Transformation of a large civil engineering department curriculum using the ASCE BOK2

Dr. Kelly Brumbelow, Texas A&M University

Dr. Kelly Brumbelow is an Associate Professor and the Assistant Department Head for Undergraduate Programs in the Zachry Department of Civil Engineering at Texas A&M University. He has been a faculty member at Texas A&M since 2002, where his technical specialty is water resources engineering, planning, and management. Prior to this position, he completed his undergraduate and graduate studies at Georgia Tech, where he taught undergraduate courses for 7 years. His professional activities have included projects in East Africa, Central America, the Middle East, Alaska's North Slope, and throughout the "lower 48 states." His current activities at Texas A&M cover a wide spectrum from K-12 outreach and recruiting to undergraduate curriculum design to retention, monitoring, and post-graduation engagement.

Dr. Debra A Fowler, Texas A&M University

Dr. Debra Fowler serves the Associate Director of the Center for Teaching Excellence at Texas A&M University. Following 16 years working in industry she completed a Ph.D. is in Interdisciplinary Engineering with a specific focus on engineering education from Texas A&M University. Her research areas of focus are faculty perspectives and growth through curriculum design and redesign, professional development of graduate students related to teaching and the influence of reflection and creation of eportfolios on student connections to learning and employment.

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Whitney L. Anthony, Zachry Department of Civil Engineering, Texas A&M University

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Transformation of a Large Civil Engineering Department Curriculum Using the ASCE BOK2

Abstract

Texas A&M's undergraduate civil engineering curriculum has been re-designed and founded on the 2nd edition of ASCE's Civil Engineering Body of Knowledge (BOK2). The curriculum transformation work involved a team of civil engineering faculty and students as well as a pedagogical expert and occurred over a deliberate two year timeframe. The process was made explicitly analogous to an engineering design process with data-driven analysis in order to build faculty consensus. The team adapted the BOK2 outcome statements and defined comprehensive rubrics to specify expectations of student performance for multiple indicators under each outcome at multiple levels in the curriculum. A curriculum map was then developed to identify how specific courses would introduce, reinforce, and demonstrate program outcomes as students advanced. The size of the program (in terms of available elective plans as well as personnel) required enhanced attention to potential student course plans, empowerment of course coordinators, and inclusion of representative stakeholders. Beyond the expected work of revising courses, the effort led to: a novel mid-curriculum zero credit hour course incorporating a high-impact learning practice and reflection, extensive cooperation with external departments to enhance non-departmental courses, and cataloging of resources for students to address knowledge gaps between courses. Lessons learned focus on how the expansive nature of the BOK2 outcomes require a process that values deliberation, inclusion, and creativity.

Introduction

The civil engineering department at Texas A&M University (approximately 1000 undergraduate students and 60 faculty) decided to undertake a curriculum transformation project based on concerns of conceptual gaps and redundancies in the degree program and the significant time that had elapsed since the last comprehensive curriculum restructuring. This curriculum redesign was noteworthy because it was among the first to incorporate the outcomes from ASCE's *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*, 2nd Edition (BOK2)[1]. Other efforts to incorporate the BOK2 holistically into curricula have been documented at the Universities of Alabama, Arkansas, and Texas-Tyler[2] and Lawrence Technological University[3], with BOK2-driven curriculum analysis and change proposals discussed at Rose Hulman Institute of Technology[4], Montana State University[5], University of Louisiana[6], Northern Arizona University[7], and North Carolina State University[8].

The curriculum transformation process has many goals, three of which will be explained in this paper:

1. Redesign the civil engineering curriculum of a large research university using the ASCE BOK2 as a basis.

2. Develop program learning outcome rubrics for each BOK outcome using pedagogical resources (ABET webinar, AAC&U rubrics, etc.) and a rigorous editing process.
3. Create a curriculum map based on program learning outcome rubrics and survey data. Use program learning outcome rubrics and curriculum map to design or revise individual courses.

This paper discusses the motivation behind using the ASCE Body of Knowledge 2 outcomes as program learning outcomes, the process used to facilitate the curriculum transformation, and best practices for creating and refining program learning outcome rubrics and a curriculum map. It also presents draft versions of the program learning outcome rubrics and curriculum map.

Curriculum Transformation Process

A curriculum transformation team (CTT), consisting of 13 civil engineering faculty, 3 students, a pedagogical expert, and a graduate assistant, was formed to re-evaluate the civil engineering curriculum and recommend changes that could make the program more relevant to the needs of today's engineers while addressing the gaps and redundancies in the current curriculum. The pedagogical expert was key because she provided a curriculum redesign process for the team to follow that was adapted from existing models[9, 10] and the process is outlined in detail in a separate paper[11].

