
AC 2012-3050: STUDENT PERCEPTIONS OF THE CIVIL ENGINEERING BODY OF KNOWLEDGE

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Student Perceptions of the Civil Engineering Body of Knowledge: Comparison of Two Academic Institutions

The updated American Society of Civil Engineers' Body of Knowledge (BOK2) defines how educational and practical experience shall fulfill developmental requirements for entry into the civil engineering profession. As the BOK2 continues to be introduced into the profession, existing and potential civil engineering student perceptions are a particular subject of interest, one recently investigated by Angela Bielefeldt at the University of Colorado, Boulder. Potential students can use the BOK2 to learn about their chosen field of study, visualize a roadmap for future development, and better understand the dedication their profession requires. Graduating seniors can use the BOK2 to assess their personal development, their own strengths and weaknesses, and identify the strengths and weaknesses of their undergraduate engineering program. Student feedback can help leaders in higher education to make positive changes in their school's program in order to better prepare students for professional service.

This study partially replicates Bielefeldt's 2010 investigation under different conditions (i.e. at a military academy as opposed to a research-oriented academic institution) in order to provide confirmation that the BOK2 framework is a useful tool for evaluating civil engineering curricula across a wide range of institutions. This study queried 42 seniors within a military academy's civil engineering program on their personal strengths and weaknesses in the context of the 24 BOK2 outcomes. In addition, students were asked to identify apparent curriculum weaknesses and rank order the 24 outcomes in terms of perceived importance.

This study will be of interest to undergraduate civil engineering program administrators concerned with assessing pedagogy and industry representatives developing learning experiences, both of whom share a common goal to better prepare students for professional licensure. This study also assists practicing engineers to provide appropriate mentorship and engineering experience to further prepare engineer interns for eventual licensure as a professional engineer.

Introduction

In 1998, the American Society of Civil Engineers (ASCE) Board of Direction adopted what is now known as the first version of Policy Statement 465 (Policy).^{1,2} The Policy was subsequently revised in 2001 and 2004.³ During each revision, the Policy, formally known as the Academic Prerequisites for Licensure and Professional Practice Policy,⁴ was unanimously approved by the Board of Direction.²

In general, the Policy supports the attainment of a Body of Knowledge (BOK) as the minimum entry level achievement prior to the practice of civil engineering at the professional level. The Policy defines the term "professional level" as meaning the active participation in the practice of civil engineering as a licensed member of the engineering community.⁵ The BOK report, now in its second edition (BOK2), defines "practice" as a licensed professional engineer to include, but not limited to, activities such as planning, design, investigation, teaching, applied research, management, public administration, and operation². Although the list of "practice" related activities may appear broad, it is reflective of the variety of activities and roles that civil

engineers undertake. The BOK was thus designed to accommodate the wide-ranging nature of the practice within the discipline.

Since the American Society of Civil Engineers (ASCE) first published the BOK report in 2004 and the BOK2 report in 2008, numerous papers have been written about this effort. A significant number of papers on the Body of Knowledge have been submitted to the American Society of Engineering Education's (ASEE's) Annual Conference and Exposition. Much of that literature is discussed and synthesized herein.

Student perceptions of the BOK2 are of particular interest in the academic realm. A study conducted by Bielefeldt at the University of Colorado at Boulder (CU) investigated such perceptions held by civil engineering students at various points in their progression toward a bachelor of science degree. The results of that study were beneficial in demonstrating how student perceptions of their chosen profession change over time. However, a limitation of that study is that the study was conducted at a single academic institution.

The investigation discussed herein is an attempted replication of the Bielefeldt study at a different academic institution. In particular, the current investigation was conducted within the civil engineering program at the U.S. Military Academy (USMA) at West Point. While both CU and USMA prepare students for the profession of civil engineering, each academic institution has a unique mission and education methods. Arguably, both academic institutions are well known for preparing students to definitively achieve the intent of ASCE's BOK2.

In performing a general replication of the Bielefeldt study, the authors sought to address the following specific research questions:

1. What perceptions of the American Society of Civil Engineers' Body of Knowledge (2nd edition) do graduating civil engineering seniors at the U.S. Military Academy have?
2. How do the perceptions of the Body of Knowledge (2nd edition) compare between civil engineering students at the University of Colorado at Boulder and U.S. Military Academy?

Literature Review

The evolution of the current 2nd edition of the Body of Knowledge (BOK2) has been well documented.⁶ ASCE *Policy Statement 465 (PS 465), Academic Prerequisites for Licensure and Professional Practice* pronounced the organization's intent to "raise the bar" with respect to the knowledge, skills, and attitudes of civil engineering graduates entering professional practice. In January 2004, ASCE published the Civil Engineering Body of Knowledge for the 21st Century report (BOK). The BOK relied heavily on ABET's 11 "outcomes" for civil engineering graduates. In fact, of the original 15 BOK outcomes, 11 came directly from ABET.

The BOK was successful in stimulating dialog, along with other engineering groups like the National Academy of Engineering (NAE) who published *The Engineer of 2020*⁷ and *Educating the Engineer of 2020*⁸ at about the same time. In 2006, a Summit on the Future of Civil Engineering published a report entitled *The Vision for Civil Engineering in 2025*⁹ which sees

civil engineers as global leaders in the creation of a sustainable world with an enhanced quality of life. Based on comments received throughout this dialog, ASCE initiated the 2nd Edition of the Body of Knowledge Committee under the Committee on the Academic Prerequisites for Professional Practice in 2005.

The BOK2 boasts several significant features. First, the BOK2 details a comprehensive list of 24 outcomes required for entry into professional practice. Second, it includes a system of identifying the level of achievement expected of an engineering apprentice using the well-established Bloom's Taxonomy. Third, the BOK2 allocates responsibility for and the timing of the achievement of each of the 24 outcomes, whether it is during the completion of a bachelor of science in civil engineering, while earning a master's degree or 30 graduate-level credits in an engineering specialty, or during pre-licensed experience with industry as an engineering intern.

