AC 2010-964: HOW THE CIVIL ENGINEERING BOK2 CAN BE IMPLEMENTED AT MONTANA STATE UNIVERSITY

Brett Gunnink, Montana State University

How the Civil Engineering BOK2 Can be Implemented at Montana State University

Abstract

The purpose of this paper is to provide a comprehensive analysis of Montana State University's civil engineering curriculum with respect to the second edition of the *Civil Engineering Body of Knowledge for the 21st Century* (BOK2), or more specifically the BOK2 outcomes associated with the baccalaureate degree since the BOK2 includes outcomes for baccalaureate and post-baccalaureate formal education as well as pre-licensure experience. Specific emphasis is given those BOK2 outcomes that previous survey data identified as being a challenge for many programs to address within current curricular design. The curriculum, as developed, is considered to be BOK2 compliant, in addition to meeting current university graduation and ABET/EAC accreditation requirements.

Introduction

The first edition of the *Civil Engineering Body of Knowledge for the 21st Century*[1] (BOK1) was released in January 2004. Based on various inputs, a second edition of the *Civil Engineering Body of Knowledge for the 21st Century*[2] (BOK2) was developed and released in February 2008. The BOK1 has already impacted accreditation criteria and civil engineering curricula. The BOK2, while being more recent and not yet addressed within accreditation criteria, is motivating additional change in some civil engineering curricula. Considering specifically the BOK2, a coordinated list of 24 outcomes is presented within three outcome categories: Foundational, Technical and Professional. The outcomes define the desired level of achievement defined according to Bloom's Taxonomy for the cognitive domain[3, 4]. Additionally, the BOK2 has recommended outcome achievement targets for each portion of the fulfillment pathway: for the baccalaureate degree (B), post-baccalaureate formal education (M/30), and pre-licensure experience (E). The emphasis herein is on those outcomes and achievement targets for the baccalaureate degree.

The BOK2 Outcomes Rubric, using Bloom's Taxonomy, is graphically presented in Figure 1. The reader is cautioned that this is simple graphical representation of the full rubric only and should refer to the full rubric as presented in Appendix I of the BOK2 report[2] (which is available at www.asce.org/raisethebar). What is clearly represented in Figure 1 is the recommended level of achievement that an individual must demonstrate for each outcome to enter the future practice of civil engineering at the professional level and, for each outcome, the level of achievement (LOA) expected to be fulfilled through the baccalaureate degree (B), the master's degree or equivalent post-baccalaureate formal education (M/30), and pre-licensure experience (E).

Recently, ASCE's Body of Knowledge (BOK) Educational Fulfillment Committee (BOKEdFC) conducted an analysis of how well civil engineering curricula, in their current design, achieve the educational outcomes of both the first and second editions of the civil engineering BOK[5]. The results of a curricular review by ten representative civil engineering programs were presented along with possible explanations as to why current curricula may fulfill or fall short of fulfilling specific outcomes. Figure 2 presents the results of one of the surveys, specifically one in which

programs reported, for the BOK2 outcome rubric, at what level of achievement they believe *all* of the outcome statement is fulfilled by *all* of their baccalaureate graduates. A color coding was provided to assist with visualizing the results of the survey. Green cells indicate baccalaureate graduates of 8 to 10 programs are believed to be fulfilling the LOA, yellow cells indicate graduate of 5-7 programs are fulfilling the LOA, and red cells indicate baccalaureate graduates of 4 or less programs are fulfilling the specified LOA. To further help with visualizing the results, the first column of each table corresponding to the outcome number has been similarly color coded consistent with the LOA corresponding to the "B" level for each outcome. For example, Outcome 6 (Humanities) is colored red and shows that six of the ten (yellow) surveyed programs believe *all* of the outcome is fulfilled by *all* of their baccalaureate graduates at a LOA 1, five of ten (yellow) at a LOA 2, and three of ten (red) at the targeted LOA 3.

Based on the survey data and analysis, the BOKEdFC[5] concluded that several BOK2 outcomes may be "challenging" for many programs to address in today's civil engineering curricula. These include the nine "red outcomes" shown in Figure 2 (i.e., Outcomes 3 – Humanities, 4 – Social Sciences, 10 – Sustainability, 11 – Contemporary Issues & History, 12 – Risk & Uncertainty, 17 – Public Policy, 18 – Business & Public Administration, 19 – Globalization, and 20 – Leadership). In addition, the committee identified Outcomes 5 – Material Science and Outcome 24 – Professional & Ethics as outcomes that may be challenging for programs to fully implement.

The purpose of this paper is to provide a comprehensive analysis of Montana State University's civil engineering curriculum with respect the BOK2 outcomes associated with the baccalaureate degree. Specific emphasis is given herein to these identified "challenging" outcomes.

Institutional Profile

On February 16, 1893, the Agricultural College of the State of Montana was founded as the state's land-grant college. Renamed The Montana College of Agriculture and Mechanic Arts, the institution was popularly known as Montana Agricultural College, or MAC. By the 1920s, the institution's preferred name was Montana State College and so it remained until July 1, 1965, when, in recognition of the enormous advances in the College's commitment to scientific and humanistic research, the thirty-ninth legislative assembly of the state of Montana changed MSC's name to Montana State University.

