



Bill and Ted's Excellent Adventure: Lessons Learned from Eight Years Instruction on the CEBOOK

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Abstract

This paper describes the development, instruction and assessment of an upper-division, undergraduate, 2-credit hour, required course designed around outcomes from the American Society of Civil Engineers (ASCE) *Body of Knowledge for Civil Engineers* (CEBOK). The course is “CE 4200, Professional Engineering Practice Issues,” sequenced to be taken during the penultimate semester of a student’s program of study in civil engineering at Texas Tech University. The course features six CEBOK outcomes: professional attitudes, professional responsibilities, teamwork and leadership, project management, critical thinking and problem solving, and social sciences. These outcomes were selected with consideration to Texas Tech University’s 129-hour program in civil engineering, focusing on topics either *not* represented, *indirectly* represented, or otherwise *underrepresented* in the curriculum. Course development has been a work in progress, with academic influences and curriculum emphases affecting instructional design and learning activities. The lessons learned illustrate how the CE 4200 course can be used to shape and polish the civil engineering curriculum relative to satisfying ABET program accreditation requirements, introducing students to less-familiar topics that are essential to professional success, placing the students’ education and learning within the framework of professional practice, and otherwise helping prepare civil engineering students for their professional careers.

Introduction

Origins of the CE 4200 Course

This paper describes experiences, assessments, and observations in curriculum design and instruction that formally implemented the ASCE *Civil Engineering Body of Knowledge* (CEBOK) [1, 2, 3] within the Civil Engineering (CE) undergraduate program of study at Texas Tech University. This was done through CE 4200, “Professional Engineering Practice Issues,” a required 2-credit hour, upper-division lecture course that the CE Department introduced in the 2010-2011 undergraduate catalog [4].

While ASCE originally published the CEBOK in 2004 [1] and the second edition was published in 2008 [2], CE 4200 was first taught in the Fall 2012 semester. One section of the course was taught every long semester through Spring 2016, and two sections have been taught since Fall 2016, typically one traditional (face-to-face instructor present) and one distance section. Enrollments have averaged 58 students per semester the last five years (Figure 1).

Gender and ethnicity enrollment data are not available for courses or programs at Texas Tech University and such data were not obtained specific to the CE 4200 course; however, gender and ethnicity data are available by college. Undergraduate enrollment in engineering by gender (3-year average, 2017-2019) shows 82.4% male, 17.4% female, and 0.2% unknown.

Combined undergraduate and graduate enrollment in engineering by ethnicity (3-year average, 2017-2019) shows 4.0% Asian, 6.0% Black/African-American, 24.1% Hispanic/LatinX, 44.1% White/Caucasian, 2.8% other ethnicity, and 19.0% Non-Resident International. These data are *generally* representative of the diversity of the CE 4200 student population.

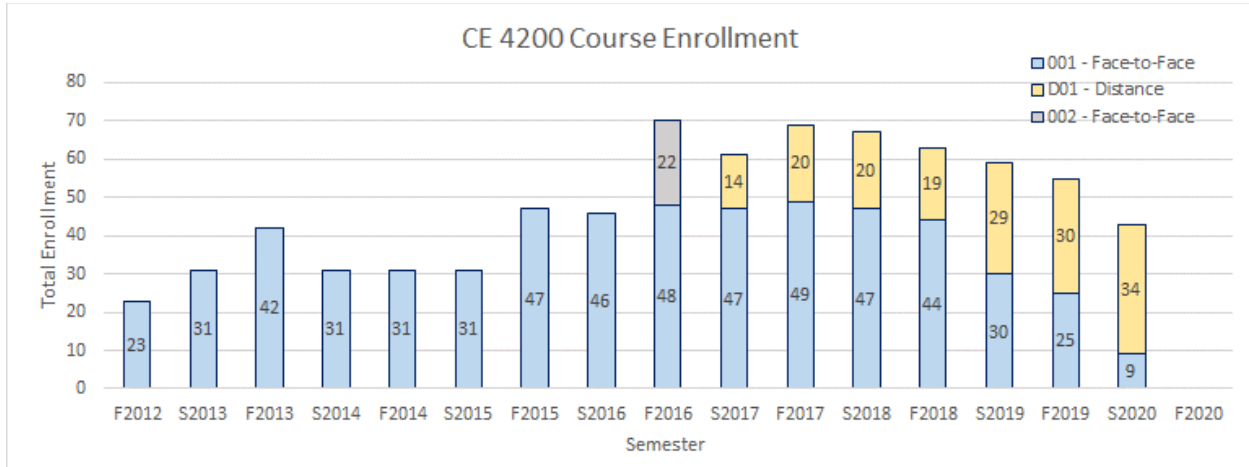


Figure 1. Student Enrollment, CE 4200, Professional Engineering Practice Issues

The one prerequisite for the course is that students must be “within two long semesters of graduation,” but the course is specifically intended for a student’s penultimate semester. From its inception, the course syllabus has identified the CEBOK as a *required* text, starting with the second edition (BOK2E) and later adding the third edition (BOK3E).