The expanded 24 outcomes are clarified and divided into three categories: Foundational, Technical, and Professional. The Foundational category is unique in that it includes the four core areas of "liberal" learning: Mathematics, Natural Sciences, Humanities, and Social Sciences.¹⁰ It is acknowledged that the "contributions of civil engineers are largely to and for human society" and that "civil engineers should have the basic scientific literacy that will allow them to be conversant with technical issues pertaining to environmental systems, public health and safety, durability of construction materials, and other such subjects."¹⁰ The BOK2's emphasis on the *artes liberalis* reflects the changing emphasis on the capabilities required of civil engineers in professional practice.

For each of the 24 outcomes, the BOK2 details an appropriate "level of achievement" according to Bloom's Taxonomy for the Cognitive Domain. (See Appendix A.) The six levels are Level 1: Knowledge, Level 2: Comprehension, Level 3: Application, Level 4: Analysis, Level 5: Synthesis, and Level 6: Evaluation. Only three of the 24 outcomes require Level 6 as the lower bound acceptable level of achievement: Design, Technical Specialization, and Professional and Ethical Responsibility.

"The [bachelor of science in civil engineering] BSCE has been treated as the defacto terminal degree for practice for over 100 years."⁶ With the BOK2, successful attainment of the level of achievement necessary for each outcome also relies on experience gained through a master's degree, or approximately 30 semester credit hours of graduate-level studies, as well as pre-licensure experience. Although the "fledgling engineer" is the one responsible for ensuring achievement, many entities are expected to assist the engineer in achieving the outcomes, including employers.⁶

Reviewing the breadth of these papers, it is evident that preliminary research exists on three main perspectives of the BOK – the perspective of university faculty on their curriculum, the perspective of employers in industry on the characteristics of their newly hired engineers, and the perspective of civil engineering students on their preparation for professional practice. Each of these three perspectives is considered subsequently in light of the available literature.

The Perspective of Faculty on Civil Engineering Curriculum

In a study of ten universities, faculty members were surveyed as to whether or not they thought their programs' curricula fulfilled the BOK2 outcomes.¹¹ In this study, not one of the three categories of outcomes (Foundational, Technical, or Professional) was of concern. However, certain outcomes that “are relatively ‘new’ or are presented with a higher degree of specificity and/or higher level of achievement than has been suggested previously” were found to be problematic.¹¹ Outcomes of particular concern included Humanities, Social Sciences, Sustainability, Contemporary Issues/History, Risk and Uncertainty, Public Policy, Business and Public Administration, Globalization, and Leadership. Less than half of the surveyed institutions reported that the appropriate level of achievement was fulfilled by all of their baccalaureate graduates for these BOK2 outcomes. This study clearly illustrates the value of the faculty perspective in pinpointing outcomes that need additional work within a curriculum.

To assist faculty in performing work to improve the ability of students to meet certain levels of achievement for select outcomes, it was recommended that the BOK2 move from using Bloom's Taxonomy to Anderson and Krathwohl's Learning Taxonomy.¹² In 1956, Benjamin Bloom led a group of educational psychologists in studying the levels of intellectual activity. Anderson and Krathwohl updated this one-dimensional framework in 2001 by changing the verbs for the cognitive dimension and adding another dimension – the knowledge dimension. (See Table 1.)

Table 1: Anderson and Krathwohl's Learning Taxonomy (Table from Bardet and Ragusa, 2009)

		Cognitive Dimension					
		Remember	Understand	Apply	Analyze	Evaluate	Create
Knowledge Dimension	Factual						
	Conceptual						
	Procedural						
	Metacognitive						

By using Table 1, it is argued that faculty can better develop engineering curriculum that involves inductive instruction, as opposed to the traditional deductive methods, that illustrates application to real life. This could have a profound effect on civil engineering graduates in the United States whose future jobs will require higher-level skills including innovation, problem solving, and leadership.

Designing curriculum is one matter; rebuilding an entire program's educational outcomes (PEOs) is another. The Department of Civil Engineering at Lawrence Technological University decided to adopt the BOK2 as the new standard for their PEOs just two years before their ABET accreditation visit in 2010.¹³ Although this was very progressive, accomplishing this effort was likened to “a quest to slay the Multi-Headed Hydra.” The department encountered numerous challenges, including faculty members who were unfamiliar with the BOK2 and Bloom's Taxonomy, adjunct professors who were suddenly bombarded with educational psychology terminology, debates on the meaning of the verbs in Bloom's Taxonomy, how to incorporate construction engineering and management practices into an established design oriented program,

etc. While overcoming these challenges, the department learned several lessons. One such lesson was the importance of developing rubrics to assist with communicating course expectations to students and faculty alike.

The Perspective of Industry on Employee Development

The adjunct faculty at Lawrence Tech had to learn elements of educational psychology in order to assist in the development of curriculum. This cooperation between industry and education highlights another important perspective on the BOK2 – the unique perspective of industry.

It has been suggested that a “licensing board” be created to monitor internship programs and ensure proper depth and breadth of experience for new engineers.¹⁴ Industry should provide feedback to academia on how well prepared graduates are as they enter internship programs. By using feedback from the industry perspective, faculty can drive the right curriculum improvements that best prepare engineers to meet the demands of professional practice.