Today, Montana State University-Bozeman has a national and international reputation for its excellence in undergraduate and graduate education in the liberal arts and sciences, agriculture, architecture, education, engineering, health and human development, and nursing. It is routinely listed by U.S. News and World Report as one of America's "best buys" for undergraduate education and ranks among the leaders in the number of Goldwater scholarship recipients. It is an institution committed to making history by better positioning today's students for meaningful lives in the globalizing economy of the 21st century. In 2006, the Carnegie Foundation for the Advancement of Teaching reclassified MSU into its highest tier (very high research activity), but the institution retains it undergraduate focus.

There are about 12,300 students enrolled at Montana State University. Over 85% (10,500) of the students are undergraduates. The graduate student population continues to rise each year with approximately 1,850 total graduate students enrolled. The student body profile consists of 47% females, 53% males and 63% Montana residents. Thirty-three percent of the student body is from out-of-state and 3% are international students representing more than 67 countries. Approximately 2000 students have majors administered by the College of Engineering, including 160 graduate students.

The Civil Engineering Department at Montana State University was established in 1936. Over the decades there have been changes in the department. Some of these were significant at the time. For example, the department name changed from the Department of Civil Engineering and Engineering Mechanics to the Department of Civil and Agricultural Engineering and then to the Department of Civil Engineering. Engineering mechanics courses are still administered and taught by Civil Engineering faculty but the Agricultural Engineering program was terminated.

The department has also founded and developed several outstanding research and outreach facilities that are now autonomous entities of the University. The Montana Water Center (USGS), the Center for Biofilm Engineering (NSF) and the Western Transportation Institute (FHWA) were all founded in the CE Department, were administered by CE faculty and staff, and have become productive and healthy autonomous units that now involve faculty from across campus.

The department awards three ABET accredited undergraduate degrees: Bachelor of Science in Civil Engineering; Bachelor of Science in Civil Engineering, Concentration: Bio-Resources Engineering and Bachelor of Science in Construction Engineering Technology. Approximately 690 students and 20 faculty members comprise the department including 360 Civil Engineering majors, 290 Construction Engineering Technology Majors and 40 graduate students.

Current BSCE Curriculum

Among the degree programs offered by the department is the Bachelor of Science in Civil Engineering, which has been continuously accredited by ABET since 1936. Significant curricular redesign was completed in 2007 and implemented in the 2008-2010 course catalog. With these changes, the faculty attempted to modify the curriculum to be consistent with the expectations of BOK1. The Bachelor of Science in Civil Engineering program objectives are shown in Table 1. Illustrative words consistent with Bloom's taxonomy are highlighted with bold print in Table 1. The Bloom's taxonomy levels of achievement (LOA) consistent with these illustrative words are also included in Table 1.

The current (Fall 2009) curriculum is presented in Table 2, which follows the accustomed ABET/EAC self-study standard format. A couple notes of explanation regarding the program and curriculum follow:

The Civil Engineering Bachelor of Science Program is a traditionally structured program that provides graduates with a strong background in math, basic sciences and engineering mechanics, and prepares graduates to become registered professional engineers capable of practicing civil

engineering in the areas of environmental, geotechnical, structural, transportation and water resources engineering. The educational objectives of the Civil Engineering Bachelor of Science Program describe what graduates can expect to accomplish during the first years after graduation.

All graduates can expect to be able to:

1. Enter the profession of Civil Engineering and advance in the profession to become registered professional engineers and leaders in the field of Civil Engineering.
2. Work on multi-disciplinary teams and effectively communicate with Civil Engineers of various sub-disciplines, architects, contractors, the public and public agents, scientists and others to design and construct Civil Engineering projects.
3. Begin to develop expertise in one of the sub-disciplines of Civil Engineering and engage in the life-long learning necessary to advance in the Civil Engineering profession;
4. Contribute to society and the Civil Engineering profession through involvement in professional related and/or other service activity, and
5. Conduct their affairs in a highly ethical manner holding paramount the safety, health and welfare of the public and striving to comply with the principles of sustainable development.

Some graduates can expect to be able to:

6. Enter the surveying profession and become licensed to practice surveying;
7. Begin careers in the construction industry;
8. Or earn advanced degrees in Civil Engineering or other fields.

Courses in the first two years of the program develop a student's mathematical skills and understanding of the physical principles that underlie the practice of civil engineering. Engineering science courses in the second, third, and fourth years develop the student's ability to apply mathematics and basic scientific principles to the solution of practical engineering problems. The third year student develops a broad perspective of the field and establishes the foundation for professional practice and further study. The student completes at least one course in each subarea of civil engineering by the end of this year. Most of these courses are combinations of engineering science and design experiences. The fourth year includes a capstone professional practice and design experience, elective courses in a subarea (or subareas) of civil engineering and elective courses that help the student develop an appreciation for the role of the professional engineer in society. Additional experience in professional practice and design may be obtained through participation in the department's optional internship program. The use of contemporary engineering tools are introduced in the first year and used in assignments throughout the rest of the program. Courses and assignments that develop oral and written communication skills are distributed throughout the curriculum and are components of the capstone professional practice and design experience in the fourth year.