The process began with identifying the need for a curriculum redesign and gathering data on the program's strengths and weaknesses[11]. The next step was to identify the attributes that an ideal graduate of the program would have. These ideal attributes were articulated through program learning outcomes and through rubrics that define each program learning outcome in terms of measurable performance indicators. The program learning outcomes and rubrics were used to create a curriculum map that identifies the level at which courses will incorporate each of the program learning outcomes. Courses can be linked to a program learning outcome at the progressive levels of "Introduce," "Reinforce," or "Demonstrate." As a final step, individual courses were designed or revised to incorporate the program learning outcomes at the level identified on the curriculum map. An important component of this final stage is to ensure that students learn the desired outcomes by designing assessment measures that are closely linked to both course and program learning outcomes.

The BOK and motivation…

In January 2004, the American Society of Civil Engineers published the first version of the Body of Knowledge in accordance with ASCE Policy Statement 465, which was originally created in 1998 and calls for attainment of a body of knowledge as a prerequisite to professional licensure. Since then, ASCE has released a second version of the BOK *(ASCE Body of Knowledge Committee 2008,* hereafter "BOK2"*)* that more accurately accounts for "stakeholder input and

recent developments in engineering education and practice" [BOK2, p.2]. Many of the driving factors for changes to the BOK are articulated in "The Vision for Civil Engineering 2025"[12] and in NAE "Engineer of 2020" reports[13]. These driving factors focus on the quickly-changing, global engineering landscape, with examples such as the increasing need for lifelong and self-directed learning, trends towards sustainability, and emphasis on professional skills in addition to technical knowledge.

The civil engineering department at Texas A&M decided to incorporate the BOK2 outcomes into the undergraduate curriculum because, unlike the program's existing ABET-based outcomes, the BOK2 outcomes are more focused toward civil engineers and are accompanied by Appendices with detailed descriptions of each outcome. When the Body of Knowledge document was first shared with the CTT, there was significant pushback from team members that did not understand the value of reading such a long document and were hesitant to adopt 24 outcomes in place of the 12 existing program outcomes. Several measures were taken to encourage CTT members to accept the BOK2 outcomes, but there were still some members who did not see the benefit of these outcomes until the curriculum mapping phase.

The first measure taken was to refocus efforts from course-level details to the big picture of the curriculum as a whole. This was accomplished by comparing the curriculum redesign process to a civil engineering design process, wherein both are iterative and require background information as inputs to a conceptual design that is then used to guide the final design. In this analogy, reviewing the BOK2 and other sources of data corresponds to the background information stage, program learning outcomes and associated rubrics are the conceptual design, and the curriculum map and individual course design are performed in the final design stage. This analogy was presented graphically in a separate paper[11], and can be found at https://sites.google.com/site/cttgraphic/.

The second measure taken to encourage civil engineering faculty to consider the BOK2 was mapping the program's existing outcomes, the required ABET outcomes, and the 24 BOK2 outcomes, as shown in Figure 1. This document helped to illustrate that the BOK2 outcomes were not significantly different from ABET requirements. In most cases, additional BOK2 outcomes were created by splitting long, compounded ABET outcomes into separate pieces. For example, ABET outcome (a), "an ability to apply knowledge of mathematics, science, and engineering", is addressed by four outcomes in the BOK2: (1) Mathematics, (2) Natural Sciences, (5) Material Sciences, and (6) Mechanics. By separating one outcome into four, it is easier to assess each area within "math, science, and engineering" individually; therefore, in many cases, the BOK2 does not add additional requirements, but instead adds detail and specificity. There are, however, a few instances, (13) Project Management, (22) Attitudes, (12) Risk/Uncertainty, and (15) Technical Specialization, of outcomes that were included in the BOK2 due to input from civil engineering stakeholders and represent areas that were not

explicitly addressed in the ABET requirements. This mapping was largely done in the BOK2 report [Appendix H and p. 101] -- there to compare ABET, BOK1, and BOK2 -- but the CTT's step of explicitly modifying that work to include the specific program's curriculum was crucial.

Other authors have discussed the tension between an increased number of program-level outcomes in the BOK2 and constrained or decreasing numbers of credit hours in baccalaureate engineering degrees[2], especially if faculty view new outcomes as being "practitioner-driven" from a viewpoint of the B.S. degree of 30 years ago with more available credit hours. In the case of Texas A&M's effort, this tension was managed in two ways. First, surveys were conducted to determine perceptions for each of the 24 BOK2 outcomes of comparative importance and preparedness of new graduates. The surveys were given to separate populations of recent graduates (less than 5 years after graduation) and industry employers (typically 20-30 years after graduation). Survey results from the two populations were very similar across the outcomes, which reinforced to faculty that perceptions were independent of experienced quantity of credit hours. Moreover, negative gaps (i.e., importance greater than preparedness) tended to occur in the "challenging" outcomes such as social sciences, public policy, and attitudes. Second, Texas A&M's civil engineering program is characterized by a high degree of emphasis on preparation for practice with industry seen as partners in education. Multiple courses – from "Introduction to CE" through "Capstone Design" – are explicitly designed to rely on external practitioner participants. The program is by far the largest source of civil engineering graduates in Texas, in some years producing almost half of all graduates despite the presence of 13 other accredited programs in the state. While this second factor may not be easily transferred to another institution, the survey provided an easily reproducible, data-driven way to persuade faculty.