The Perspective of Students on their Preparation for Professional Practice

Bielefeldt’s recent study at CU investigated how civil engineering students perceived the educational outcome requirements in the BOK2.¹⁵ The project had three main goals:

- 1) Introduce the BOK2 to first year civil engineering students and determine what information they perceived as most important and/or motivational.
- 2) Contrast senior [civil engineering] students’ opinions on the importance of the various BOK2 outcomes with the first year students.
- 3) Determine how well the students felt their experiences at CU prepared them for the broad requirements of the civil engineering profession and the level of achievement expectations of the BOK2.

To assess the freshmen, the BOK2 and ABET criteria were given to students in a 1-credit Introduction to Civil Engineering course. The first homework assignment was to define civil engineering, the five most important skills/abilities to the profession, three skills unique to civil engineering, and the steps required to become a Professional Engineer (PE). The final homework assignment was a reflective essay on whether or not the student planned to remain a civil engineering major and why/why not, and what strengths/weaknesses did they have when it comes to the skills/attributes outlined by the BOK2 and ABET.

The freshmen thought that the five most important skills were communication, ethics, teamwork, creativity, and design. Although the small number of female and minority students made identifying statistically significant differences difficult, at the conclusion of the Introduction to Civil Engineering course, reportedly a greater percentage of females (20%) had lost interest in civil engineering compared to their white male peers (10%). Out of 134 students, 11 lost interest in being a civil engineering major, yet eight of these 11 students said that the “ability to help people and society was an attractive feature of civil engineering.”¹⁵ A majority of the freshmen said they enjoy teamwork or think of it as a personal strength.

To assess the seniors, 68 students in a senior capstone design course were asked to complete a 1-page written survey on the outcomes of the BOK2. They ranked the three most important outcomes, ranked the outcomes least important to a civil engineering career, ranked the three outcomes they were personally weakest at, and ranked the three outcomes within CU's program that need the most attention.

In addition, five students (3 females, 2 males) in an environmental engineering design capstone were asked to examine the BOK2 in more detail. Two were asked to read the BOK2 in depth and indicate how well their coursework fulfilled the BOK2. Three were given more explicit instructions to map their courses and extracurricular activities to the BOK2 outcomes and appropriate levels of achievement. These students also wrote a half-page on whether the BOK2 was interesting to read, what surprised them about civil engineering, if they thought all civil engineering students should be required to read the BOK2, and what skills/attributes in the BOK2 they would like to learn more about.

Although some seniors in the Bielefeldt study did not follow the survey instructions and this impacted the study, it was found that five of the 24 outcomes were not rated in the top three important outcomes by any student. These five outcomes were Experiments, Public Policy, Business and Public Administration, Globalization, and Social Sciences. More than 50% of the students ranked Problem Recognition, Problem Solving, and Design in the top three most important outcomes. Design, Project Management, and Problem Solving were ranked as needing more attention at CU. There was large diversity in the reported personally weakest outcome.

By comparing the results between freshmen and seniors, Bielefeldt found that both groups perceived Mathematics and Design as critically important. She also noted that freshmen assigned more significance to Communication, Professional and Ethical Responsibility, and Teamwork than did the seniors. She also found that extracurricular activities were important in meeting the BOK2 outcomes, that a student's role(s) within design teams impacts the perception of importance for certain outcomes (e.g. a team project manager is more likely to assign higher importance to Leadership and Project Management), and "as students gain a better understanding of the attributes desired for civil engineering professionals, they will be better equipped to seek out experiences and courses to develop these skills."¹⁵

As ASCE notes, it is the student, the "fledgling engineer," who is responsible for meeting the appropriate level of achievement for each outcome as he or she prepares for professional practice as a civil engineer. Of the three main perspectives on the BOK2, the perspective of the student is of great importance. Projects like Bielefeldt's at CU illustrate the benefit of studies on the student's perspective. Findings from studies of this type can assist faculty in improving curricula, improving retention of minorities, and improving the recruitment of the right students into a civil engineering program in the first place.

Methods

For the purposes of comparing results obtained during the Bielefeldt study and the USMA study, a request was made to obtain the CU data. The authors gratefully acknowledge CU's willingness

to provide the raw data from the Bielefeldt study. The CU raw data was utilized in the current investigation and greatly expedited the process of making comparisons.

The USMA data were obtained from seniors in their final semester prior to graduation. All civil engineering seniors at USMA are required to take CE400, which is only offered during the spring semester. CE400 is a seminar class with required attendance and multiple required assignments. All students in this course were provided with access to an electronic copy and were required to read ASCE's BOK2. After reading the document, all students were required to rank order the top three "most important" and bottom three "least important" of the 24 outcomes discussed in the BOK2. Next, the students rank ordered the top three outcomes that the civil engineering program needs to devote more attention to. At the suggestion of Dr. Bielefeldt at CU, the instructions provided to the USMA students were slightly modified from the original instructions provided to the CU students to provide greater clarity in the use of the instrument. Otherwise, the instrument utilized by USMA is identical to that utilized at CU. A copy of the instructions and data collection instrument are included in Appendix B of this manuscript.

In addition, all students at USMA were required to write a minimum 1-page essay in response to the following items:

- Was the BOK2 interesting to read? Why or why not?
- What did you read in the BOK2 that surprised you about civil engineering? Why?
- Do you think all civil engineering students should be required to read the BOK2? Why or why not?
- What skills/attributes in the BOK2 would you like to learn more about?

Again, these are the same items that students at CU were asked to address.

Enrollment in the CE400 course during Spring 2011 was 42 students. Due to the relative small size of the population, the USMA data was not analyzed for demographic characteristics.

The survey data were analyzed by totaling the number of responses for 1st rank, 2nd rank, and 3rd rank for each outcome (for example Problem Solving and Recognition received 11 top rank responses, five 2nd rank responses and five 3rd rank responses). A weighted score for each outcome was then created by multiplying the total 1st rank responses by three, the 2nd rank response by two and the 3rd rank responses by one and summing the total weighted values for each outcome (for example, the total weighted score for Problem Solving and Recognition was 69). The weighted scores were then compared to determine the top eight most important outcomes for USMA seniors, and the top eight outcomes most needed in the USMA curriculum.