Graduating students are required to take the Fundamentals of Engineering exam administered by the Montana Board of Professional Engineers and Land Surveyors as the first step toward

professional registration. ENGR 499 (Engineering Program Assessment), a zero-credit course, is used to administer the exam. Students are encouraged to take the discipline-specific version. This examination is administered by the National Council of Engineering Examining Boards and is accepted nationwide through reciprocity with the Montana Board of Professional Engineers and Land Surveyors.

Evaluation of Current Curriculum vs. BOK2 Outcomes

As mentioned earlier, the current BSCE program outcomes exist largely in response to the ASCE BOK1 report. Accordingly, curricular and course-content changes have been made to support these program outcomes. A comparison of the BOK2 baccalaureate outcomes and the current BSCE program outcomes is provided in Table 3. Figure 3 shows the results of a current self appraisal of MSU civil engineering graduates for each BOK2 outcome. A color coding is provided to assist with visualizing the results of the appraisal. Green cells indicate the level baccalaureate graduates are believed to be fulfilling. If all the cells are green, then it is believe that that graduate are fulfilling the outcome at the BOK2 expected LOA. Yellow cells show where the believed LOA is less than theBOK2 expected LOA. If the first column of the table corresponding to the outcome number is color coded red, then this outcome is one of the so-called "challenging" outcomes as identified by the BOKEdFC[5]. For example, Outcome 9 (Design) is colored green and shows that current MSU LOA equals the BOK2 expected LOA. In contrast, for outcome 3 (humanities) the MSU LOA is less than the BOK2 expected LOA. It is worth noting that the appraised LOAs shown in Figure 3 are sometimes higher than target LOAs associated with the current MSU program outcomes (see Table 1). It is noting that there is a lot of overlap between the MSU "yellow" outcomes (3, 5, 17-20) and the BOKEdFC5 "challenging" outcomes (3-5, 10-12, 17-20, and 24).

Current Curriculum and the "Challenging" BOK2 Outcomes

Considering the so-called "challenging" BOK2 outcomes as identified by the BOKEdFC[5], the current curriculum at Montana State University is considered to fully address some (outcomes 10-12, and 24) and not fully address others (outcomes 3-5 and 17-20). A more detailed discussion of how the curriculum addresses these "challenging" outcomes follows:

Outcome 3 – Humanities: The BOK2 envisions graduates with a bachelor's degree in civil engineering be able to "demonstrate the importance of the humanities in the professional practice of engineering." The university as part of its general education requires 2 courses in what the BOK2 defines as the humanities; both inquiry in the arts (IA) and inquiry in the humanities (IH) courses are required. What is currently lacking in the curriculum is the humanities tie to engineering and their impact on engineering decisions.

Outcome 4 – Social Sciences: Similar to Outcome 3, the BOK2 aspires to have graduates "demonstrate the incorporation of social sciences knowledge into the professional practice of engineering." The university as part of its general education requires 1 course in what the BOK2 defines as the social sciences. This course is an inquiry in the social sciences (IS) course. Students are also required to a take a diversity (D) course which may be in a social science field. Social Science topics are found in a few other courses, i.e., I&ME 325, Engineering Economic Analysis, CE 308, Construction Practice, and CE 401, Professional Practice and Ethics. Students apply knowledge of social sciences in their capstone design

classes (CE 457 and 458) as they complete design projects considering economic, safety, and sustainability constraints.

Outcome 5 – Material Science: The BOK2 envisions graduates to "use knowledge of materials science to solve problems appropriate to civil engineering." Students may elect to take a broad engineering material course as their engineering science elective. They also learn about a narrower spectrum of civil engineering materials in CE 315, Structures II (steel and concrete) and use this knowledge to solve structural design problems in civil engineering. The program is probably weak in this area because not all students will take the materials course.

Outcome 10 – Sustainability: The BOK2 expects future graduates to "apply the principles of sustainability to the design of traditional and emergent engineering systems." Since the BOK2 outcomes explicitly ties sustainability to design, sustainability was formally integrated with the program's design outcome by stating the design must be conducted "including sustainability and within realistic constraints." Sustainability is emerging as an important design constraint in all design classes. Capstone projects require students to balance the conflicting objectives of economy, safety, and sustainability when considering design alternatives. Sometimes this is accomplished by applying a formal mechanism such as LEED certification for a building.

Outcome 11 – Contemporary Issues & History: The BOK2 expects students, "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." Students are required to take an inquiry in the humanities course (IH) that may be a history course. However, this history course is unlikely to discuss engineering at all. Students are asked to study contemporary issues and engineering history to some extent in the context of engineering ethics. This occurs in CE 401, Ethics and Professional Practice. However this is only a 1 credit hour course.

Outcome 12 – Risk & Uncertainty: The BOK2 envisions graduates with a bachelor's degree in civil engineering to "apply the principles of probability and statistics to solve problems containing uncertainties." Students take a class in probability and statistics (I&ME 250). Students apply principles of probability and statistics required civil engineering designs course. These courses include CE 331, hydrology, and CE 315, structures II.