CVEN Outcomes[a]	*ABET Outcomes*[a]	*BOK2 Outcomes*[b]
(a) Mathematics, science, engineering	(a) Mathematics, science, engineering	1. Mathematics 2. Natural sciences 5. Materials science 6. Mechanics
(b) Experiments	(b) Experiments	7. Experiments
(c) Design	(c) Design	9. Design 10. Sustainability
(d) Multidisciplinary teams	(d) Multidisciplinary teams	21. Teamwork
(e) Engineering problems	(e) Engineering problems	8. Problem recognition and solving
(f) Professional and ethical responsibility	(f) Professional and ethical responsibility	24. Professional and ethical responsibility
(g) Communication	(g) Communication	16. Communication
(h) Impact of engineering	(h) Impact of engineering	11. Contemporary issues and historical perspectives
(i) Lifelong learning	(i) Lifelong learning	23. Lifelong learning
(j) Contemporary issues	(j) Contemporary issues	11. Contemporary issues and historical perspectives 19. Globalization
	Program Criteria for Civil and Similarly Named Engineering Programs	17. Public policy 18. Business and public administration 20. Leadership
(k) Engineering tools	(k) Engineering tools	8. Problem recognition and solving
(l) Four specialty areas	Program Criteria for Civil and Similarly Named Engineering Programs	14. Breadth in civil engineering areas
EAC/ABET Criterion 5[c]	EAC/ABET Criterion 5[c]	3. Humanities 4. Social sciences
	Program Criteria for Civil and Similarly Named Engineering Programs	13. Project management 22. Attitudes
		12. Risk/uncertainty 15. Technical specialization

a) Short names
b) Short names from the BOK 2 report, Table 1, page 16
c) General education component

Figure 1. Mapping between existing civil engineering (CVEN) program outcomes, existing ABET outcomes, and new BOK2 outcomes.

Program learning outcomes and rubrics

In order to articulate how the BOK2 outcomes would be adapted to the civil engineering program under consideration, CTT members created a one-sentence statement for each program learning, based on descriptions in the BOK2 document (Figure 2). Each program learning outcome statement begins with an action verb and is both specific and measurable.

Foundational Outcomes

1. *Mathematics* - Apply knowledge of mathematics (through differential equations) to civil engineering problems.
2. *Natural sciences* - Apply knowledge of natural science (calculus-based physics, chemistry, and an elective) to civil engineering problems.
3. *Humanities* - Recognize and incorporate aesthetic, ethical, historical, and other human considerations into the development and evaluation of solutions to engineering and societal problems.
4. *Social sciences* - Demonstrate the incorporation of social sciences (economics, political science, psychology, etc.) knowledge into the professional practice of civil engineering.

Technical Outcomes

5. *Materials science* - Apply knowledge of materials, such as steel, concrete, wood, soil, asphalt, and composites of materials, used in civil engineering construction.
6. *Mechanics* - Analyze and solve problems involving solid and fluid mechanics.
7. *Laboratory and Field Methods* - Conduct experiments in civil engineering according to established procedures, report results, and evaluate the accuracy of the results within the known boundaries of the test and materials.
8. *Problem recognition and solving* - Develop problem statements and solve fundamental civil engineering problems by applying appropriate techniques and tools.
9. *Design* - Design and evaluate a system, component, or process to meet desired needs within realistic constraints such as those based on economic, environmental, sustainability, constructability, ethical, health and safety, social, and political issues.
10. *Sustainability* - Apply the principles of sustainability to the design of civil engineering systems and articulate their importance.
11. *Contemporary issues and historical perspectives* - Explain historical and contemporary issues in civil engineering and consider their impacts while solving engineering problems.
12. *Risk and/or uncertainty* - Apply the principles of probability and statistics (including defining all uncertainties) to civil engineering problems.
13. *Project management* - Apply the principles of project management to civil engineering problems.
14. *Breadth in civil engineering areas* - Solve engineering problems by integrating knowledge from at least four civil engineering technical areas (defined as coastal/ocean, construction, environmental, geotechnical, materials, structural, transportation, and water resources engineering).

Figure 2. One-sentence statements of BOK2 program learning outcomes as written by CTT members. (continued next page)

15. *Technical specialization* - State the process to become a specialist, solve problems, and analyze a complex system or process in one technical area of civil engineering.