The total number of USMA seniors responding to the BOK2 outcomes ranking survey was 37 of 42. To compare the USMA survey data to the CU survey data, the CU weighted scores were normalized to the USMA sample population size (multiplied by 37/72). A comparison summary of the USMA and CU survey data is shown in Figures 1 and 2.

The total number of USMA seniors who completed the one-page essay was 40 of 42, although not all essays directly addressed the provided questions. The process of reviewing the student essays permitted direct investigation of perceptions of the BOK2. A system of open coding and

selective coding was used to extract theme-based evidence from the essays. An iterative process of comparison of findings was used during the course of qualitative data evaluation.

Results

Six of the eight “most important” outcomes ranked by USMA seniors were also ranked among the eight “most important” by CU seniors (Figure 1). The “most important” outcomes shared between the two groups of seniors were: Problem Recognition and Solving (USMA-1 / CU-1), Design (2/2), Communication (3/6), Project Management (4/7), Math (5/3), and Professional and Ethical Responsibility (6/8).

Of the eight “most important” outcomes ranked by seniors at USMA only two were also ranked in the top eight “needing more to improve the curriculum” (Figure 1) and five were ranked in the bottom five as “needing more to improve the curriculum” (20-24). CU seniors ranked four of the eight “most important” outcomes in the top eight “needing more to improve the curriculum,” and none of the eight “most important” were in the bottom eight as “needing more to improve the curriculum.” Additionally, of the five outcomes ranked 20-24 for “more needed” in the USMA curriculum, one is ranked in the top three for “more needed” in the CU curriculum, and the remaining four are ranked in the middle third.

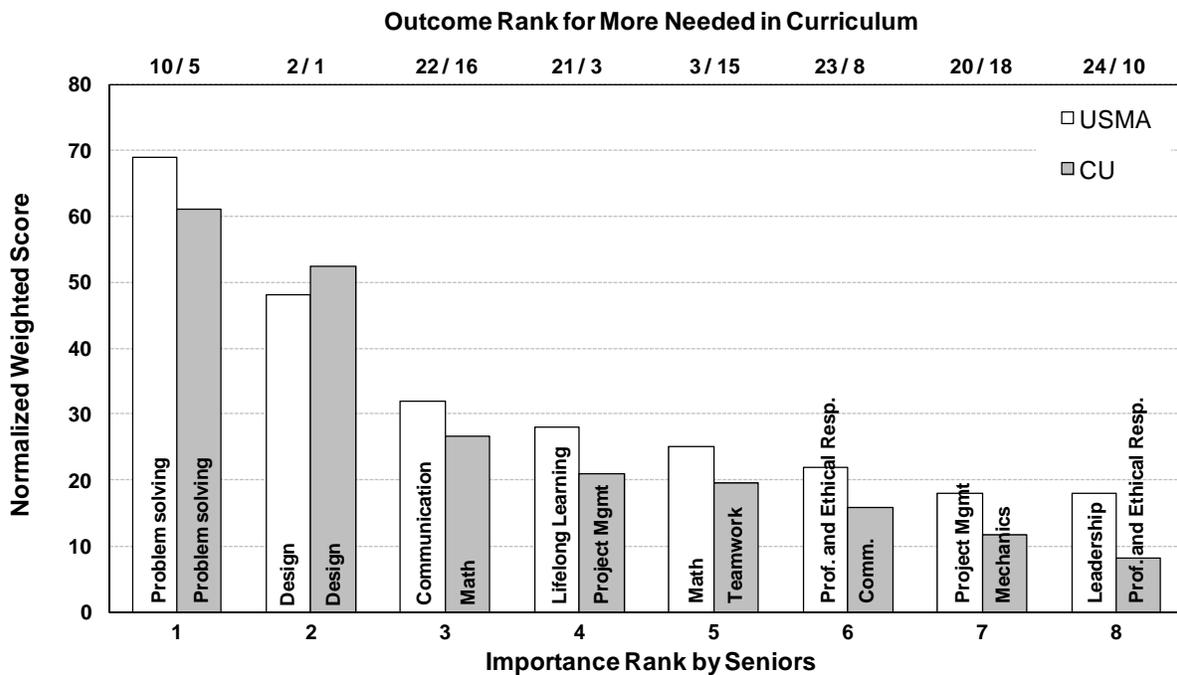


Figure 1: Comparison of Most Important Outcomes and Rank for More Needed in Curriculum as identified by Seniors at USMA and CU

When considering the student reported “needs more”-related data, an assumption must be made that the students were sufficiently familiar with Bloom’s Taxonomy to accurately evaluate their own academic experiences relative to the required levels of achievement specified for the 24 outcomes. For example, the BOK2 specifies level 3, application, for the mathematics outcome. Thus, it is an assumption of this study that the students understood what it means to reach the

application level and were not evaluating their own academic experiences based on either higher or lower levels of Blooms' Taxonomy.

Five of the eight “more needed” outcomes for improvement in the USMA curriculum were also ranked in the top eight “more needed” for improvement in the CU curriculum (Figure 2). The “more needed” outcomes for improvement in the curriculum shared between the two groups for seniors are: Sustainability (USMA-1/CU-2), Design (2/1), Business and Public Administration (6/4), Globalization (8/6), and Risk and Uncertainty (7/7). The three outcomes “more needed” for improvement in the USMA curriculum not shared by CU are: Math (3), Contemporary Issues and Historical Perspectives (4), and Technical Specialization (5) – none of these three outcomes were ranked in the bottom third (8) for more needed in the CU curriculum for improvement.