Outcome 17 – Public Policy: Under the BOK2, future graduates will be expected to "discuss and explain key concepts and processes involved in public policy." Students are required to take a Business, Public Policy, and Public Administration Elective (BPPA) course. This elective restricts students' choices for their general education electives. The courses they may choose form include ECNS 101IS, Economic Way of Thinking, MGMT 231IS Knowledge Creation and Inquiry in Business, MGMT 245D, Cultural Dimensions of International Business, MKTG 242D, Introduction to Global Markets, PSCI 210IS, Introduction to American Government, PSCI 214IS, Principles of Political Science, and PSCI 230D Intro to International Business. It is recommended that student take two of these courses. Collectively, these courses cover Public Policy, Business & Public Administration, and Globalization topics. Since students are required to take only one of these course, one or

two of these outcomes (17, 18, and 19) will be include in their curriculum, but one or more is likely to be excluded as well. Because of this the program is weak respect to these outcomes.

Outcome 18 – Business & Public Administration: Following the BOK2, graduates with a CE degree will be expected to "explain key concepts and processes used in business and public administration." See the statement for *Outcome 17*.

Outcome 19 – Globalization: This new outcome to the BOK2 expects students to "organize, formulate, and solve engineering problems within a global context." See the statement for *Outcome 17*.

Outcome 20 – Leadership: The BOK2 envisions civil engineering graduates of the future to "apply leadership principles to direct the efforts of a small, homogenous group." Students work in teams on design project often in the curriculum, most particularly, in ENGR 310, Introduction to Engineering Design, CE 457R, Senior Project I, and CE 458R, Senior Project II. They receive some instruction on the leadership principles in these and other courses. The challenge in meeting this outcome is insuring that all students assume a leadership role at some point rather than defaulting to a follower role throughout their academic career.

Outcome 24 – Professional & Ethics: The BOK2 outcome expecting graduates to "analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action" is not new to civil engineering curricula. Students take a 1 credit hour, ethic and professional practice course (CE 401). Students approach the study of ethics from both a theoretical approach and an applied approach. This is accomplished through reading assignments, short writing assignments, and ethical case study presentations.

Curricular Changes Needed to Fully Implement the BOK2

The current curriculum at Montana State University is considered to not fully address outcomes 3-5 and 17-20. A more detailed discussion of how the curriculum might be modified to better addresses these outcomes follows:

Outcome 3 – Humanities: The BOK2 envisions graduates with a bachelor's degree in civil engineering to "demonstrate the importance of the humanities in the professional practice of engineering." The university as part of its general education requires 2 courses in what the BOK2 defines as the humanities; both inquiry in the arts (IA) and inquiry in the humanities (IH) courses are required. What is currently lacking in the curriculum is the humanities tie to engineering and their impact on engineering decisions. This tie might be made by requiring students to take ENGR125CS, Technology Innovation and Society. This contemporary issues in science (CS) course was developed by faculty in the MSU department of Electrical Engineering, primarily to educate non-engineer about engineering and it role in society. The course explores the innovative engineering processes that connect the creative elements of science and engineering with solving problems of everyday life[6]. This course would be taken during the 1st year in the BOK2 compliant curriculum. A result of the addition of this course is one less professional elective course. Students are currently required to take 12 hours of professional electives. In the BOK2 compliant curriculum, student would be required to take 9 hours of professional electives.

Outcome 4 – Social Sciences: Similar to Outcome 3, the BOK2 aspires to have graduates "demonstrate the incorporation of social sciences knowledge into the professional practice of engineering." The university as part of its general education requires 1 course in what the BOK2 defines as the social sciences. This course is an inquiry in the social sciences (IS) course. Students are also required to a take a diversity (D) course which may be in a social science field. Social Science topics are found in a several other courses, i.e., I&ME 325, Engineering Economic Analysis, CE 308, Construction Practice, and CE 401, Professional Practice and Ethics. Students apply knowledge of social sciences in their capstone design classes (CE 457 and 458) as they complete design projects considering economic, safety, and sustainability constraints. It is anticipated the requiring a second BPPA elective course (see discussions concerning *Outcome 17*) will strength compliance with this outcome.

Outcome 5 – Material Science: The BOK2 envisions graduates to "use knowledge of materials science to solve problems appropriate to civil engineering." The current curriculum is strengthened by making ChBE 215, Materials Science, a required course. It is currently one of three possible engineering science electives. This course will provide instruction in the broad field of material science. Student will continue more in-depth learning about a narrower spectrum of civil engineering materials in CE 315, Structures II (steel and concrete). Knowledge of these materials is used to solve structural design problems in civil engineering

Outcome 17 – Public Policy: Under the BOK2, future graduates will be expected to "discuss and explain key concepts and processes involved in public policy." Students are required to take a Business, Public Policy, and Public Administration Elective (BPPPA) course. This elective restricts students' choices for their general education electives. The courses they may choose form include ECNS 101IS, Economic Way of Thinking, MGMT 231IS Knowledge Creation and Inquiry in Business, MGMT 245D, Cultural Dimensions of International Business, MKTG 242D, Introduction to Global Markets, PSCI 210IS, Introduction to American Government, PSCI 214IS, Principles of Political Science, and PSCI 230D Intro to International Business. The BOK2 compliant curriculum would require students to take two of these courses, one with a diversity, D, designation and one with an inquiry in science, IS designation. The requirement of a diversity course assures a "global" element is included in a student's education.

