AC 2010-275: A POSSIBLE CIVIL ENGINEERING BOK2 CURRICULUM

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A Possible Civil Engineering BOK2 Curriculum at Northern Arizona University

Abstract

The second edition of the *Civil Engineering Body of Knowledge for the 21st Century* (BOK2) is a comprehensive, coordinated list of 24 outcomes which define the knowledge, skills, and attitudes expected of the future civil engineer. The BOK2 outcomes use Bloom's Taxonomy for cognitive development to help define the levels of achievement (LOA) expected to be achieved prior to entry into the professional practice of civil engineering, as well as the levels of achievement for each outcome relative to each stage in the engineer's development, from the baccalaureate degree program, to post-baccalaureate formal education, to pre-licensure working experience.

As part of a continuing effort, ASCE's Body of Knowledge Educational Fulfillment Committee (BOKEdFC) is examining how programs are responding to the BOK2 and possible ways the BOK2 outcomes may be integrated into civil engineering curricula. Previously, the BOKEdFC examined survey data illustrating how well programs, in their current design, achieve the educational outcomes of both the first and second editions of the civil engineering BOK. Based on the survey data and analysis, the BOKEdFC 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": 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 24 – Professional & Ethics as outcomes that may be challenging for programs to fully implement.

The purpose of this paper is threefold: (1) provide an analysis of Northern Arizona University's current undergraduate civil engineering curriculum with respect to the BOK2 with attention given to the challenging outcomes; (2) propose a revised BOK2-orientated curriculum within Northern Arizona University's context; and (3) provide an analysis of that curriculum.

Engineering science courses and senior-level technical electives were removed to make room for courses more suitable to the BOK2 and to reduce overall program credit hours. Compliance to the current ABET EAC was maintained, along with the commitment to our unique program of meaningful, varied, and multiple design experiences delivered in a problem-based format every year of the curriculum. Constraints including budgetary pressures and implementation of the XBOR's 2020 vision coupled to an evolving and complicated general education program with a

semester abroad agenda strained Northern Arizona University's BOK2 curriculum redesign efforts. Without relaxation of the requirements that liberal studies courses must come from outside the major requirements and that creation of new courses is to be minimized, four of the "challenging" BOK2 outcomes are not achievable at the prescribed LOA. Furthermore, concerns were developed about the BOK2 curriculum's impact on students' future success with the FE if this exam is not aligned to the BOK2.

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. The BOK2 is essentially a coordinated list of 24 outcomes presented within three outcome categories: Foundational, Technical and Professional. The outcomes define the desired level of achievement (LOA) 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 the baccalaureate degree.

The BOK2 Outcomes Rubric, using Bloom's Taxonomy, is graphically presented in Figure 1. The reader is cautioned that this is a simplified graphical representation. The complete rubric is presented in Appendix I of the BOK2 report[2]. The purpose of Figure 1 is to represent the recommended LOA that an individual must demonstrate for each outcome through the fulfillment pathway.

Recently, ASCE's Body of Knowledge Educational Fulfillment Committee (BOKEdFC) conducted an analysis of how well current civil engineering curricula 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 civil engineering programs were presented along with possible explanations as to why current curricula may fulfill or fall short of achieving specific outcomes. Figure 2 presents the results of one of the surveys in which programs reported LOA they believe *all* of the outcome statement is fulfilled by *all* of their baccalaureate graduates for the BOK2. A color coding was provided to better visualize the results. Green cells indicate baccalaureate graduates of eight or more programs meet the target LOA, yellow cells indicate graduates of five to seven programs are fulfilling the LOA, and red cells indicate baccalaureate graduates of four or less programs are fulfilling the specified LOA.

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). Two yellow outcomes, Outcomes 5 – Material Science and Outcome 24 – Professional & Ethics, were likewise categorized as challenging because only five programs (vs. four for a red outcome) reported reaching the desired LOA.

The purpose of this paper is threefold: (1) provide an analysis of Northern Arizona University's current undergraduate civil engineering curriculum with respect to the BOK2 with attention given to the challenging outcomes; (2) propose a revised BOK2-orientated curriculum within Northern Arizona University's context; and (3) provide an analysis of that curriculum.

Institutional Profile

Northern Arizona University (NAU) is a public university of the State of Arizona founded in 1899 and directed by the Arizona Board of Regents (ABOR). It is a comprehensive, high research university with its main campus in Flagstaff, which is a largely residential campus with a local student population of over 16,000. NAU-YUMA shares a campus with Arizona Western College in Yuma, AZ, and together with NAU Extended Campuses serves more than 7,500 students. NAU is noted for its emphasis on undergraduate education, graduate research programs in forest health and bioterrorism, for its personal attention in the form of small classes with full-time professors who know their students' names, and for its caring and committed staff whose goal is to help every student succeed. The largest ethnic minority in the student population is Hispanic, accounting for 13% of the total enrollment. The enrollment of Native Americans is 6%. These students are affiliated with over 55 separate tribes with the largest tribe being Navajo (Dine). In fiscal year 2009, the university absorbed a 13% reduction in its state-appropriated budget.

