to BOK1 Outcome 3 on design as the topics of risk and uncertainty do not appear in the Outcome 3 language. In contrast, this author suggests that BOK2 Outcome 17 **is** related to BOK1 Outcome 14.

Comparison to NAU

In this section, the civil engineering undergraduate program of NAU, which is currently benchmarked to the 2007-2008 ABET Criteria for Accrediting Engineering Programs[2], is compared against both the BOK1 and BOK2. Members of the department faculty were formed into teams of two to estimate the level of achievement of recent graduates in comparison to the BOK1 and BOK2. The results of the four faculty teams were averaged and rounded to the nearest whole number ranging from a low of 1, which corresponds to Bloom's Knowledge

category, to a high of 6, which corresponds to Bloom's Evaluation category. The rounded mean result was then compared to the ASCE target level of achievement (indicated as LOA in the following tables) at the baccalaureate level. Mean to target results of 1.0 indicate that the NAU evaluation and BOK LOA were the same. These comparative results are presented as Tables 3 and 4.

Table 2. ASCE's BOK2 Outcomes

BOK2 Outcomes at the Baccalaureate	Achiev. Level	BOK1
1. Solve problems in mathematics through differential equations and apply this knowledge to the solution of engineering problems.	3: Application	1
2. Solve problems in calculus-based physics, chemistry, and one additional area of natural science and apply this knowledge to the solution of engineering problems.	3: Application	1
3. Demonstrate the importance of the humanities in the professional practice of engineering.	3: Application	
4. Demonstrate the incorporation of social sciences knowledge into the professional practice of engineering.	3: Application	
5. Use knowledge of materials science to solve problems appropriate to civil engineering.	3: Application	1
6. Solve problems in solid and fluid mechanics.	4: Analysis	1
7. Analyze the results of experiments and evaluate the accuracy of the results within the known boundaries of the tests and materials in or across more than one of the technical areas of civil engineering.	4: Analysis	2
8. Develop problem statements and solve well-defined fundamental civil engineering problems by applying appropriate techniques and tools.	3: Application	5
9. Design a system or process to meet desired needs within such realistic constraints as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.	5: Synthesis	3
10. Apply the principles of sustainability to the design of traditional and emergent engineering systems.	3: Application	3
11. Drawing upon a broad education, explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and explain the impact of engineering solutions on the economy, environment, political landscape, and society.	3: Application	8 & 10
12. Apply the principles of probability and statistics to solve problems containing uncertainties.	3: Application	
13. Develop solutions to well-defined project management problems.	3: Application	13
14. Solve problems in or across at least four technical areas appropriate to civil engineering.	4: Analysis	
15. Define key aspects of advanced technical specialization appropriate to civil engineering.	1: Knowledge	12
16. Organize and deliver effective verbal, written, virtual, and graphical communications.	4: Analysis	7
17. Discuss and explain key concepts and processes involved in public policy.	2: Comprehend	14
18. Explain key concepts and processes used in business and public administration.	2: Comprehend	14
19. Organize, formulate, and solve engineering problems within a global context.	3: Application	10

20. Apply leadership principles to direct the efforts of a small, homogenous group.	3: Application	15
21. Function effectively as a member of an intra-disciplinary team.	3: Application	4
22. Explain attitudes supportive of the professional practice of civil engineering.	2: Comprehend	15
23. Demonstrate the ability for self-directed learning.	3: Application	9
24. Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action.	4: Analysis	6

Table 3. Estimating NAU BS Graduates' Level of Achievement to BOK1

	BOK1 Outcome at Baccalaureate Level	BOK 1 LOA	NAU Rounded Mean	Mean-to-LOA
1	Solve problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science.	3	3	1.0
2	Design a civil engineering experiment to meet a need; conduct the experiment, and analyze and interpret the resulting data.	5	4	0.8
3	Design a complex system or process to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	5	5	1.0
4	Function effectively as a member of a multi-disciplinary team	3	4	1.3
5	Solve well-defined engineering problems in four technical areas appropriate to civil engineering.	3	3	1.0
6	Analyze a complex situation involving multiple conflicting professional and ethical interests, to determine an appropriate course of action.	4	3	0.8
7	Organize and deliver effective verbal, written, and graphical communications.	4	4	1.0
8	Determine the global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution.	3	2	0.7
9	Demonstrate the ability to learn on their own, without the aid of formal instruction.	3	4	1.3
10	Incorporate specific contemporary issues into the identification, formulation, and solution of a specific engineering problem.	3	3	1.0
11	Apply relevant techniques, skills, and modern engineering tools to solve a simple problem.	3	4	1.3
12		NA	4	NA
13	Explain key concepts and problem-solving processes used in management.	2	2	1.0
14	Explain key concepts and problem-solving processes used in business, public policy, and public administration.	2	1	0.5
15	Explain the role of the leader, leadership principles, and attitudes conducive to effective professional practice of civil engineering.	2	2	1.0

The BOK1 analysis of Table 3 suggested that the NAU curriculum of 130 semester units and the corresponding educational environment prepares its students to meet or exceed the expected levels of achievement for ten of the fourteen applicable BOK1 outcomes. For three cases -

BOK1 Outcomes 4, 9, and 11 - the NAU evaluation exceeded the LOA by one level. Of the four below-target outcomes, one was unique to BOK1 and not a part of ABET prior to 2008-2009. The well-defined levels of achievement specified by the BOK1 for the other three below-target outcomes required a higher level of intellectual performance than that required by the corresponding ABET outcomes.