Outcome 18 – Business & Public Administration: Following the BOK2, graduates with a CE degree will be expected to "explain key concepts and processes used in business and public administration." See the statement for *Outcome 17*.

Outcome 19 – Globalization: This new outcome to the BOK2 expects students to "organize, formulate, and solve engineering problems within a global context." See the statement for *Outcome 17*.

Outcome 20 – Leadership: The BOK2 envisions civil engineering graduates of the future to "apply leadership principles to direct the efforts of a small, homogenous group." Students work in teams on design project often in the curriculum, most particularly, in ENGR 310, Introduction to Engineering Design, CE 457R, Senior Project I, and CE 458R, Senior Project II. They receive some instruction on the leadership principles in these and other courses. The challenge in meeting this outcome is insuring that all students assume a leadership role at some point rather than defaulting to a follower role throughout their academic career. It is

anticipated that if team assignments in these classes are structured to force the leadership role to rotate from one member of the group to another, then each student will apply leadership principles to direct the effort of these student groups.

The BOK2 Compliant Curriculum

Table 4 illustrates what the BOK2 compliant might look like at MSU. The courses that would comprise the BOK2 compliant curriculum are not very different than the courses that comprise the current curriculum. There is a new required course in the freshman year, ENGR 125, Technology Innovation and Society. This course replaces a professional elective course in the senior year. Also, a second Business Professional and Public Policy (BPPA) in required in the BOK2 compliant curriculum. This requirement would limit student choice with respect to general education (core) courses, specifically, inquiry in social sciences and diversity courses.

Conclusions

MSU recently completed revising its curriculum to be consistent with new ABET program criteria and with the BOK. The anticipated additional revision necessary to be BOK2 compliant is not onerous. The anticipated additional revision would result, from the student perspective, in a more restrictive curriculum with fewer choices. The combined effect of BOK and BOK2 revisions result in a curriculum where students spend somewhat less time studying fundamental engineering science and design topics and somewhat more time studying basic science, social science, humanities and professional practice topics. This seemingly is the intent of both the BOK and BOK2. The greatest concern of the author with regards to both the BOK and BOK2 is that the more restrictive bachelors programs coupled with the onus of additional post-baccalaureate education being necessary to enter the profession of civil engineering will result in many fewer students choosing civil engineering as a professional career.

Bibliography

1. ASCE Body of Knowledge Committee of CAP^3. 2004. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future,* Reston, VA, January. (http://www.asce.org/raisethebar).

2. ASCE Body of Knowledge II Committee of CAP^3. 2008. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future,* Second Edition, Reston, VA, January. (http://www.asce.org/raisethebar).

3. ASCE Levels of Achievement Subcommittee of CAP^3. 2005. *Levels of Achievement Applicable to the Body of Knowledge Required for Entry Into the Practice of Civil Engineering at the Professional Level,* Reston, VA, September. (http://www.asce.org/raisethebar)

4. Bloom. B. S., Englehart, M. D., Furst. E. J., Hill, W. H., and Krathwohl, D. 1956. *Taxonomy of Educational Objectives, the Classification of Educational Goals, Handbook I: Cognitive Domain.* David McKay, New York, NY.

5. Fridley, K.J., et al., 2009. "Educating the Future Civil Engineering for the New Civil Engineering Body of Knowledge," *Proceeding of the 2009 ASEE Annual Conference*, June 2009, Austin, TX.

6. Montana State University, 2008. Course Bulletin 2008-2010, Montana State University, Bozeman, MT.

OUTCOME	OUTCOME TITLE	BLOOM'S LEVEL OF ACHIEVEMENT (LOA)					
		1	2	3	4	5	6
1	Mathematics	B	B	B			
2	Natural Sciences	B	B	B			
3	Humanities	B	B	B			
4	Social Sciences	B	B	B			
5	Material Science	B	B	B			
6	Mechanics	B	B	B	B		
7	Experiments	B	B	B	B	M/30	
8	Problem Recognition & Solving	B	B	B	M/30		
9	Design	B	B	B	B	B	E
10	Sustainability	B	B	B	E		
11	Contemporary Issues & History	B	B	B	E		
12	Risk & Uncertainty	B	B	B	E		
13	Project Management	B	B	B	E		
14	Breadth in CE	B	B	B	B		
15	Tech Specialization	B	M/30	M/30	M/30	M/30	E
16	Communication	B	B	B	B	E	
17	Public Policy	B	B	E			
18	Business & Public Admin	B	B	E			
19	Globalization	B	B	B	E		
20	Leadership	B	B	B	E		
21	Teamwork	B	B	B	E		
22	Attitudes	B	B	E			
23	Lifelong Learning	B	B	B	E	E	
24	Professional & Ethics	B	B	B	B	E	E