NAU's engineering programs are located in the College of Engineering, Forestry, and Natural Sciences which contains ten academic units that support two PhD programs (Biology and Forestry) and thirteen masters programs with many sub-programs. The college employs 205 tenure/tenure-track faculty and, in fiscal year 2009, secured a total of $19.1 million in externally funded grant awards. The four accredited engineering programs reside in three departments: the Department of Civil Engineering, Construction Management, and Environmental Engineering (CE-CM-ENE); the Department of Electrical Engineering and Computer Science; and the Department of Mechanical Engineering. The engineering programs share two interdisciplinary masters-level graduate programs: a Master of Engineering and a newly organized Master of Science in Engineering in Sustainable Systems and Advanced Design. The baccalaureate

programs in civil, electrical, and mechanical engineering received their first accreditation from ABET's Engineering Accreditation Commission (EAC) in 1974.

The CE-CM-ENE department was recently created by merging two previous stand-alone departments as part of the college's response to the 2009 FY budget cuts. The newly combined department has sixteen tenure/tenure-track faculty and two full-time lecturers. In addition to the merging of departments, the combined department experienced a loss of two full-time tenure/tenure-track faculty positions and a .25 FTE loss in its lab manager position. The department hosts two ABET accredited programs in civil engineering and environmental engineering, and an ACCE accredited construction management program. Per the fall 2009 official 21-day head count, the department enrolls 537 undergraduates. It also supports a small number of graduate students through the shared masters programs. The department faculty and students participates in many interdisciplinary educational, research and service activities including Design4Practice, Institute of Tribal Environmental Professionals, Water Research and Education Program, and the Arizona Laboratory for Applied Transportation Research.

The university is currently undergoing a review to transform NAU into a global campus and to prepare its students for global competency. Although recommendations have yet to be adopted into the university's curriculum requirements, eventually the CE curriculum will need to respond to these future demands. One recommendation - each undergraduate plan of study will be modified in structure to accommodate one semester of education abroad - could require a significant redesign to the CE curriculum.

Motivated by the ABOR 2020 Vision and Strategic Plan[6], the university is encouraging its programs to streamline curricula, reduce the total number of credit hours for degree attainment, delete low-enrolled curricula and courses, minimize new course offerings, reduce DFW rates, and increase retention to improve graduation performance. These strategies are being implemented to better position the university as it shoulders the budget cuts of FY 2009 and to meet possible future reductions.

Current BSCE Curriculum

The department's BSE-Civil Engineering has been continuously accredited by the EAC of ABET since its initial accreditation in 1974. Its most recent general review by ABET was completed during the 2007-2008 academic year. In preparation for this review, metric statements were added to the program's outcomes. These metric statements are unequivocal performance goals that students must demonstrate to illustrate their achievement of the Criterion 3 Outcomes (a) thru (k). They were developed from the taxonomic approach advocated by the ASCE Levels of Achievement subcommittee in their report[7] in which the fifteen BOK1 outcomes were rewritten and framed 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 BOK1 fulfillment pathway. Recently, Outcomes 13 - 15 of the revised BOK1 have been incorporated into the 2008-2009 ABET EAC[8] within Criterion 9 for civil engineering programs. Specifically, graduates must now 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 of the 2007-2008 ABET EAC[9] was clarified so that programs now demonstrate graduates' abilities to "apply knowledge" in four technical areas appropriate to civil engineering. The departments current outcomes, benchmarked against the 2007-2008 ABET EAC, are provided in Table 1.

The current 2009-2010 curriculum of 131 semester credit hours is presented in Table 2, which follows the accustomed ABET EAC self-study standard format. This 2007-2008 ABET EAC compliant curriculum also attends to the requirements of the university and incorporates the unique design focus of NAU's engineering programs.

Liberal Studies Requirements: Thirty-five credit hours of liberal studies are required of all students seeking their first baccalaureate degree from NAU. These liberal studies requirements consist of both Foundation Requirements and Distribution courses which are offered at the 100-300 levels. The requirements as they apply to the engineering programs are as follows:

- Foundation Requirements (7 credits)
  - 4 credits of English 105
  - 3 credits of Math
- Distribution Requirements (28 credits)
  - 7 credits of Science (to include at least one Lab Science)
  - 6 credits of Social and Political Worlds
  - 6 credits of Aesthetic and Humanistic Inquiry
  - 6 credits of Cultural Understanding
  - 3 additional credits of any liberal studies distribution course

Courses in the aesthetic and humanistic inquiry (AHI) block involve students in the study of the human condition through philosophical inquiry and analysis of the various forms of creative expression. Courses in the cultural understanding (CU) block enhance students' understanding of different cultures of the world through the study of language, literature, religion, and artistic creations or other disciplines. Courses in the social and political worlds (SPW) block engage

students in the study of the patterns that characterize the history of human communities, the relationships between the psychological, social, cultural and political components of human communities, and the dynamics of human behavior in varied contexts.