The three outcomes “more needed” for improvement in the CU curriculum not shared by USMA are: Project Management (3), Problem Recognition and Solving (5), and Communication (8). Two of these three outcomes are ranked in the bottom third as being “more needed” for improvement in the USMA curriculum; Project Management is ranked in the bottom five “more needed” for improvement at USMA and Communication is ranked in the bottom three “more needed” for improvement at USMA (Figure 2).

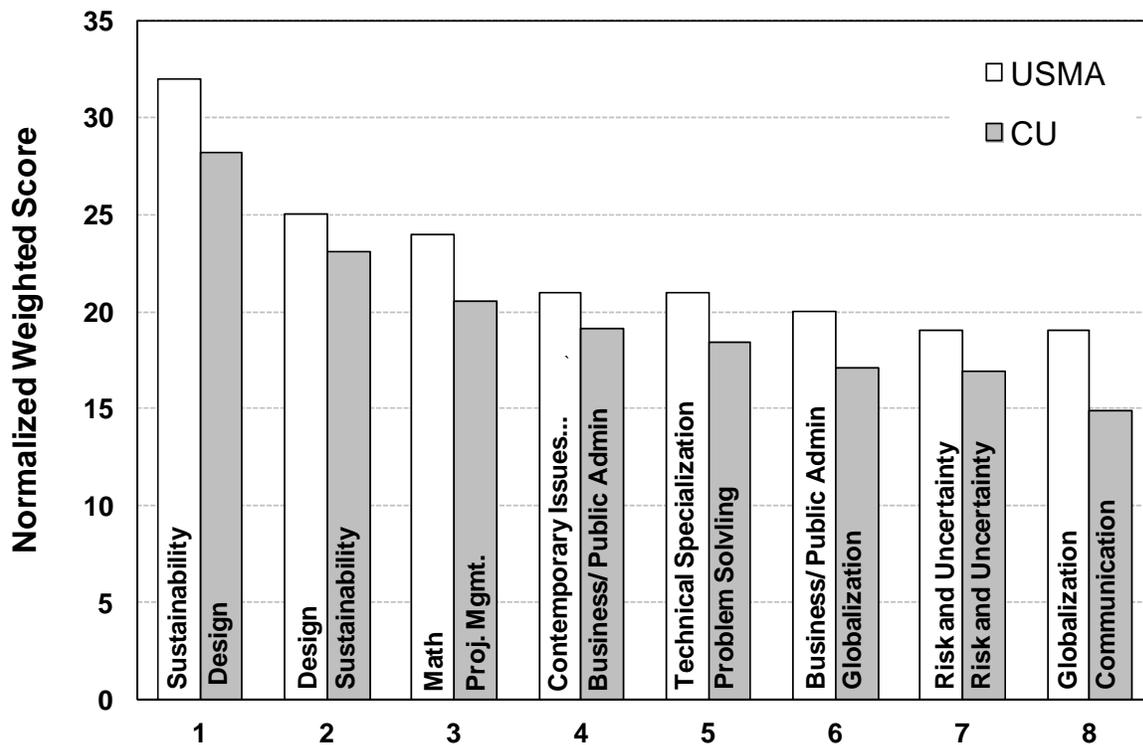


Figure 2: Top 8 Results for More Needed for Improvement in the Curriculum

Qualitative analysis of the essays revealed several interesting perceptions of the BOK2 held by USMA seniors. In general, the vast majority of participants felt that the document was overly long and too detailed. Just over half of the participants reported that they found the document interesting to read. Among those that found the document interesting, many commented on the

high level of detail and consideration that went into its preparation. Many students reported that they were surprised by the post-baccalaureate (experience and MS/30) expectations. A little more than half of the students believe that all civil engineering students should be required to read the BOK2. However, there was a significant amount of debate on the timing associated with reading the document. The students offered a wide range of skills/attributes in the BOK2 that they would like to learn more about, but the most commonly mentioned were Sustainability, Mathematics, and Risk and Uncertainty. Teamwork, Leadership, Public Policy, and Globalization were also mentioned by more than one student.

Discussion

Although this investigation is largely a replication of Bielefeldt's study at CU, some aspects of the original study could not be truly replicated. For example, at USMA, civil engineering majors take core courses (common to all academic majors) for the first two years, and it is only in the second semester of their second year that they begin to take engineering courses. Whereas, civil engineering students at CU begin their study of engineering during their first term of their freshman year. USMA also does not have an Introduction to Civil Engineering course; civil engineering majors start their engineering sequence with The Fundamentals of Engineering Mechanics and Design. Therefore, it was not possible to replicate the freshmen surveys as performed at CU.

As noted previously, the USMA senior perceptions place five (Project Management, Lifelong Learning, Communication, Professional and Ethical Responsibility, and Leadership) of the top eight "most important" outcomes in the bottom third of the outcomes "needing more" in the current curriculum (Figure 2). One possible interpretation of this is that the students believe that the current USMA curriculum is adequately preparing them for entrance into the profession. It is important to distinguish that student perceptions likely differ from faculty perceptions, but faculty perceptions were not included as part of this investigation.

The uniqueness of the profession that USMA civil engineering seniors enter upon graduation is worth mentioning and likely has an impact on the USMA student perceptions of the BOK2. While a large percentage of the USMA civil engineering seniors pass the Fundamentals of Engineering Principles (FE) Exam and are registered Engineer Interns (EI) shortly after graduation, very few enter directly into the civil engineering profession and practice engineering. The civil engineering graduates of USMA are first commissioned officers in the US Armed Forces (known as the Profession of Arms), and therefore view their preparation for entrance into the civil engineering profession and the application of the BOK2 differently than many CE seniors from other programs across the country. USMA civil engineering seniors who choose to enter the US Army Corps of Engineers may experience some practical engineering as young officers. However, they are just as likely to find themselves leading combat engineers in operational units across the Army and the globe, and therefore must ensure that they are equally prepared to fulfill their professional role as commissioned officers.