Figure 1: Graphical Representation of the BOK2 Outcome Rubric

OUTCOME	OUTCOME TITLE	BLOOM'S LEVEL OF ACHIEVEMENT					
		1	2	3	4	5	6
1	Mathematics	10	10	9	2	0	0
2	Natural Sciences	10	10	9	2	0	0
3	Humanities	6	5	3	2	0	0
4	Social Sciences	7	4	2	1	0	0
5	Material Science	9	7	5	2	0	0
6	Mechanics	10	9	9	7	0	0
7	Experiments	9	9	9	8	2	0
8	Problem Recognition & Solving	10	9	9	2	1	0
9	Design	9	10	9	8	7	0
10	Sustainability	6	3	2	2	0	0
11	Contemporary Issues & History	7	3	2	1	0	0
12	Risk & Uncertainty	7	3	2	1	0	0
13	Project Management	9	9	6	0	0	0
14	Breadth in CE	10	10	9	9	0	0
15	Tech Specialization	9	7	5	3	0	0
16	Communication	10	10	8	8	2	0
17	Public Policy	5	4	0	0	0	0
18	Business & Public Admin	7	4	0	0	0	0
19	Globalization	5	3	1	0	0	0
20	Leadership	9	7	4	0	0	0
21	Teamwork	9	8	7	2	0	1
22	Attitudes	7	7	0	0	0	0
23	Lifelong Learning	10	10	9	0	0	0
24	Professional & Ethics	10	10	7	5	0	0

Figure 2: Number of Programs (out of 10) Reporting *All* of the BOK2 Outcomes at Each LOA are Fulfilled by *All* of Their Baccalaureate Graduates.[5]

Table 1: Montana State University Current BSCE Program Outcomes.

1	Ability to **apply** knowledge of mathematics, science and engineering. (LOA 3)
2	Ability to **design** and **conduct** experiments, as well as **analyze** and **interpret** data. (LOA 5)
3	Ability to **design** a system, component, or process to meet desired needs. (LOA 5)
4	Ability to **function** on multi-disciplinary teams. (LOA 3)
5	Ability to **identify, formulate, and solve** engineering problems. (LOA 4)
6	**Understand**ing of professional and ethical responsibility. (LOA 1)
7	**Ability** to communicate effectively. (LOA 2)
8	The broad education necessary to **understand** the impact of engineering solutions in a global and societal context. (LOA 1)
9	Recognition of the need for, and an **ability** to engage in, life-long learning. (LOA 2)
10	**Knowledge** of contemporary issues. (LOA 1)
11	Ability to **use** the techniques, skills, and modern engineering tools necessary for engineering practice. (LOA 3)
12	Ability to **apply** knowledge in a specialized area related to civil engineering (primarily MS level).
13	**Understand**ing of the elements of project management, construction, and asset management. (LOA 1)
14	**Understand**ing of business and public policy and administration fundamentals. (LOA 1)
15	**Understand**ing of the role of the leader and leadership principles and attitudes. (LOA 1)

Table 2: Montana State University's Current BSCE Curriculum.

Year, Semester	Course	Category (Credit Hours)			
		Math & Basic Sciences	Engineering Topics *Significant Design (✓)*	General Education	Other
Year 1, Fall	COM 110US – Public Communication, or CLS 101US – University Seminar, or US 101US – First Year Seminar			3	
	Core Elective			3	
	M 171Q – Calculus I	4			
	ME 115 – Engineering Design Graphics		1		
	WRIT 101W – College Writing I			3	
Year 1, Spring	CHMY 141 – College Chemistry I	4			
	CE 201 – Surveying		3		
	CE 202 – Applied Analysis & Communication		1	1	
	M 172Q – Calculus II	4			
	PHYS 211 – General and Modern Physics I	4			
Year 2, Fall	BIOL 102 – Molecular and Cellular Biology, or GEO 101N – Intro to Physical Geology, or GPHY 284 – Intro to GIS Science and Cartography, or LRES 201 – Soil Resource, or MB 101N – Microbiology in Today's World	4 or 3			
	M 273Q – Multivariable Calculus	4			
	CHMY 143 – College Chemistry II	4			
	EM 251 – Statics & Particle Dynamics		3		
	PHYS 212 – Gen. & Mod Physics II	4			
Year 2, Spring	BUS 201 – Managerial Communication, or WRIT 201 – College Writing II, or WRIT 221 – Intermediate Technical Writing			3	
	EM 252 – Rigid Body Mechanics		3		
	EM 253 – Mechanics of Materials		3		
	I&ME 350 – Applied Engineering Data Analysis, or STAT 332 – Statistics for Scientists & Engineers	2 or 3			
	M 274 – Differential Equations	4			
	ME 116 – Engineering Design Graphics Lab		1		
Year 3, Fall	CE 312 – Structures I		3 ✓		
	CE 320 – Geotechnical Engineering		3		
	CE 331 – Engineering Hydrology		2 ✓		
	CE 350 – Transportation Engineering		3 ✓		
	EM 335 – Fluid Mechanics		3		
	I&ME 325 – Engineering Economy		3		

Table 2: Montana State University's BSCE Curriculum - Continued.