Additional University Requirements: Some university requirements are embedded within the major, such as junior writing and senior capstone, and others, such as the diversity requirement, are fulfilled by the civil program with courses from the liberal studies course list that also satisfy diversity. These requirements as they apply to the engineering programs are as follows:

- In Major (6-7 credits)
  - 3-4 credits of Junior Level Writing Expectation
  - 3 credits of Capstone Course/Experience in the Major
- Diversity Requirement (6 Credits)
  - 3 credits of U.S. Ethnic Diversity
  - 3 credits of Global Awareness

The global awareness requirement is intended to provide students with an understanding of the perspectives (e.g. theoretical; historical; social; political; economic; cultural; religious; geographic or sense of place; environmental; or intellectual traditions and/ or ways of knowing) of non-Western peoples. Through the U.S. ethnic diversity course, students will acquire an understanding of the perspectives (e.g. theoretical; historical; social; political; economic; cultural; religious; geographic or sense of place; environmental; or intellectual traditions and/ or ways of knowing) of U.S. ethnic minorities.

Design: Thirteen of the 24 design hours in the CE program come from the Design4Practice (D4P) curriculum, which is reflective of the engineering program's long standing orientation and commitment to professional practice. The D4P is a four-year sequence of classes that were carefully designed through a joint industry and university effort to provide all engineering students with hands-on learning and the continuous practice of a broad set of professional skills in better preparation for careers as engineering practitioners. The program builds these technical, managerial, and professional skills by increasing project intensity, technical difficulty, and process complexity one step (course) at a time. EGR 186 and 286 are multi-disciplinary courses followed by the disciplinary CENE 386W, 476, and 486C. Each preceding D4P course serves as a prerequisite to the proceeding one and fosters the accumulation of skills and knowledge to ensure a successful major design experience in the senior year.

Technical Electives: Because of the previously described demands, only six semester hours of technical electives are available in the civil engineering curriculum. Of these six hours, three must be from an approved list of CENE courses. The remaining three could come from an approved list of non-CENE courses in math, computer science, statistics, construction management, mechanical engineering, planning, and geography.

Evaluation of Current Curriculum vs. BOK2 Outcomes

The civil engineering undergraduate program of NAU, which is currently benchmarked to the 2007-2008 ABET Criteria for Accrediting Engineering Programs[9], was compared against the BOK2 in the fall of 2008. Members of the department faculty were formed into teams of two to estimate the LOA of recent graduates in comparison to the BOK2. The results[10] 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 LOA at the baccalaureate level. These results were then translated to the previously discussed curricula review template utilized in the BOKEdFC[5] analysis of the BOK2.

Figure 3 is a graphical comparison of the BSE-CE program outcomes with the BOK2 rubric. For reference, the 11 "challenging" outcomes identified by the BOKEdFC[5] are shaded red in the first column of the figure. Also represented in Figure 3 is the recommended 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). The green shaded cells indicate the BOK2 outcomes that are completely fulfilled by the all the graduates of the current BSE-CE curriculum; the yellow shaded cells indicate partial fulfillment of the complete outcome by all of the graduates of the current curriculum.

The BOK2 analysis of Figure 3 suggests that the NAU curriculum of 131 semester units and the corresponding educational environment prepares all of its students to meet or exceed the expected LOAs for all aspects of thirteen of the twenty-four applicable BOK2 outcomes. Nine (BOK2 Outcomes 3, 4, 5, 10, 11, 13, 17, 18, and 19) of the below-target results are for outcomes unique to BOK2 in their identification or enhanced specificity as compared to the 2007-2008 ABET EAC. The remaining two below-target outcomes (BOK2 Outcomes 12 and 24) are addressed in the 2007-2008 ABET EAC, but the performance expectations in that criteria are vague using the ambiguous words: "proficiency" as related to probability and statistics per Criterion 8 and "understanding" for professional and ethical responsibility per Criterion 3. These below target BOK2 outcomes for NAU align closely with the BOKEdFC's identified "challenging" outcomes.

Although efforts are underway by the department to begin addressing the BOK1 motivated changes to Criterion 9 Program Criteria of the 2008-2009 ABET EAC, this work has yet to be articulated to the curriculum. This ABET-driven revision will strengthen the curricula's compliance to three of NAU's below-target BOK2 outcomes - Outcome 13 Project Management, Outcome17 Public Policy, and Outcome18 Business and Public Administration. It is useful to note, however, that students need to only "explain" (e.g. level 2 - comprehension) project

management in the 2009-2010 ABET EAC Criterion 9, while the corresponding BOK2 outcome is set to level 3 - application. The corresponding BOK2 and ABET EAC requirements for Public policy and business and public administration are aligned at level 2 - comprehension. 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 modest effort to completely meet the BOK1 as it has been translated to the current (e.g. 2009-2010) ABET EAC through Criterion 9.

Current Curriculum and the "Challenging" BOK2 Outcomes

As noted earlier, the BOKEdFC identified BOK2 Outcomes 3, 4, 5, 10, 11, 12, 17, 18, 19, 20, and 24 as challenging for current curriculums to achieve. Indeed, the above analysis shows NAU's civil engineering to be similarly challenged. The following is a detailed discussion, comparing the current undergraduate curriculum to the respective challenging outcomes.