ABET Accreditation and FE Exam Influences

Two primary factors contributed to the creation of CE 4200. Chief among these was an intentional effort by Texas Tech University CE faculty to introduce selected CEBOK outcomes within the CE curriculum, consistent with ABET requirements for accreditation of our program. In particular, the discussion of curriculum under ABET’s discipline-specific “Program Criteria” for Civil Engineering Programs makes direct reference to ASCE and requires that graduates must be able to “...explain basic concepts in project management, business, public policy, and leadership... and explain the importance of professional licensure” [5]. Further, ABET’s (then-current) General Criteria for Baccalaureate Level Programs, Criterion 3 required the program to have documented student outcomes – (a) through (k) – that prepared graduates to attain the program educational objectives [6]. Prior to CE 4200, the “professional” outcomes were covered as part of instruction within other upper-division design courses, most notably the senior capstone design course. But that approach interrupted systematic presentation of content and did not facilitate clear assessment of learning for these outcomes.

The second factor that influenced the creation and instructional design of CE 4200 was a time period when our CE students’ performance on the NCEES Fundamentals of Engineering (FE) Exam was inexplicably low for certain topics. CE students were responsible for taking a 1-hour FE review course, but NCEES topic-level data [7] at the time indicated that Texas Tech students were performing surprisingly below students at peer universities on certain subjects for

which they had received instruction and were expected to know the content. CE 4200 offered an opportunity to provide focused re-learning for these particular topics. Further, CE 4200 provided a natural way to formally introduce the FE Exam to our students at an appropriate time in their program, to explain the CE Department's philosophy on engineering licensure, and to offer recommended guidance on preparing for and taking the FE Exam.

Not surprisingly, the purpose of CE 4200 was to integrate technical and social issues to help prepare senior CE students to enter professional practice. Course content focused on the importance of licensure, an introduction to the FE Exam, and also awareness of leadership, management, public policy, and business issues in civil engineering. The course also provided technical instruction for selected general and CE discipline-specific topics from the FE Exam.

Background

Early CE 4200 Course Design (2012-2018)

As originally created, CE 4200 devoted about half of its instructional lectures to selected CEBOOK outcomes, and half to FE review (technical) topics. This division can be clearly seen by reviewing a typical semester schedule, Figure 2. CEBOOK outcome lectures included an introduction to the CEBOOK, as well as lectures on engineering professionalism, engineering licensure, the FE Exam, successfully starting one's engineering career, qualifications-based selection, the business of civil engineering, civil engineering in the public sector, engineering leadership, and other topics of interest.

For each of the four FE topic reviews, the instruction consisted of a series of prepared lectures (captioned video by a subject matter expert), a detailed homework set (formative), and a proctored diagnostic quiz (assessment of content mastery). The course also included a 3.0-hour "half-length" version of the FE Exam at the beginning of the semester – the "Mock FE" Exam – to serve as a diagnostic assessment of student preparedness for taking the real FE Exam later in their program of study.

Present CE 4200 Course Design (2019-2020)

The instructional design for CE 4200 has been continuously evaluated, updated and refined in response to assessment data, student comments, instructor observations, and various curriculum influences. However, a *major* course re-design occurred in Fall 2018, which was to remove the four FE topic reviews and to focus instruction on CEBOOK outcomes.

This change occurred due to two significant factors associated with the NCEES FE Exam. First, in Spring 2014, NCEES changed their delivery of the FE Exam from the April and October administrations in pencil/paper format, to year-round delivery as a computer-based test [8]. This change, among other things, relaxed our students' preparation schedule for the FE Exam. Simultaneously – noting that Texas Tech University does not require its engineering students take the FE Exam – we observed a significant drop in the percentage of CE exam takers from 98 percent (1997 to 2011) to about 80 percent (2015 to 2019).

Fall 2013 Course Schedule
CE 4200-001: Professional Engineering Practice Issues (2:2:0)