Year, Semester	Course	Category (Credit Hours) Math & Basic Sciences	Engineering Topics *Significant Design (✓)*	General Education	Other
Year 3, Spring	CHBE 213 – Material Science, or EE 250 – Circuits, Devices & Meters, or ME 320 – Thermodynamics I, or ME 324 – Engineering Thermodynamics		3		
	CE 308 – Construction Practice		3		
	CE 315 – Structures II		3 ✓		
	CE 332 – Engineering Hydraulics		2 ✓		
	CE 340 – Principles of Environmental Engineering		3 ✓		
	ENGR 310 – Introduction to Engineering Design		3 ✓		
Year 4, Fall	CE 401 – Professional Ethics		1		
	CE 457 – Senior Project I		2 ✓		
	Business, Public Policy, Public Administration (BPPPA) Core Elective			3	
	Analytical Professional Elective		3		
	Professional Electives		6 ✓		
Year 4, Spring	CE 458 – Senior Project II		2 ✓		
	Core Electives			6	
	Professional Electives		6 ✓		
	ENGR 499 – Engineering Program Assessment				0
Totals of ABET Basic Level Requirements		37-39	69	22	0
Total Credit Hours Required for Degree = 128					
Percent of Total		29%	54%	17%	0%
Totals must satisfy one of:	Minimum semester credit hours	32	48		
	Minimum percentage	25%	37.5 %		

Table 3. Mapping of BOK2 Outcomes with MSU Program Outcomes.

BOK2 Outcomes	Program Outcomes
1: **Solve** problems in mathematics through differential equations and **apply** this knowledge to the solution of engineering problems. (LOA 3)	1: Ability to **apply** knowledge of mathematics, science and engineering. (LOA 3)
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. (LOA 3)	1: Ability to **apply** knowledge of mathematics, science and engineering. (LOA 3)
3: **Demonstrate** the importance of the humanities in the professional practice of engineering (LOA 3)	8: The broad education necessary to **understand** the impact of engineering solutions in a global and societal context. (LOA 1)
4: **Demonstrate** the incorporation of social sciences knowledge into the professional practice of engineering (LOA 3)	8: The broad education necessary to **understand** the impact of engineering solutions in a global and societal context. (LOA 1)
5: **Use** knowledge of materials science to **solve** problems appropriate to civil engineering (LOA 3)	1: Ability to **apply** knowledge of mathematics, science and engineering. (LOA 3)
6: **Analyze** and solve problems in solid and fluid mechanics (LOA 3)	1: Ability to **apply** knowledge of mathematics, science and engineering. (LOA 3)
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. (LOA 4)	2: Ability to **design** and **conduct** experiments, as well as **analyze** and **interpret** data. (LOA 5)
8: **Develop** problem statements and **solve** well-defined fundamental civil engineering problems by **applying** appropriate techniques and tools (LOA 3)	5: Ability to **identify**, **formulate**, and **solve** engineering problems. (LOA 4)
	11: Ability to **use** the techniques, skills, and modern engineering tools necessary for engineering practice. (LOA 3)
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. (LOA 5)	3: Ability to **design** a system, component, or process to meet desired needs. (LOA 5)
10: **Apply** the principles of sustainability to the design of traditional and emergent engineering systems (LOA 3)	3: Ability to **design** a system, component, or process to meet desired needs. (LOA 5)
	10: **Knowledge** of contemporary issues. (LOA 1)

Table 3. Mapping of BOK2 Outcomes with MSU Program Outcomes - continued.

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. (LOA 3)	8: The broad education necessary to **understand** the impact of engineering solutions in a global and societal context. (LOA 1) 10: **Knowledge** of contemporary issues. (LOA 1)
12: **Apply** the principles of probability and statistics to **solve** problems containing uncertainties (LOA 3)	3: Ability to **design** a system, component, or process to meet desired needs. (LOA 5)
13: **Develop** solutions to well-defined project management problems (LOA 3)	13: **Understand**ing of the elements of project management, construction, and asset management. (LOA 1)
14: **Analyze** and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering (LOA 4)	5: Ability to **identify**, **formulate**, and **solve** engineering problems. (LOA 4)
15: **Define** key aspects of advanced technical specialization appropriate to civil engineering (LOA 1)	12. Ability to apply knowledge in a specialized area related to civil engineering (primarily MS level).
16: **Organize** and **deliver** effective verbal, written, virtual, and graphical communications (LOA 4)	7: **Ability** to communicate effectively. (LOA 2)
17: **Discuss** and **explain** key concepts and processes involved in public policy (LOA 2)	14: **Understand**ing of business and public policy and administration fundamentals. (LOA 1)
18: **Explain** key concepts and processes used in business and public administration (LOA 2)	14: **Understandi**ng of business and public policy and administration fundamentals. (LOA 1)
19: **Organize, formulate,** and **solve** engineering problems within a global context (LOA 3)	5: Ability to **identify**, **formulate**, and **solve** engineering problems. (LOA 4) 10: **Knowledge** of contemporary issues. (LOA 1)
20: **Apply** leadership principles to direct the efforts of a small, homogenous group (LOA 3)	15: **Understand**ing of the role of the leader and leadership principles and attitudes. (LOA 1)
21: **Function** effectively as a member of an intra-disciplinary team. (LOA 3)	4: Ability to **function** on multi-disciplinary teams. (LOA 3)
22: **Explain** attitudes supportive of the professional practice of civil engineering (LOA 3)	15: **Understand**ing of the role of the leader and leadership principles and attitudes. (LOA 1)

Table 3. Mapping of BOK2 Outcomes with MSU Program Outcomes - continued.