Outcome 3 Humanities: Demonstrate the importance of the humanities in the professional practice of engineering and Outcome 4 Social Sciences: Demonstrate the incorporation of social sciences knowledge into the professional practice of engineering. The university's liberal studies program requires six credit hours of each AHI and SPW coursework that must come from a list of approved liberal study course that are not from the student's major. These university requirements appear to satisfactorily prepare students for achieving Outcomes 3 and 4 at the Knowledge level (LOA = 1), corresponding to defining factual information from more than one area of, respectively, the humanities and the social sciences. A higher LOA requiring the application of humanities and social sciences to civil engineering through this liberal studies requirement is not currently possible. In addition, the current civil engineering program does not integrate humanities and social sciences into the professional practice of engineering. The program's faculty, likewise, are not content experts in this interdisciplinary area.

Outcome 5 Material Science: Use knowledge of materials science to solve problems appropriate to civil engineering. At NAU, an introduction to materials science is integrated into the program's required one hour CENE 253L Mechanics of Materials laboratory. Two additional required courses in the curriculum, CENE 253 Mechanics of Materials and CENE 438 Reinforced Concrete Design require students to use specific materials science knowledge. This introduction with the limited application in two courses will not adequately prepare students to achieve this outcome at the specified LOA.

Outcome 10 Sustainability: Apply the principles of sustainability to the design of traditional and emergent engineering systems. Civil engineering students at NAU are introduced to the principles of sustainability in their required CENE 150 Introduction to Environmental Engineering course and in CENE 433Hydrology and Flood Control. Sustainability is also

addressed as a design constraint in the senior capstone experience of CENE 476 Engineering Design Process Lab and CENE 486C Engineering Design Capstone or in their required CENE 386W Engineering Design Methods. These requirements appear to satisfactorily prepare students for achieving Outcome 10 at the Knowledge level (LOA = 1), which is specified as "define key aspects of sustainability relative to engineering phenomena, society at large, and its dependence on nature resources; and relative to the ethical obligation of the factual information from more than one area of the humanities." Sustainability has not been explicitly identified in the department's current program outcomes. It has, however, been assigned to the new interdisciplinary MSE graduate program that requires all students to take EGR 501 Topics in Sustainable Systems. Implementation of NAU's global campus goal may further strengthen future students' knowledge of sustainability in a general vs. disciplinary way.

Outcome 11 Contemporary Issues and History: 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. The civil engineering program, which reflects the related 2007-2008 ABET EAC Criterion 3 Outcome (j), has integrated contemporary issues into its program through six required courses: CENE 150 Intro to Environmental Engineering, CENE 386W Engineering Design III – The Methods, CENE 331 Sanitary Engineering, CENE 450 Geotechnical Evaluation & Design, CENE 438 Reinforced Concrete Design, CENE 433 Hydrology & Flood Control, CENE 486C Engineering Design – Capstone. As such, the contemporary issue aspects of this outcome are addressed in sufficient breadth and depth to satisfy this LOA. On the other hand, the department has not integrated in a deliberate way historically relevant teachings. Certainly, the faculty brings historical references into the classroom, but this practice has not been formalized and assessed by the department.

Outcome 12 Risk and Uncertainty: Apply the principles of probability and statistics to solve problems containing uncertainties. The current civil engineering program does not explicitly address the solution of problems containing uncertainties, but it does address probability and statistics through its required course CENE 225 Engineering Analysis. The department faculty has determined that the current curriculum prepares students to achieve a LOA of 1.

Outcome 17 Public Policy: Discuss and explain key concepts and processes involved in public policy. Students are introduced to public policy in their required CENE 150 Introduction to Environmental Engineering course. In addition, application examples are occasionally threaded into CENE 386W Engineering Design Methods as a function of the case study being utilized that semester. CENE 418 Highway Design provides additional opportunities for topic integration. Curriculum revisions to become compliant with Criterion 9 the recent ABET EAC will result in a curriculum complying with this LOA.

Outcome 18 Business and Public Administration: Explain key concepts and processes used in business and public administration. The current curriculum is compliant to the 2007-2008 ABET EAC which had yet to adopt the public policy requirements of Criterion 9 in the later versions of the criteria. ABET motivated revisions will result in a curriculum complying with this level of achievement.

Outcome 19 Globalization: Organize, formulate, and solve engineering problems within a global context. Students are introduced to globalization in their required CENE 150 Introduction to Environmental Engineering course. In addition, application examples are occasionally threaded into CENE 386W Engineering Design Methods as a function of the case study being utilized that semester. The department also hosts an active and large Engineers Without Borders (EWB) student chapter that has infused the student body with an awareness of small-scale technology applications in developing worlds. EWB has resulted in the creation of an elective course intended to prepare our students for travel abroad including health, safety, and basic construction skills. Implementation of NAU's global campus goal may further strengthen future students' knowledge of globalization.