The Profession of Arms influence and mission of USMA is evidenced in the comparison of the top eight ranked "most important" outcomes to those "needing more" in the curriculum for both USMA and CU. Many of the outcomes that CU seniors perceive as "needing more" in the

curriculum (eg. Project Management, Communication, Professional and Ethical Responsibility) rank in the bottom third at USMA for “needing more” in the curriculum because they are paramount in the development of professional military leaders, not just engineers, and are therefore addressed throughout the USMA core curriculum. Project Management, Lifelong Learning, Communication, Leadership, and Professional and Ethical Responsibility are all ranked in the top eight most important outcomes, but at USMA, they are all addressed as part of the leader development process, and are therefore viewed as being adequately incorporated into the curriculum at USMA. Notably, while USMA seniors perceive that they are being adequately incorporated into the curriculum, professional and ethical responsibility, lifelong learning, and leadership were all mentioned in the essays as areas that they would like to learn more about. Conversely, CU seniors ranked Project Management, Communication, Professional and Ethical Responsibility, and Teamwork in the top eight most important and in the top two-thirds for needing more in the CU curriculum. The CU core curriculum likely does not explicitly address these outcomes as part of a leader development process as does USMA, and thus, it is possible that the CU seniors do not believe they have adequate exposure to these outcomes.

The top two “most import” outcomes for both USMA and CU are Problem Solving and Recognition, and Design (Figure 2). Design is also ranked in the top two for both institutions as “needing more” in the curriculum and Problem Solving and Recognition is ranked in the top 10 for USMA and top 5 for CU as “needing more” in the curriculum. The leader development process at USMA addresses problem solving throughout the four-year curriculum as a critical asset for future combat leaders. The USMA civil engineering program also has a significant problem solving and design emphasis, which makes this result somewhat inconsistent with the rankings of the other BOK2 outcomes by USMA seniors. However, it is likely that USMA seniors’ perceptions of design expectations for engineers entering the profession are higher than faculty or industry expectations for recent civil engineering graduates. Further research into the student perceptions of these outcomes at USMA would enable USMA faculty to adjust the current curriculum to better address the BOK2.

USMA seniors ranked math in the top five “most important” outcomes and the top three for “needing more” in the curriculum (Figure 1), whereas CU seniors ranked math in the top three “most important,” but only in the top 16 for “needing more” in the curriculum (Figure 1). It is possible that the perception of a lack of math by USMA seniors is an artifact of the core curriculum at USMA. As part of the core curriculum, all USMA students take four full semesters of math to include two semesters of calculus, a semester of discrete mathematical modeling, and a semester of probability and statistics. USMA civil engineering majors are only required to take one additional semester of math (typically engineering mathematics with partial differential equations and vector calculus) as part of the program, thus the perception is that there is not much additional math required for the engineering program. However, what most USMA seniors do not realize is that other academic institutions do not require non-engineering students to take four semesters of math, so the USMA senior perspective of the amount of additional math needed for the program is possibly errantly skewed.

An observation made by the USMA seniors and noted within their essays was the realization that the committee responsible for preparing the BOK2 was devoid of student representation. While many essays discussed positive perceptions of the level of consideration and thought that goes

into preparing a document with such a high-degree of detail and foresight, several essays specifically expressed concern that there was a lack of student level viewpoint.

Not all of the essays reported agreement that the BOK2 should be required reading among civil engineering students. Among those who believed it should be required, there was support for reading the document as either an introduction to a program of study or as an exit activity, as utilized during this investigation. Those supporting the early reading of the BOK2, note that it could be used as a sort of road map when making decisions about their education and future. At least one student acknowledged that had he/she read the BOK2 earlier in their academic program, they would have made different decisions related to their technical electives. Other essays, also supporting an early read, note that familiarity with the document would provide a student with a better understanding of the theory behind the practice of education and why their curriculum is structured as it is. One student even referred to the BOK2 as a “recipe for success.” On the other hand, many of the essays also discussed the benefits of reading the document near the end of their academic program. Several such essays referred to the BOK2 as a stimulus for reflection upon what the student had accomplished and an appreciation for their education. A handful of essays also noted that while the BOK2 is a useful tool for undergraduate education, it is also a valuable resource for individuals embarking on their post-baccalaureate careers.

The civil engineering program at USMA will be able to use the results of this investigation to improve the civil engineering curriculum and better prepare graduates for professional licensure within the context of the BOK2. The results will be shared with the Program’s ABET Advisory Committee for collaboration and recommendations in curriculum development. Additionally, the continued collaboration with industry representatives (relationships with U.S. Army Research Laboratory, Engineer Research and Development Center, U.S. Army Corps of Engineers and other professional industry entities) in the out years will enable USMA results to enhance the feedback from industry which further contributes to curriculum development.

The comparison of outcomes ranked as the “most important” with those outcomes that are “needed more” in the curriculum (Figure 2) is of importance for curriculum development. It allows academic institutions to adjust the current curriculum to better address those outcomes which are perceived as the most important for graduating seniors entering the profession – the “fledgling engineers” as described by Anderson et al.⁶. While the literature suggests three perspectives of the BOK2 that are of importance, perhaps the perspective of the student preparing for professional experience is of most importance because it is that student who is responsible for their own achievement of the BOK2 outcomes with the assistance of many other entities, ie. academic faculty, industry, professional organizations, etc.⁶

Conclusions

Clearly, the graduating seniors at USMA that participated in this study hold specific perceptions of ASCE’s BOK2. Among the 24 outcomes identified in the BOK2, the USMA students identified a ranking of what they believe are the “most important” and “least important.” Further, that group also considered their own academic experiences to identify which outcomes “need more” attention within their program of study. In addition to survey analysis, the authors’

review of the short essays written by the USMA seniors also further shaped the perceptions of the BOK2 that those students held.