15A. Construction and Engineering Management
15B. Coastal and Ocean Engineering
15C. Environmental Engineering
15D. Geotechnical Engineering
15E. Structural Engineering
15F. Transportation Engineering
15G. Water Resources Engineering

Professional Outcomes

16. *Communication* - Communicate clearly and effectively through verbal, written, mathematical, and visual means to promote understanding by both technical and non-technical audiences.
17. *Public policy* - Explain public policy concepts and processes that are relevant to civil engineering systems.
18. *Business and public administration* - Explain key concepts and processes used in public and business administration, and compare public policy and business procedures across regions and cultures.
19. *Globalization* - Organize, formulate, and solve civil engineering problems within a global context.
20. *Leadership* - Apply leadership principles to direct the efforts of a group.
21. *Teamwork* - Function effectively as a member of a team.
22. *Attitudes* - Demonstrate attitudes (curiosity, persistence, flexibility, etc.) conducive to effective practice of civil engineering.
23. *Lifelong learning* - Explain the need for self-directed learning, and identify and gather appropriate academic and professional information.
24. *Professional and ethical responsibility* - Explain the professional and ethical responsibilities of a civil engineer, and use codes of ethics to determine an appropriate course of action in a situation.

Figure 2. (continued from previous page)

Next, members of the CTT created one rubric for each of the 24 outcomes, with an exception for (15) Technical Specialization, where one rubric was created for each specialty area in the department. In total, the team created 30 rubrics. The rubrics provide a set of consistent, detailed descriptions of the program learning outcome rubrics in Figure 2. Each rubric breaks one of the program learning outcomes into 3 to 5 performance indicators and articulates what a student will be able to do at four levels within the curriculum:

- Level 1 is a student that first enters the civil engineering program, which is typically the beginning of sophomore year.
- Level 2 is an intermediate level.
- Level 3 is the minimum level that a student must accomplish to graduate.
- Level 4 is the desired level that a student will accomplish upon graduation.

The rubric template is shown in Figure 3, and two example rubrics are presented in Appendix 1. These types of rubrics are useful for making curriculum and course decisions[14]. If presented to students, they will also encourage students to become self-directed learners and allow them to track their progress throughout college.

Since most of the faculty and students on the CTT were unfamiliar with the idea of a rubric, especially when used in this context, several resources were provided for background and guidance. For each outcome, a "Toolkit" was assembled that contained:

- A document containing example verbs to use in rubric descriptions[15]. The verbs were grouped into four "Depth of Knowledge" categories.
- The mapping of BOK outcomes, which have become the department's new program learning outcomes, to ABET outcomes and the department's previous outcomes (Figure 1, above).
- An example rubric for outcome 24: Professional and Ethical Responsibility.
- "Appendix I - Body of Knowledge Outcome Rubric" from the BOK2 report to provide context as to how all of the outcomes fit together as a whole.
- A detailed description of the outcome from "Appendix J - Explanations of Outcomes" from the BOK2 report, and as appropriate, Appendices K through O.
- Example rubrics from the department's existing assessment tools and other sources[16, 17, 18], as appropriate.
- An ABET webinar on "Developing Rubrics"[19].

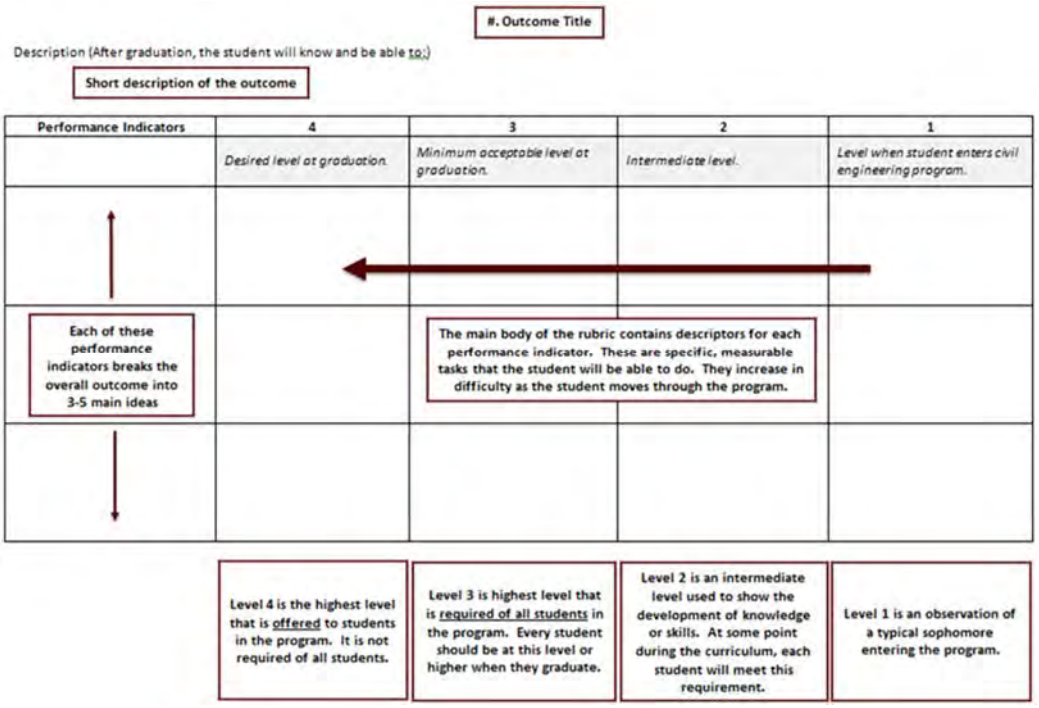

Figure 3. Template used for program learning outcome rubrics.