Outcome 20 Leadership: Apply leadership principles to direct the efforts of a small, homogenous group. Our students are required to take part in the five course D4P curriculum that stresses among many things: teaming, team and project management, and leadership. By the time they graduate, our students will have participated in a variety of teaming environments ranging from multiple small teams of short duration via EGR 186 Introduction to Engineering Design to a large, multidisciplinary team of short duration in EGR 286 Engineering Design: The Process to small teams of longer duration lasting one to two semesters via CENE 386W Engineering Design: The Methods, CENE 476 Engineering Design Lab and CENE 486C Engineering Design: Capstone. In addition to the D4P, our students participate in team-based learning environments in CENE 270 Plane Surveying, CENE 253L Mechanics of Materials Lab, CENE 333L Applied Hydraulics Lab, CENE 383L Soil Mechanics Lab, CENE 420 Traffic and Signal Systems, and CENE 418 Highway Engineering.

Outcome 24 Professional and Ethical Responsibility: Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action. As noted earlier, this BOK2 LOA is set at level 4 - Analysis, which represents a significant step up from the current ABET EAC requirements of Criterion 3 which sets the corresponding outcome to perhaps, at best, level 2 - Comprehension. Outcome (f) makes use of the ambiguous verb "understanding", which is difficult to directly map to the Bloom's taxonomic approach of the BOK2. On the other hand, NAU's civil engineering program has established its corresponding outcome to reach level 3 - application. Through a variety of CENE courses, as well as a required 100-level or 300-level philosophy course in ethics, the department has been consistently successful in reaching an LOA of 3.

A BOK2 Curricular Redesign Effort

One of the tasks of the ASCE's BOKEdFC is to suggest possible ways the BOK2 outcomes may be integrated into civil engineering curricula. In that regard, the authors have attempted to hypothetically redesign the civil engineering program at NAU to meet BOK2 while also attending to the various constraints or requirements presented by the university's context including:

- An uncertainty due to the state's current fiscal deficits about whether or not lost faculty and staff positions lines will be replaced.
- A desire to maintain the department's commitment to design education as a distinguishing feature of our program that is strongly valued by the program's constituency.
- The need to reduce the total number of credit hours for degree attainment and minimize the creation of new courses.
- The need to meet university curricula requirements for liberal studies distribution and diversity coursework that must come from outside the discipline along with an intensive junior level writing experience and capstone.
- The anticipated need to incorporate flexibility into the progression plan to permit study abroad experiences.
- The need to meet the governing ABET EAC criteria, which for these purposes, was taken as that associated with the 2009-2010 cycle.

The results of this redesign effort are presented in Table 3. It was premised on the above constraints while allowing for redesign of some existing courses. The resulting proposed curriculum is seven units less than the current curriculum. The reduction was supported by eliminating EE 188 Electrical Engineering I and a CENE technical elective at the senior level. In addition, various courses were targeted for redesign, existing courses from other programs were added, technical requirements were loosened, and the liberal studies electives were specified. The details included:

- Disallowing students to select their science elective, replacing this by one of two Geology courses to strengthen the program's approach towards Outcome 2 Natural Science, Outcome 10 Sustainability, Outcome 11 Contemporary Issues and Historical Perspectives, and Outcome 19 Globalization.
- Specifying all of the six liberal studies courses to strengthen the program's approach towards Outcome 3 Humanities, Outcome 4 Social Sciences, Outcome 10 Sustainability, Outcome 11 Contemporary Issues and Historical Perspectives, and Outcome 19 Globalization, while also simultaneously meeting the university requirements for

distribution blocks and diversity. In the current program, students are permitted to select these courses from lengthy lists of approved courses.

- Dropping the requirement that students must take both ME 252 Dynamics and ME 291 Thermodynamics and changing this to an either/or situation to make room in the program to add the exiting ME 340 Material Science course to strengthen the curriculum's approach to Outcome 5 Material Science.
- Modifying CENE 386WEngineering Design: The Methods to deliberately incorporate topics that build from the liberal studies and strengthen compliance with Outcome 10 Sustainability, Outcome 17 Public Policy and Outcome 19 Globalization.
- Threading historical learning activities with documentation through CENE 253 Mechanics of Materials, CENE 383Geotechnical Engineering I, and CENE 331 Sanitary Engineering to strength compliance with Outcome 11 Contemporary Issues and Historical Perspectives.
- Directing the content in CENE 225 Engineering Analysis towards uncertainty to strengthen achievement of Outcome 12 Risk and Uncertainty.
- Modifying the existing junior level structural analysis course to a four credit course to incorporate the topics of loads and the inherent uncertainties to strengthen compliance to Outcome 12 Risk and Uncertainty.
- Modifying the prerequisites of CM 388 Construction Scheduling and adding it to the program to strengthen compliance with Outcome 13 Project Management and Outcome 14 Breadth in Civil Engineering topics. Curricula room was found by dropping ME 395 Fluid Mechanics and adding applicable theoretical content into an existing course. The existing course is renamed and the number of credits are increased from three to four.
- Adding CM 489 Construction Administration to strengthen compliance with Outcome 18 Business and Public Administration, Outcome 13 Project Management, and Outcome 14 Breadth in Civil Engineering topics. Curricula room was enabled by reducing the number of required transportation courses from two to one.
- Modifying the approach taken in the D4P toward ethics and professional practice so that these topics are coherently threaded through the program with better documentation of achievement to strengthen compliance with Outcome 24 Professionalism and Ethical Responsibility.