By comparing the USMA students' survey data and essays with the perceptions reported in the CU study, it is possible to identify how institutional mission and educational practices influence student perceptions of the BOK2. While USMA and CU have significantly different, but no less critical missions, several distinct similarities were identified in how these two populations perceive the BOK2. Where differences were noted, readily plausible explanations, related to mission and/or practices, were identified.

While the BOK2 has many intended audiences, perhaps it is most critical that the students, as future members of the civil engineering profession, be familiar with this document. Whether as a road map to assist with making undergraduate decisions, as a tool for reflecting upon the undergraduate experience, or as a compass for navigating post-baccalaureate choices, the ASCE BOK2 is unquestionably a valuable resource for all civil engineering students.

References

- ¹ American Society of Civil Engineers, *Engineering the Future of Civil Engineering*, T.C.o.t.F.P. Degree, Editor. 2001, American Society of Civil Engineers. p. 155.
- ² American Society of Civil Engineers, *Civil Engineering Body of Knowledge for the 21st Century*, B.o.K. Committee, Editor. 2004, American Society of Civil Engineers: Reston. p. 128.
- ³ Welsh, S.G. *Body of Knowledge for Civil Engineers: Essential for Success in the International Arena*. in *35th International IGIP Symposium*. 2006. Tallinn, Estonia: IEEE.
- ⁴ American Society of Civil Engineers. *Body of Knowledge*. 2007 [cited 03 March 2007]; Available from: <http://www.asce.org/professional/educ/>.
- ⁵ American Society of Civil Engineers. *ASCE Policy 465*. 2007 [cited 3 March 2007]; Available from: http://www.asce.org:80/pressroom/news/policy_details.cfm?hdlid=15.
- ⁶ Anderson, R., S. Welsh, and K. Fridley. *The new and improved civil engineering body of knowledge*. 2008. Pittsburg, PA, United States: American Society for Engineering Education.
- ⁷ National Academy of Engineering, *The engineer of 2020 : visions of engineering in the new century*. 2004, Washington, DC: National Academies Press. xv, 101 p.
- ⁸ National Academy of Engineering., *Educating the engineer of 2020 : adapting engineering education to the new century*. 2005, Washington, DC: National Academies Press. xvi, 192 p.
- ⁹ ASCE Steering Committee to Plan a Summit on the Future of the Civil Engineering Profession in 2025, *The vision for civil engineering in 2025*. 2007, American Society of Civil Engineers: Reston.
- ¹⁰ Evans, J. and D. Lynch. *Foundational outcomes of the new civil engineering Body of Knowledge*. 2008. Pittsburg, PA, United States: American Society for Engineering Education.

¹¹ Fridley, K., K. Hall, D. Larson, K. Sutterer, J. Alleman, K. McManis, J.-P. Bardet, B. Gunnink, G. List, R. Smith, and T. Lenox. *Educating the future civil engineer for the new civil engineering Body of Knowledge*. 2009. Austin, TX, United States: American Society for Engineering Education.

¹² Bardet, J.-P. and G. Ragusa. *Analysis of body of knowledge in civil engineering*. 2009. Austin, TX, United States: American Society for Engineering Education.

¹³ Tocco, J. and D. Carpenter. *Adopting the BOK2: The quest to slay the multi-headed Hydra*. 2010. Louisville, KY, United States: American Society for Engineering Education.

¹⁴ Kirschenman, M. and B. Brenner, *Implementation of the ASCE BOK-2: Some thoughts*. *Leadership and Management in Engineering*, 2010. 10(2): p. 97-99.

¹⁵ Bielefeldt, A. *Student perceptions of the Civil Engineering Body Of Knowledge*. 2010. Louisville, KY, United States: American Society for Engineering Education.

Appendix A – Required Outcomes and Levels of Achievement from the BOK2

Outcome Number and Title	Level of Achievement					
	1	2	3	4	5	6
	Knowledge	Compre- hension	Application	Analysis	Synthesis	Evaluation
<i>Foundational</i>						
1. Mathematics	B	B	B			
2. Natural sciences	B	B	B			
3. Humanities	B	B	B			
4. Social sciences	B	B	B			
<i>Technical</i>						
5. Materials science	B	B	B			
6. Mechanics	B	B	B	B		
7. Experiments	B	B	B	B	M/30	
8. Problem recognition and solving	B	B	B	M/30		
9. Design	B	B	B	B	B	E
10. Sustainability	B	B	B	E		
11. Contemp. issues & hist. perspectives	B	B	B	E		
12. Risk and uncertainty	B	B	B	E		
13. Project management	B	B	B	E		
14. Breadth in civil engineering areas	B	B	B	B		
15. Technical specialization	B	M/30	M/30	M/30	M/30	E
<i>Professional</i>						
16. Communication	B	B	B	B	E	
17. Public policy	B	B	E			
18. Business and public administration	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 and ethical responsibility	B	B	B	B	E	E

- Key:
- | | |
|-------------|---|
| B | Portion of the BOK fulfilled through the bachelor's degree |
| M/30 | Portion of the BOK fulfilled through the master's degree or equivalent (approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses in a specialized technical area and/or professional practice area related to civil engineering) |
| E | Portion of the BOK fulfilled through the prelicensure experience |

Appendix B – Survey and Writing Assignment Administered to USMA Seniors

11-2

CE400

Civil Engineering Body of Knowledge (BOK2)

The prescribed skills necessary to become a licensed professional civil engineer are described in the Body of Knowledge (BOK2) for Civil Engineering that was written by the American Society of Civil Engineers (ASCE). The table on the flip-side of this page lists the 24 abilities that you are expected to have when you complete your B.S. degree in civil engineering.