Those that were creating rubrics were also asked to schedule a 30 minute meeting with the pedagogical consultant and the graduate student on the team to talk through their progress on the rubric. These small meetings were very beneficial because they gave team members a chance to discuss their questions or concerns in a more private setting. It was also effective in reminding busy faculty to take some time out of their schedule to work on creating their rubric.

Curriculum map

The program learning outcomes and rubrics were used, along with the courses in the curriculum, as the basis for a curriculum map. An example of a curriculum map is shown in Figure 4. It contains program learning outcomes along the side and courses across the top. Each course that addresses one of the program learning outcomes contains either an I, R, or D in the intersecting box. Each program learning outcome is introduced, "I", reinforced, "R", and then demonstrated, "D" in one or more places across the curriculum. A process similar to this is presented elsewhere[20].

The first draft of the curriculum map was created in a four-hour workshop session, where the Curriculum Transformation Team was broken into three groups, each tasked with identifying the program learning outcomes corresponding to their assigned courses. As with the rubric creation process, detailed instructions were crucial to the success of this meeting. Each group was provided with a binder that contained instructions, the program learning outcome rubrics, data and summaries of the data, course syllabi, and many other relevant resources. An excerpt from the curriculum map is presented in Appendix 2.

Refinement

After the program learning outcomes, program learning outcome rubrics, and curriculum map were created, a very important next step was to edit and refine each piece. This was done first within the CTT by sending each document out to the team members and discussing areas of concern in one of the bi-weekly CTT meetings. Then each piece was shared with all of the faculty through online surveys or short presentations. The refinement process is ongoing and will continue as changes to the curriculum are implemented.

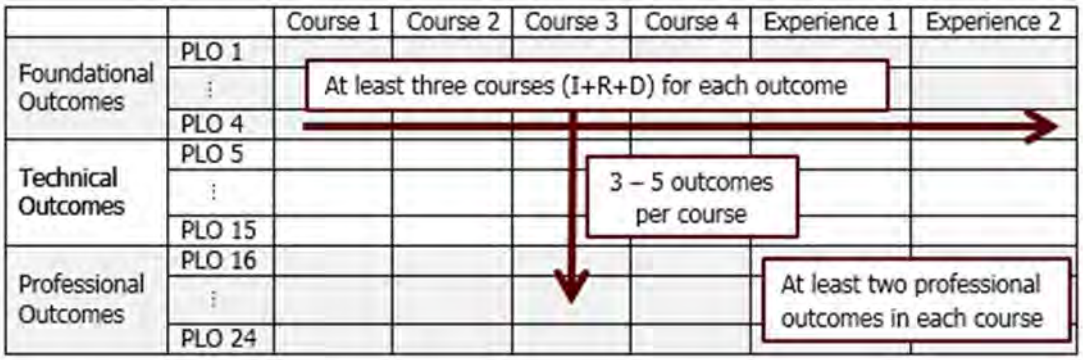

Figure 4. Template for creating the program curriculum map.

For the rubrics, an additional sub-committee within the CTT was assigned to review the rubrics in further detail and complete missing pieces. It took CTT members several months to really understand the purpose of the rubrics. They started to see potential applications after they had seen the full rubric packet. In addition to these formal review processes, items have been added and rearranged as the rubrics have been used to create the curriculum map and design courses.

Other than faculty surveys, another key source of data that has guided revisions to the rubrics and curriculum map is a survey format that contains each of the program learning outcomes with likert-scale questions to assess how well a recent graduate is able to perform the outcome and how often a recent graduate is required to perform the outcome. This survey was sent to recent graduates, employers, and faculty at graduate schools. The "gaps", or outcomes where the importance rating exceeded the preparedness rating, were identified, and special attention was given to those outcomes to make sure they were incorporated into the curriculum map well enough. From the recent graduates survey, the outcomes that resulted in gaps were (9) Design, (13) Project Management, (16) Communication, (17) Public Policy, (18) Business and Public Administration, (21) Teamwork, (22) Attitudes, and (23) Lifelong/Self-Directed Learning. Outcomes in the map that were not incorporated as thoroughly were also highlighted for additional review. These outcomes included (4) Social Sciences, (10) Sustainability, (19) Project Management, (18) Business and Public Administration, (19) Globalization, and (23) Lifelong/Self-Directed Learning.