23: **Demonstrate** the ability for self-directed learning (LOA 3)	9: Recognition of the need for, and an **ability** to engage in, life-long learning. (LOA 3)
24: **Analyze** a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action (LOA 4)	6: **Understand**ing of professional and ethical responsibility. (LOA 1)

BOK2 Outcome	BOK2 Outcome Name	BSCE Outcome	BLOOM'S LEVEL OF ACHIEVEMENT (LOA)					
			1	2	3	4	5	6
1	Mathematics	F1	B	B	B			
2	Natural Sciences	F1	B	B	B			
3	Humanities	F2	B	B	B			
4	Social Sciences	F2	B	B	B			
5	Material Science	T1	B	B	B			
6	Mechanics	T1	B	B	B	B		
7	Experiments	T2	B	B	B	B	M/30	
8	Problem Recognition & Solving	T3	B	B	B	M/30		
9	Design	T6	B	B	B	B	B	E
10	Sustainability	T6	B	B	B	E		
11	Contemporary Issues & History	T4	B	B	B	E		
12	Risk & Uncertainty	F1	B	B	B	E		
13	Project Management	T5	B	B	B	E		
14	Breadth in CE	T3	B	B	B	B		
15	Tech Specialization	T7	B	M/30	M/30	M/30	M/30	E
16	Communication	P2	B	B	B	B	E	
17	Public Policy	P5	B	B	E			
18	Business & Public Admin	P5	B	B	E			
19	Globalization	P5	B	B	B	E		
20	Leadership	P4	B	B	B	E		
21	Teamwork	P4	B	B	B	E		
22	Attitudes	P4	B	B	E			
23	Lifelong Learning	P3	B	B	B	E	E	
24	Professional & Ethics	P1	B	B	B	B	E	E

Figure 3: Graphical Comparison of Montana State University's BSCE Program Level of Achievement to BOK2 Outcomes.

Table 4: Montana State University's BOK2 BSCE Curriculum.

Year, Semester	Course	Category (Credit Hours)			
		Math & Basic Sciences	Engineering Topics *Significant Design (✓)*	General Education	Other
Year 1, Fall	COM 110US – Public Communication, or CLS 101US – University Seminar, or US 101US – First Year Seminar			3	
	ENGR 125CS – Technology Innovation & Society			3	
	M 171Q – Calculus I	4			
	ME 115 – Engineering Design Graphics		1		
	WRIT 101W – College Writing I			3	
Year 1, Spring	CHMY 141 – College Chemistry I	4			
	CE 201 – Surveying		3		
	CE 202 – Applied Analysis & Communication		1	1	
	M 172Q – Calculus II	4			
	PHYS 211 – General and Modern Physics I	4			
Year 2, Fall	BIOL 102 – Molecular and Cellular Biology, or GEO 101N – Intro to Physical Geology, or GPHY 284 – Intro to GIS Science and Cartography, or LRES 201 – Soil Resource, or MB 101N – Microbiology in Today's World	4 or 3			
	M 273Q – Multivariable Calculus	4			
	CHMY 143 – College Chemistry II	4			
	EM 251 – Statics & Particle Dynamics		3		
	PHYS 212 – Gen. & Mod Physics II	4			
Year 2, Spring	BUS 201 – Managerial Communication, or WRIT 201 – College Writing II, or WRIT 221 – Intermediate Technical Writing			3	
	EM 252 – Rigid Body Mechanics		3		
	EM 253 – Mechanics of Materials		3		
	I&ME 350 – Applied Engineering Data Analysis, or STAT 332 – Statistics for Scientists & Engineers	2 or 3			
	M 274 – Differential Equations	4			
	ME 116 – Engineering Design Graphics Lab		1		
Year 3, Fall	CE 312 – Structures I		3 ✓		
	CE 320 – Geotechnical Engineering		3		
	CE 331 – Engineering Hydrology		2 ✓		
	CE 350 – Transportation Engineering		3 ✓		
	EM 335 – Fluid Mechanics		3		
	I&ME 325 – Engineering Economy		3		

Table 4: Montana State University's BOK2 BSCE Curriculum - Continued.

Year, Semester	Course	Category (Credit Hours)			
		Math & Basic Sciences	Engineering Topics *Significant Design (✓)*	General Education	Other
Year 3, Spring	CHBE 213 – Material Science		3		
	CE 308 – Construction Practice		3		
	CE 315 – Structures II		3 ✓		
	CE 332 – Engineering Hydraulics		2 ✓		
	CE 340 – Principles of Environmental Engineering		3 ✓		
	ENGR 310 – Introduction to Engineering Design		3 ✓		
Year 4, Fall	CE 401 – Professional Ethics		1		
	CE 457 – Senior Project I		2 ✓		
	Business, Public Policy, Public Administration (BPPPA) Core Elective			3	
	Analytical Professional Elective		3		
	Core Elective			3	
	Professional Electives		3 ✓		
Year 4, Spring	CE 458 – Senior Project II		2 ✓		
	Business, Public Policy, Public Administration (BPPPA) Core Elective			3	
	Core Electives			3	
	Professional Electives		6 ✓		
	ENGR 499 – Engineering Program Assessment				0
Totals of ABET Basic Level Requirements		37-39	66	25	0
Total Credit Hours Required for Degree = 128					
Percent of Total		29%	51.5%	19.5%	0%
Totals must satisfy one of:	Minimum semester credit hours	32	48		
	Minimum percentage	25%	37.5 %		