The end result is a significantly changed curriculum that is broader in content coverage than the current curriculum. Notable changes include a reduction in engineering science content by eight semester credits, a reduction of in-depth disciplinary coursework by six credits, and the addition of six credits of construction management coursework. The proposed curriculum's success in meeting the BOK2 as well as preparing students for success in the Fundamentals of Engineering exam is explored in the next section of this paper. The incorporation of the semester abroad pending requirement was not addressed in this redesign as solutions within the current climate of budgetary compression were not readily evident.

Evaluation of Proposed Curriculum vs. the BOK2 and the FE

Similar to Figure 3, Figure 4 is a graphical comparison of the proposed BSCE program outcomes with the BOK2 rubric. It represents the authors' evaluation of the potential of the proposed curricula, if implemented in its entirety, to prepare all of its graduates to completely achieve the outcomes at the specified LOAs. The BOK2 analysis of Figure 4 suggests that the proposed NAU curriculum of 124 semester units might prepare its students to meet the expected LOA for twenty of the twenty-four applicable BOK2 outcomes. This is a gain of seven outcomes in comparison with the current curriculum that may be achievable with the proposed changes. These seven outcomes that were brought into compliance are BOK2 Outcomes 5, 11, 12, 13, 17, 18, and 24. Although the authors anticipate improvement in the LOA for the remaining unmet Outcomes 3, 4, 10, and 19, the curriculum falls short of providing explicit opportunities to apply humanities, social sciences, sustainability, and globalization to engineering problems. We attribute this to the requirement that liberal studies are met from outside the discipline and that the current faculty from within the discipline do not possess the interdisciplinary expertise to properly assert these applications within the civil engineering curriculum. In addition, the proposed curriculum is anticipated to reduce graduates LOA in Outcomes 8 Problem Solving and Recognition and Outcome 15 Technical Specialization from the current LOAs which are evaluated at the M/30 level. This coincides with the reduction of opportunities in the proposed curriculum for in-depth study within specialized areas of civil engineering, which is in-line with the BOK2 shift of technical depth to the masters level.

In order to make room in the curriculum for coursework more in-line with the BOK2 outcomes, adjustments were made to the existing engineering science coursework. The electrical circuits course was eliminated, and the required thermodynamics and dynamics courses were made optional with students making the choice between the two. Questions in electricity and magnetism make up 9% of the morning section of the FE exam, while thermodynamics, fluids, and dynamics make up, respectively 7%, 7%, and 4%. The proposed curricula directly impacts these subject areas covered in the morning part of the FE with anticipated negative impacts to students' performance in the FE as a result. A similar concern exists with afternoon test focusing on the civil engineering subject areas, and the potential negative impact that a reduction in in-depth curricula study will have towards FE success.

Conclusions

This paper provided an analysis of NAU's current undergraduate civil engineering curriculum with respect to the BOK2 with attention given to the challenging outcomes; proposed a revised BOK2-orientated curriculum within the NAU context; and analyzed that curriculum.

NAU current BSE-CE curriculum of 131 semester units, which is benchmarked to the 2007-2008 ABET EAC, meet or exceed the LOAs for thirteen of the twenty-four applicable BOK2 outcomes. Nine (BOK2 Outcomes 3, 4, 5, 10, 11, 13, 17, 18, and 19) of the below-target results are for outcomes unique to BOK2 in their identification or enhanced specificity as compared to the 2007-2008 ABET EAC. The remaining two below-target outcomes (BOK2 Outcomes 12 and 24) are addressed in the 2007-2008 ABET EAC, but the performance expectations in that criteria are vague using the ambiguous words: “proficiency” as related to probability and statistics per Criterion 8 and "understanding" for professional and ethical responsibility per Criterion 3.

Although efforts are underway by the department to begin addressing the BOK1 motivated changes to Criterion 9 Program Criteria of the 2008-2009 ABET EAC, this work has yet to be articulated to the curriculum. This ABET-driven revision will strengthen the curricula's compliance to three of NAU's below-target BOK2 outcomes - Outcome 13 Project Management, Outcome17 Public Policy, and Outcome18 Business and Public Administration.