Changes were made to the curriculum to incorporate these outcomes more comprehensively. For instance, reflection prompts were created for each of the program learning outcomes to encourage faculty to incorporate reflection into their courses. The reflection exercises are designed to improve lifelong and self-directed learning skills by asking the students to articulate what they know, describe how they know what they know, and explain how the information could be applied in the future. Asking the students to reflect will help them to think more intently about what they have learned and create more meaning for themselves. A significant role in learning is that the students create their own meaning[21] which leads to better retention of the material.

Issues Facing Large Programs

As stated in the introduction, this curriculum transformation process is occurring in a large civil engineering program of almost 1000 students and over 55 faculty. Accordingly, the process has encountered various challenges and opportunities that are illustrative for other programs of similar size.

The breadth of faculty expertise in this department allows it to offer 8 different "technical elective plans," which represent specialization tracks at the junior and senior levels of courses. Consequently, the major tasks of rubric development and curriculum mapping required an order-

of-magnitude increase in work to deal with all possible routes that students may take through the B.S. curriculum. However, this often yielded useful insights among CTT members as they discussed teaching and learning philosophies in the various areas of specialization.

The large number of faculty present often results in a single course being taught by a large group of different faculty in multiple sections in the same semester and/or in different semesters. As courses are re-aligned to the new curriculum map and program learning outcome rubrics, this reality requires extensive cooperation and communication for successful and consistent revisions. Course coordinators given real authority to write common syllabi and regularly review others' sections are essential.

A large student body can often be difficult for department faculty and administration to communicate with. Thus, it was considered very important to include student representation in the CTT to include student input and to communicate to other students the goals and value of the curriculum transformation effort.

Notable Curriculum Changes

As other programs have found, much – but not all – of the BOK2 can be addressed within an existing curriculum with minor changes. The experience at Texas A&M did not find that radical restructuring was necessary. In many cases, the effort simply yielded focused thought by faculty on how to include outcomes by enhancing assignments and assessment in existing courses. However, the expansive nature of the BOK2 did require some concerted effort to show assessable achievement for all outcomes at multiple levels. A few of these efforts are described below.

Mid-Curriculum Professional Development

The curriculum mapping exercise revealed that the existing curriculum could introduce many of the "challenging" BOK2 outcomes (e.g., social science, contemporary issues and historical perspectives, globalization, attitudes, among others) at the sophomore-level in the "Intro to CE" course and have student demonstration of the outcomes at the senior-level in course on "Professional Practice" and "Capstone Design." However, this left a gap in the mid-curriculum where reinforcement should occur. Congruent with this gap was a desire to build high-impact learning practices and reflection on learning into the curriculum. In the midst of the re-design process, the university created "zero credit hour courses" as an instrument for tracking high-impact practices. Thus, a zero credit hour course "Mid-Curriculum Professional Development" is being created that will require completion of a high-impact practice (internship, service learning, undergraduate research, study abroad, or co-curricular leadership). The course must be taken at a designated mid-point in the curriculum (enforced by pre-requisite structures), and is graded on a pass/fail basis. Student deliverables include: (1) a description of the experience using the state licensing board Supplementary Experience Record form typically used for PE applications, (2) a survey for students to provide likert-style evaluation of progress in achieving the BOK2 program

outcomes, and (3) a reflective writing document focusing on the student's choice of outcomes to have students consider what she/he learned in the experience, the importance of this learning, and how this learning is important for the future.

Cooperation Outside the Department

Many of the BOK2's foundational outcomes are necessarily met through university core curriculum classes (a.k.a., "general education requirements" at other institutions). Texas state law and Texas A&M policies combined lead to a curriculum where 50 out of 128 credit hours are taught outside the College of Engineering. In order to achieve the focused performance indicators in the outcome rubrics, civil engineering faculty reached out to multiple departments to influence external courses. In some cases, this has resulted in a slowly developing discussion to be concluded in the future. However, one notable success in this effort is a cooperative effort with the Department of Geography to create an "engineers only" section of its GEOG 201 "Introduction to Human Geography" course, which satisfies university requirements for social/behavioral science and international/cultural diversity. The rubrics for outcomes for social sciences, globalization, and public policy have been used by geography faculty to design course instruments that will be shared with the civil engineering department for assessment. This cooperative work has been so successful that the geography department is adding sections for anticipated enrollment of 750 in the 2015-2016 academic year in service to the entire college of engineering.

Addressing Gaps and Redundancies

One of the initial goals of the curriculum re-design was to eliminate gaps between courses (course B expects its pre-requisite course A to cover a topic, but A does not or there is a time-gap between A and B greater than 1 year) and redundancies (courses A and B both discuss a topic). Two often cited examples were the discussion of shear and moment diagrams in 3 successive courses (redundancies), and the teaching of graphics in the freshman year with no reinforcement before senior capstone design (gaps).