Directions

Step 1: Review the complete ASCE BOK2 which can be downloaded for free at the following weblink: <http://www.asce.org/Content.aspx?id=2147486178>

Step 2: Review the table of 24 Outcomes as listed on the flip-side of the page, clearly write your name and ID# on the top of the page, and give critical consideration to the items requested in **Steps 3-7**.

Step 3: In Column 1, please rank order the 3 outcomes that you think are the most important. Place a “1” next to the Outcome you think is most important; place a “2” next to the 2nd most important Outcome; place a “3” next to the 3rd most important Outcome.

Step 4: Also in Column 1, please rank order the 3 Outcomes that you think are the least important. Place a “4” next to the Outcome you think is least important; place a “3” next to the 2nd least important Outcome; place “2” next to the 3rd least important Outcome. (Note: you do not need to rank order all 24 Outcomes; just the 3 most important and 3 least important in your opinion.)

Step 5: In Column 2, please rank order the 3 Outcomes that you think you are the strongest at. Place a “1” next to the Outcome you are strongest at; place a “2” next the Outcome that you are 2nd most strong at; place a “3” next to the Outcome that you are 3rd most strong at.

Step 6: In Column 2, please rank order the 3 Outcomes that you think you are the weakest at. Place a “1” next to the Outcome you are most weak at; place a “2” next the Outcome that you are 2nd most weak at; place a “3” next to the Outcome that you are 3rd most weak at. (Note: you do not need to rank order all 24 Outcomes; just the 3 personal strongest and 3 personal weakest in your opinion.)

Step 7: In Column 3, please rank order the 3 Outcomes that you think should receive more attention in the curriculum at USMA (including both the core curriculum and the CE curriculum). Place a “1” next to the Outcome that needs the greatest amount of additional attention; place a “2” next to the Outcome that needs the 2nd most amount of additional attention; place a “3” next to the Outcome that needs the 3rd most amount of additional attention.

Step 8: Write a minimum 1 page (double spaced) essay that answers the following questions:

- Was the BOK2 interesting to read? Why or why not?
- What did you read in the BOK2 that surprised you about civil engineering? Why?
- Do you think all civil engineering students should be required to read the BOK2? Why or why not?
- What skills/attributes in the BOK2 would you like to learn more about?

Step 9: Submit your essay and this form (with Steps 3 – 7 complete) to Dr. Barry during CE400 session on 03 May 2011.

Name _____ ID# _____

Civil Engineering BOK2 Outcome at the Bachelor's degree level	Column 1 Most & Least Important	Column 2 Personal Strongest & Weakest	Column 3 More needed @ USMA
1. MATH. <i>Solve</i> problems in math through differential equations and <i>apply</i> this knowledge to the solution of engineering problems			
2. NATURAL SCIENCES. <i>Solve</i> problems in calculus-based physics, chemistry, and one additional area of natural science and <i>apply</i> this knowledge to the solution of engineering problems			
3. HUMANITIES. <i>Demonstrate</i> the importance of the humanities in the professional practice of engineering.			
4. SOCIAL SCIENCES. <i>Demonstrate</i> the incorporation of social sciences knowledge into the professional practice of engineering			
5. MATERIAL SCIENCE. Use knowledge of materials science to <i>solve</i> problems appropriate to civil engineering			
6. MECHANICS. <i>Analyze</i> / solve problems in solid & fluid mechanics.			
7. EXPERIMENTS. Conduct experiments and analyze the results in more than 1 of the technical areas of Civil Engineering.			
8. PROBLEM RECOGNITION & SOLVING. <i>Develop</i> problem statements and <i>solve</i> well-defined fundamental civil engineering problems by <i>applying</i> appropriate techniques and tools			
9. DESIGN. Design a system or process to meet desired needs within such realistic constraints as economic, environmental, social, political, ethical, health and safety, constructability, & sustainability.			
10. SUSTAINABILITY. <i>Apply</i> the principles of sustainability to the design of traditional and emergent engineering systems.			
11. CONTEMPORARY ISSUES & HISTORICAL PERSPECTIVES. <i>Explain</i> the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and <i>explain</i> the impact of engineering solutions on the economy, environment, political landscape, and society.			
12. RISK and UNCERTAINTY. <i>Apply</i> the principles of probability and statistics to <i>solve</i> problems containing uncertainties.			
13. PROJECT MANAGEMENT. <i>Develop</i> solutions to well-defined project management problems			
14. BREADTH in civil engineering. <i>Analyze</i> and solve well-defined engineering problems in at least 4 technical areas appropriate to CVEN			
15. TECHNICAL SPECIALIZATION. <i>Define</i> key aspects of advanced technical specialization appropriate to civil engineering.			
16. COMMUNICATION. <i>Organize</i> and <i>deliver</i> effective verbal, written, virtual, and graphical communications.			
17. PUBLIC POLICY. <i>Discuss</i> and <i>explain</i> key concepts and processes involved in public policy			
18. BUSINESS and PUBLIC ADMINISTRATION. <i>Explain</i> key concepts and processes used in business and public administration			
19. GLOBALIZATION. <i>Organize, formulate,</i> and <i>solve</i> engineering problems within a global context.			
20. <i>Apply</i> LEADERSHIP principles to direct a small group.			
21. TEAMWORK. <i>Function</i> effectively in an intradisciplinary team.			
22. ATTITUDES. <i>Explain</i> attitudes supportive of the professional practice of civil engineering.			
23. LIFELONG LEARNING. <i>Demonstrate</i> the ability for self-directed learning.			
24. PROFESSIONAL and ETHICAL RESPONSIBILITY. <i>Analyze</i> a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action.			