A redesign effort in attempts to create a BOK2-compliant civil engineering curriculum at NAU, while also attending to the various constraints and requirements resulted in a 124 semester credit proposed curriculum that is broader in content coverage than the current program. Notable differences include a reduction in engineering science content by eight semester credits, a reduction of in-depth disciplinary coursework by six credits, and the addition of six credits of construction management coursework. Compliance to the current ABET EAC was maintained, along with the commitment to our unique program of meaningful, varied, and multiple design experiences delivered in a problem-based format every year of the curriculum. Constraints including budgetary pressures and implementation of the state board’s 2020 vision coupled to an evolving and complicated general education program with a semester abroad agenda strained NAU's BOK2 curriculum redesign efforts. Without relaxation of the requirements that liberal studies courses must come from outside the major constraints and the creation of new courses is to be minimized, four of the “challenging” BOK2 outcomes are not achievable at the prescribed LOA. Furthermore, concerns were developed about the BOK2 curriculum’s impact on students’ future success with the FE, if this exam is not aligned to the BOK2.

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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 (LOA)					
		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.

Table 1: NAU's BSE-CE Program Outcomes

Upon the successful completion of our Civil Engineering curricula, the students of CENE will be proficient in the areas of structural engineering, water resources engineering, transportation engineering, and geotechnical engineering. They will:	2007-08 ABET Outcome	Compliance is achieved by students who:
1. Possess a foundation of mathematical and scientific principles in calculus through differential equations, statistics, calculus-based physics, and general chemistry.	(a)	**solve** engineering problems using principles of mathematics and science.
2. Define and solve engineering problems, and create, evaluate, and document engineering designs of systems or components.	(c)	**design** systems or processes to meet desired needs within realistic constraints.
	(e)	**solve** well-defined engineering problems in four technical areas appropriate to civil engineering (e.g. structures, water resources, transportation, and geotechnical).
3. Properly apply tools and methodologies to design and conduct experiments, to model or simulate processes and phenomena, and to analyze, interpret, and report results.	(b)	**design** civil engineering or environmental engineering experiments to meet a need, **conduct** the experiments, and **analyze** and **interpret** the resulting data.
	(k)	**apply** relevant techniques, skills, and modern engineering tools of the engineering practice.
4. Work successfully and communicate effectively, both orally and in writing, with diverse and multi-disciplinary teams and as individuals in public and private organizations, understanding the impact of societal and political systems on the engineering design process.	(c)	**design** systems or processes to meet desired needs within realistic constraints.
	(d)	**perform and communicate effectively** on diverse teams.
	(g)	**organize** and **deliver** effective verbal, written, and graphical communications.
	(h)	generally **describe** the impacts of a constrained engineering solution to relevant economic, environmental, social, and global-political systems.
5. Strive to improve their professional skills and abilities and to update their knowledge and understanding of contemporary professional issues.	(c)	**design** systems or processes to meet desired needs within realistic constraints.
	(h)	generally **describe** the impacts of a constrained engineering solution to relevant economic, environmental, social, and global-political systems.
	(i)	**demonstrate** the ability to learn on their own, without the aid of formal instruction, and **express** the need to continually improve their professional skills throughout their careers.
	(j)	**incorporate** into the engineering problem solving process well-defined contemporary issues such as regulations and compliance, economics, environmental impacts, political influences, and globalization.
	(k)	**apply** relevant techniques, skills, and modern engineering tools of the engineering practice.
6. Recognize the practice of engineering as a privilege and adhere to the standards and ethics of the profession, including licensure requirements, to protect and promote public health, safety, and welfare.	(f)	**recognize** and **analyze** situations involving professional and ethical interests.

Table 2: NAU's Current Bachelor of Science Engineering – Civil Engineering Curriculum

			Math &	Eng.	Eng.	Gen.
		Hours	Science	Topics	Design	Ed.
Freshman Year, 1st Semester						
CHM 151	General Chemistry I	4	4			
CHM 151 L	General Chemistry I Laboratory	1	1			
ENG 105	Critical Reading and Writing	4				4
EGR 186	Intro to Engineering Design	3			3	
MAT 136	Calculus I	4	4			
UNIV N 100	Transition to College	1				1
Freshman Year, 2nd Semester						
PHY 161	Univ. Physics I (& Lab)	4	4			
CENE 150	Intro to Envir. Engineering	3		3		
MAT 137	Calculus II	4	4			
PHI 105 or 331	Intro to Ethics or Envr. Ethics	3				3
CENE 180	Computer Aided Drafting	2		1	1	
Sophomore Year, 1st Semester						
CENE 251	Applied Mechanics--Statics	3		3		
PHY 262	Univ. Physics II	3	3			
MAT 238	Calculus III	4	4			
CENE 225	Engineering Analysis	3	2	1		
CENE 270	Plane Surveying (& Lab)	3		3		
Sophomore Year, 2nd Semester						
CENE 253	Mechanics of Materials	3		2	1	
CENE 253 L	Mechanics of Materials Lab	1		1		
EGR 286	Engineering Design: The Methods	3			3	
MAT 239	Differential Equations	3	3			
ME 291	Thermodynamics I	3		3		
Lib. Studies	AHI or CU or SPW plus Diversity	3				3
Junior Year, 1st Semester						
CENE 376	Structural Analysis I	3		3		
ME 252	Applied Mechanics--Dynamics	3		3		
ME 395	Fluid Mechanics	3		3		
Science Elect	Geol, Chem II, Physics III, Bio	3	3			
CENE 420	Traffic & Signal System (& Lab)	3		1	2	
Lib. Studies	AHI or CU or SPW	3				3
Junior Year, 2nd Semester						
CENE 333	Applied Hydraulics	3		2	1	
CENE 333 L	Applied Hydraulics Lab	1		1		
CENE 383	Soil Mech & Foundations (& Lab)	4		3	1	
CENE 386W	Engineering Design: The Methods	3		1	2	
CENE 433	Hydrology & Flood Control	3		2	1	
Lib. Studies	AHI or CU or SPW plus Diversity	3				3
Senior Year, 1st Semester						
CENE 331	Sanitary Engineering	3		2	1	
CENE 418	Highway Engineering (& Lab)	3		1	2	