Redundancies were addressed by discussions in the forum of the curriculum re-design process. Simply having faculty in the same room charged with thinking holistically about the curriculum led to specific agreements on exact placement of topics among courses and undoing years of accretion.

Gaps were addressed in a variety of ways. Structural curriculum changes included moving engineering graphics to a new sophomore-level course and creation of a senior level "refresher" course. As in the case of redundancies, discussions between faculty led to small-scale changes in course topics. Perhaps most novel is a significant effort, still ongoing, to identify and develop online resources that students can use for reinforcement and refreshment of difficult topics. A catalog of dozens of pre-existing, publicly available online videos (e.g., Khan Academy) has

been compiled and disseminated to students covering a wide range of topics in calculus, physics, chemistry, statistics, and others, with cross-referencing to specific courses (currently available at http://ceresources.weebly.com/). Departmental faculty are at work on producing similar videos to cover topics at more mid- and upper-levels in the curriculum. Combined with beginning-of-course diagnostics, these resources should help students identify weak points in their understanding (another form of gap) and have ready resources to address them.

In essence, these efforts focused faculty attention on the concept of curricular "efficiency": assuring that credit hours yield uniform benefits throughout the program.

Lessons Learned

The process of implementing the BOK2 as a guiding document for a large civil engineering curriculum will doubtless require continuous evolution and improvement. Nevertheless, the experience so far has yielded lessons which can be shared with other civil engineering programs.

- *The process requires sufficient time.* In the case of Texas A&M's program, two full years have been needed, and there is wide agreement among the participants that all of this time has been necessary to gather data, generate new ideas, deliberate, build confidence, and clear administrative hurdles.
- *The team requires more than just civil engineering departmental faculty.* The "curriculum transformation team" included a pedagogical expert, a civil engineering graduate assistant employed full-time just to work on the effort, and undergraduate and graduate students, in addition to the civil engineering faculty members. Data was gathered through interviews and surveys of graduates and industry stakeholders. Cooperation was required with faculty in other departments on-campus.
- *Following an engineering design process makes sense to faculty.* The tendency of curriculum examination efforts to quickly devolve into course-focused arguments was avoided by starting at the "big picture" level and working down. Data-driven assessment of alternatives and questions kept deliberation moving and focused on productivity rather than "turf protection."
- *Writing rubrics associated with program outcomes is valuable.* The program-level rubrics are now often referred to as "the syllabus for the entire curriculum," which highlights their usefulness for defining how the program defines the BOK2 outcomes and how individual courses contribute to them. Contrary to initial faculty doubts, focus groups of students have reacted very positively to the rubrics regarding them as useful for understanding stages of learning in the program.
- *Creativity and open-mindedness are important.* Baccalaureate engineering degrees will not likely see increasing credit hours in the future. Some faculty entered this process expecting to be asked "to put 10 gallons in a 5 gallon bucket." However, this attitude has been dispelled by identifying novel ways to increase curricular efficiency through a variety of mechanisms.

Conclusion

Incorporating the set of twenty-four program-level BOK2 learning outcomes into a civil engineering curriculum along with a means to assess them is not a trivial task. However, with the assistance of an eighteen member curriculum redesign committee the task was accomplished. Implementation of the program-level outcomes and performance criteria are in process and will be monitored through the upcoming departmental assessment process. The curriculum transformation team will work with individual faculty to incorporate the program-level BOK2 and course-level outcomes into revised course designs. In addition, the curriculum transformation team will continue to meet to define assessments that will be gathered to determine if the program is reflecting both the course-level and program-level learning that is intended.

APPENDIX 1 - Program Learning Outcome Rubrics

Two rubrics out of the full set of 30 are presented here as examples: (5) Materials Science, and (10) Sustainability.

5. Materials science

After graduation, the student will be able to:

Apply knowledge of materials, such as steel, concrete, wood, soil, asphalt, and composites of materials, used in civil engineering construction.

Performance Indicators	4	3	2	1
	Desired level at graduation.	*Minimum acceptable level at graduation.*	*Intermediate level.*	*Level when student enters CVEN (after completing CBK).*
a. **Material Properties**	**Evaluate** and **determine** material systems interactions with aggressive environments.	**Describe** properties at macroscopic and microscopic levels for civil engineering materials such as steel, concrete, wood, soil, and asphalt.	**Identify** materials and material properties relevant to civil engineering construction.	**Minimally articulate** or **explain** material properties at macroscopic or microscopic levels.
b. **Material Performance**	**Evaluate** material performance in various environments and loading conditions.	**Select** materials for an application based on expected performance.	**Quantify** material performance in different applications.	**Recognize** that different materials perform differently.
c. **Material Selection**	**Specify** appropriate materials (or protection systems) for civil engineering designs, considering the presence of aggressive environments.	**Explain** problem-solving processes involving material selection in the context of civil engineering.	**Organize** and **convey** the materials available for civil engineering design.	**Partially list** materials available for civil engineering problems.