These NAU results are consistent to the results of an ASCE committee – Curriculum Committee of the Committee on Academic Prerequisites for Professional Practice – representing twenty institutions charged to determine the status of civil engineering education in relation to the BOK1. In their 2006 report[8], the committee concluded that none of the twenty programs addressed all of the BOK1 outcomes to the level of achievement expected.

Table 4. Estimating NAU BS Graduates' Level of Achievement to BOK2

	BOK2 Outcome at Baccalaureate Level	BOK 2 LOA	NAU Rounded Mean	Mean-to-LOA
1	Solve problems in mathematics through differential equations and apply this knowledge to the solution of engineering problems.	3	3	1.0
2	Solve problems in calculus-based physics, chemistry, and one additional area of natural science and apply this knowledge to the solution of engineering problems.	3	3	1.0
3	Demonstrate the importance of the humanities in the professional practice of engineering.	3	2	0.7
4	Demonstrate the incorporation of social sciences knowledge into the professional practice of engineering	3	2	0.7
5	Use knowledge of materials science to solve problems appropriate to civil engineering.	3	2	1.0
6	Analyze and solve problems in solid and fluid mechanics.	4	4	1.0
7	Analyze the results of experiments and evaluate the accuracy of the results within the known boundaries of the tests and materials in or across more than one of the technical areas of civil engineering.	4	4	1.0
8	Develop problem statements and solve well-defined fundamental civil engineering problems by applying appropriate techniques and tools.	3	3	1.0
9	Design a system or process to meet desired needs within such realistic constraints as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.	5	5	1.0
10	Apply the principles of sustainability to the design of traditional and emergent engineering systems.	3	1	0.3
11	Drawing upon a broad education, explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and explain the impact of engineering solutions on the economy, environment, political landscape, and society.	3	2	0.7
12	Apply the principles of probability and statistics to solve problems containing uncertainties.	3	1	0.3

13	Develop solutions to well-defined project management problems.	3	2	0.7
14	Analyze and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering.	4	4	1.0
15	Define key aspects of advanced technical specialization appropriate to civil engineering.	1	3	3.0
16	Organize and deliver effective verbal, written, virtual, and graphical communications.	4	4	1.0
17	Discuss and explain key concepts and processes involved in public policy.	2	1	0.5
18	Explain key concepts and processes used in business and public administration.	2	1	0.5
19	Organize, formulate, and solve engineering problems within a global context.	3	1	0.3
20	Apply leadership principles to direct the efforts of a small, homogenous group.	3	3	1.0
21	Function effectively as a member of an intradisciplinary team.	3	3	1.0
22	Explain attitudes supportive of the professional practice of civil engineering.	2	2	1.0
23	Demonstrate the ability for self-directed learning.	3	3	1.0
24	Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action.	4	3	0.8

In contrast, the same curriculum and educational environment prepares the NAU civil engineer to meet or exceed the expected levels of achievement for fourteen of the twenty-four applicable BOK2 outcomes. Eight (BOK2 Outcomes 3, 4, 10, 11, 13, 17, 18, and 19) of the ten below-target results are for outcomes unique to BOK2 and not a part of the 2007-2008 ABET Criteria. The remaining two below-target outcomes (BOK2 Outcomes 12 and 24) are for outcomes with a level of achievement higher than the corresponding expectations of 2007-2008 ABET Criteria.

These NAU results are consistent to the soon to be published results[9] of an ASCE committee – BOK Educational Fulfillment Committee – representing ten institutions charged to investigate and document how programs are incorporating and/or can incorporate the BOK2. A synthesis of each institution's analysis of their graduates' performance relative to the BOK2 revealed that eleven of the twenty-four outcomes are believed to not be currently met at the expected level of achievement by four or more institutions.

Conclusions

The Department of Civil and Environmental Engineering at NAU is currently investigating ways to better align its curricula and environment to the BOK1. The motivation primarily comes from ABET, whereby three of the four new outcomes are now a part of Criterion 9. The department believes that its current program with strengths in design, multi-disciplinary teaming, life-long learning, modern engineering tools, and leadership can be modified with some modest effort to

completely meet BOK1. On the other hand, meeting the BOK2 that contains seven new outcomes in comparison to the BOK1 will be a challenge for NAU's already overly-constrained, unit-limited undergraduate program.

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Biographical Information

Debra Larson, PhD, PE is the associate dean of the College of Engineering, Forestry and Natural Sciences at Northern Arizona University. Prior to this appointment, she served as the chair for the Department of Civil and Environmental Engineering and before that as Professor of Civil Engineering. Debra is currently serving as chair for the ASEE PSW Section.