CENE 438	Reinforced Concrete Design	3		2	1	
CENE 476	Egr Design Process Lab	1			1	
CENE 450	Geotechnical Eval & Design	3		2	1	
CENE xxx	CENE Technical Elective	3		3		
	Senior Year, 2nd Semester					
EE 188	Electrical Engineering I	3		3		
CENE 486C	Engineering Design: Capstone	3			3	
Tech Elec	CENE or (ME, CM, GLG, MAT)	3		3		
Lib. Studies	AHI or CU or SPW	3				3
Lib. Studies	AHI or CU or SPW	3				3
	Total	131	32	52	24	23
	% of Curriculum	100.0%	24%	40%	18%	18%

BOK2 Outcome	BOK2 Outcome Name	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 3: Graphical Comparison of NAU's BSE-CE Program Level of Achievement to BOK2 Outcomes.

Table 3: A Possible BOK2 Related Curriculum at Northern Arizona University

		Units	Math & Science	Eng. Topics	Eng. Design	Gen. Ed.
Freshman Year, 1st Semester						
CHM 151	General Chemistry I	4	4			
CHM 151 L	General Chemistry I Laboratory	1	1			
EGR 186	Intro to Engineering Design	3			3	
MAT 136	Calculus I	4	4			
UNIV N 100	Transition to College	1				1
CENE 180	Computer Aided Drafting	2		2		
Freshman Year, 2nd Semester						
PHY 161	Univ. Physics I (& Lab)	4	4			
CENE 150	Intro to Environmental Engineering	3		3		
MAT 137	Calculus II	4	4			
ENG 105	Critical Reading and Writing	4				4
Sophomore Year, 1st Semester						
CENE 251	Applied Mechanics--Statics	3		3		
PHY 262	Univ. Physics II	3	3			
MAT 238	Calculus III	4	4			
CENE 225	Engineering Analysis	3	2	1		
CENE 270	Surveying & Spatial Analysis (& Lab)	3		3		
Sophomore Year, 2nd Semester						
CENE 253	Mechanics of Materials	3		2	1	
CENE 253 L	Mechanics of Materials Lab	1		1		
EGR 286	Engineering Design: The Methods	3			3	
MAT 239	Differential Equations	3	3			
ME 252 or 291	Applied Mechanics--Dynamics or Thermodynamics	3		3		
L. Studies: CM 120	Building the Human Environment (CU)	3				3
Junior Year, 1st Semester						
CM 388	Construction Scheduling	3		3		
CENE 376	Structural Analysis & Loads	4		3		
GLG 110/L or 112/L	Environ Geology or Geologic Disasters	4	4			
CENE 333	Fluids & Applied Hydraulics	4		3	1	
CENE 333 L	Applied Hydraulics Lab	1		1		
Junior Year, 2nd Semester						
CENE XXX	Steel and Concrete Design	4			4	
CENE 383	Geotechnical Eng I	3		2	1	
CENE 383L	Geotechnical Eng I L	1		1		
CENE 386W	Engineering Design: The Methods	3			3	
CENE 331	Sanitary Engineering	3		2	1	
L. Studies: ANT 120	Exploring Cultures (CUG)	3				3
Senior Year, 1st Semester						
CENE 433	Hydrology & Flood Control	3		3		
CENE 418 or 420	Highway Engineering (& Lab) or Traffic Study (& Lab)	4		2	2	
ME 340	Materials Science	3		3		
CENE 476	Egr Design Process Lab	1			1	
L. Studies: ANT 351	SW Archaeology or Multi. Persp. of	3				3

or FOR 230	Natural Res. (SPWE)					
L. Studies: ECO 284 or EC0 285	Principles of Economics: Micro or Macro (SPW)	3				3
Senior Year, 2nd Semester						
CM 489	Construction Administration	3		3		
CENE 486C	Engineering Design: Capstone	3			3	
L. Studies: PHI 105 or 331	Intro to Ethics (AHI) or Envr. Ethics (AHI)	3				3
L. Studies: HIS 308	Science, Technology & Society in the American West (AHI)	3				3
	Total	124	33	44	23	23
	% of Curriculum	100%	27%	35%	18%	18%

BOK2 Outcome	BOK2 Outcome Name	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 4: Graphical Comparison of a Proposed BSE-CE Curriculum at NAU to BOK2 Outcomes and LOAs