10. Sustainability

After graduation, the student will be able to:

Apply the principles of sustainability to the design of civil engineering systems and articulate their importance.

	Performance Indicators	4	3	2	1
		Desired level at graduation.	*Minimum acceptable level at graduation.*	*Intermediate level.*	*Level when student enters CVEN (after completing CBK).*
a.	**Role of Sustainability in Engineering Practice**	**Develop and explain** a list of best practices and a personal program of continued development to improve skills necessary for sustainable practice.	**Describe** the effect of civil engineering designs and decisions on future generations and the natural world. **Identify** past and current examples of sustainable practice.	**State** the presence of sustainability in the ASCE Code of Ethics. **List** commonly used sustainability recognition programs* in engineering practice.	**Define** sustainability.
b.	**Incorporation of Sustainability into Design**	**Describe** how any specific design decision can incorporate principles of sustainability. **Critique** a commonly used sustainability recognition program* for its strengths and weaknesses in encouraging principles of sustainability in design.	**Describe** the process of designing a civil engineering project to meet standards of a commonly used sustainability recognition program*.	**List** a few examples of design elements and practice included in commonly used sustainability recognition programs*.	**Define** sustainability.

* As of 3/2014, commonly used sustainability recognition programs in civil engineering practice are: (1) U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) (http://www.usgbc.org), and (2) Institute for Sustainable Infrastructure's Envision (http://www.sustainableinfrastructure.org). This list could grow or change in future years.

APPENDIX 2 - Curriculum Map

The full program curriculum map would require several pages to reproduce. Thus, an excerpt is given here to provide a sample of the curriculum mapping process. This excerpt primarily shows lower- and mid-level courses, and thus most courses are indicated at the “introduce” (I) and “reinforce” (R) levels for program learning outcomes, with a few “demonstrate” (D) entries. This excerpt also shows only program learning outcomes 1-8.

			Course	1	2	3	4	5	6	7	8
Gateway Courses	CVEN 426 (W)	3	Civil Eng. Professional Practice			R					D
Taken by ALL Civil Engineers	CVEN 3xx (W)	1	Junior-level Soft Skills Seminar				R				R
	CVEN 345	3	Theory of Structures						D		R
	CVEN 322	3	Civil Engineering Systems	D			—				R
	CVEN 363	3	Engineering Mechanics: Dynamics						D	—	R
Foundation Courses	CVEN 311	3	Fluid Dynamics	D	R				—		R
	CVEN 300 (L)	1	Materials Eng. for Civil Engineers		R			I/R	—	R	
	CVEN 305	3	Mechanics of Materials	R	R			R	R		R
	CVEN 303 (L)	1	Civil Engineering Measurement							R	—
	CVEN 302 (L)	1	Computer App. in Eng. and Const.	—							—
	CVEN 221	3	Engineering Mechanics: Statics	R	R				—		
	CVEN 250	2	Introduction to Graphics in CE Design								R
	CVEN 207	1	Introduction to the CE Profession			—	—				
Taken by ALL Civil Engineers	CVEN 469 Seminar (L)	1	Seminar	R	R			R	R	D	R
Taken to CEN Requirement	CEEN 215*	3	Principles of Electrical Engineering	R	R						
	CHEN ___*	3	Thermodynamics for Chemical Engineers								
	BAEN 320*	3	Thermodynamics for Bio and Ag. Engineers	R	R						
	MEEN 365*	3	Thermodynamics	R	R						
	ENGR 402 *(W)	3	Ethics and Engineering			D					
Common Body of Knowledge	STAT 211*	3	Principles of Statistics I	—							
	ENGL 104*	3	Composition and Rhetoric								
	CHEM 107* (L)	4	General Chemistry for Engineers		—			—		—	
	PHYS 208* (L)	4	Electricity and Magnetism	R	—				—	—	
	PHYS 250* (L)	4	Mechanics	R	—				—	—	
	MATH 308*	3	Differential Equations	—							R
	MATH 251*	3	Calculus III	—							R
	MATH 152*	4	Calculus II	—							—
	MATH 151*	4	Calculus I	—							—
	ENGR 112*	2	Foundations of Engineering II			—					—
	ENGR 111*	2	Foundations of Engineering I			—					—
University Core	ICD*	3	International and Cultural Diversity								
	COMM	3	Technical Communication								
	SBS*	3	Social and Behavioral Sciences				—				
	CA*	3	Creative Arts (formerly VPA)			—					
	HIS 1*	3	American History			—					
	POLS*	3	Federal (200) and State/local (201) Government								
	Course Number	Credit Hours	Program Learning Outcome	Outcome 1: Mathematics	Outcome 2: Natural sciences	Outcome 3: Humanities	Outcome 4: Social sciences	Outcome 5: Mechanics science	Outcome 6: Mechanics	Outcome 7: Laboratory and Field Work	Outcome 8: Problem recognition and solving

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