Mtg No.	Date	Day	Topic	Instructor	Assignment	Due
1	26-Aug	M	Course Introduction/ ASCE Body of Knowledge (1)	Lawson	Assign 1 (40 pts)	4-Sep
2	28-Aug	W	Professionalism	Lawson	Assign 2 (40 pts)	9-Sep
	2-Sep	M	University Holiday: LABOR DAY			
3	4-Sep	W	Engineering Licensure	Lawson	Assign 3 (40 pts)	11-Sep
4	9-Sep	M	The NCEES Fundamentals of Engineering Exam	Mock FE Exam	Lawson	Quiz 4 (20 pts)
5	11-Sep	W	ASCE Body of Knowledge (2)	Mock FE Exam	Lawson	Assign 5 (40 pts)
6	16-Sep	M	FE-Surveying Review	Mock FE Exam	Online	HW 6 (35 pts)
7	18-Sep	W	FE-Surveying Review	Mock FE Exam	Online	Mock FE (300 pts)
8	23-Sep	M	FE-Surveying Review	Online		
9	25-Sep	W	FE-Surveying Review	Lawson	Quiz 7 (35 pts)	25-Sep
10	30-Sep	M	Qualifications Based Selection	Lawson	Assign 8 (40 pts)	7-Oct
11	2-Oct	W	FE-Materials Review	Online	HW 9 (35 pts)	9-Oct
12	7-Oct	M	FE-Materials Review	Online		
13	9-Oct	W	FE-Materials Review	Online		
14	14-Oct	M	FE-Materials Review	Lawson	Quiz 10 (35 pts)	14-Oct
15	16-Oct	W	Civil Engineering Business	Guest - TBD	Assign 11 (30 pts)	23-Oct
16	21-Oct	M	FE- Statistics Review	Online	HW 12 (35 pts)	28-Oct
17	23-Oct	W	FE- Statistics Review	Online		
18	28-Oct	M	FE- Statistics Review	Online		
19	30-Oct	W	FE- Statistics Review	Lawson	Quiz 13 (35 pts)	30-Oct
20	4-Nov	M	Civil Engineering Public Policy	Guest - TBD	Assign 14 (30 pts)	11-Nov
21	6-Nov	W	FE- Structural Analysis Review	Online	HW 15 (35 pts)	13-Nov
22	11-Nov	M	FE- Structural Analysis Review	Online		
23	13-Nov	W	FE- Structural Analysis Review	Online		
24	18-Nov	M	FE- Structural Analysis Review	Lawson	Quiz 16 (35 pts)	18-Nov
25	20-Nov	W	Civil Engineering Leadership	Guest - TBD	Assign 17 (40 pts)	2-Dec
26	25-Nov	M	Open Topic	Lawson		
	27-Nov	W	Student Holiday: THANKSGIVING			
27	2-Dec	M	Open Topic	Lawson		
28	4-Dec	W	Course Evaluation, Semester Review	Lawson		4-Dec
	5-Dec	TH	Individual study day			
29	6-Dec	F	Comprehensive Final Exam: 7:30am-10:00am	Lawson	FINAL (300 pts)	6-Dec

Figure 2. Example of “Original” CE 4200 Course Schedule, Fall 2013

Anecdotally the reason for the drop in FE exam takers was because many of our CE students were entering the workforce in construction and other industries where licensure is not strongly emphasized. Collectively these trends did not align well with the strict sequencing

reflected in requiring students to enroll in CE 4200 (penultimate semester) and the 1-hr FE review course (final semester). So, in early 2018 the CE faculty voted to sunset the 1-hr FE review course as a required course in the CE curriculum.

Removing the FE review topics from the CE 4200 course represented a shift from what had been viewed as heavy externally-guided (required) FE review to more self-guided (student-motivated) preparation for the FE Exam. This effectively doubled the number of lectures available for instruction on CEBOK outcomes, and about this same time ASCE issued its third edition of the *Body of Knowledge* [3]. Using BOK3E as the foundational text, instructional design for CE 4200 was updated to intentionally focus on six CEBOK outcomes selected because they were either *not* represented, *underrepresented*, or only *indirectly* represented in the CE curriculum at Texas Tech University.

Figure 3 shows the revised (updated, current) CE 4200 course schedule. In addition to identifying each BOK3E outcome, this schedule identifies the individual elements of instruction associated with each outcome. The CEBOK outcomes (referenced by BOK3E name and number) include the following:

- [Outcome 3] SOCIAL SCIENCES... concepts and principles relevant to civil engineering
- [Outcome 8] CRITICAL THINKING AND PROBLEM SOLVING... of a complex problem, question or issue relevant to civil engineering
- [Outcome 9] PROJECT MANAGEMENT... concepts and principles for complex civil engineering projects
- [Outcome 17] TEAMWORK AND LEADERSHIP... concepts and principles, including diversity and inclusion, in the solution of civil engineering problems
- [Outcome 19] PROFESSIONAL ATTITUDES... including creativity, curiosity, flexibility, and dependability in the practice of civil engineering
- [Outcome 20] PROFESSIONAL RESPONSIBILITIES... relevant to the practice of civil engineering, including safety, legal issues, licensure, credentialing, and innovation

CE 4200 course learning objectives now focus on BOK3E “levels of achievement” for each outcome in both the cognitive and affective domains, as applicable. As has been noted, CE 4200 is simultaneously offered via traditional (face-to-face, instructor present) classroom instruction and by distance learning (video/ web-based) modalities. The core of the course is expressed through its learning exercises, of which 60 percent are analysis/ reflection (written) assignments, 20 percent consists of the half-length Mock FE Exam, and 20 percent is a take-home final exam over professional and ethics aspects of the Texas Engineering Practice Act and Rules [9]. In addition to these required assignments, the course design allows for several bonus learning activities, both to earn extra credit and/or to replace missed assignments.

Assessment of Course Objectives and Outcomes

How successful has CE 4200 been in achieving its intended learning objectives and underlying student learning outcomes? Two classes of assessment data are available, “direct”

and “indirect.” Direct measures of student achievement include grades on individual assignments and overall student performance in the course. These are briefly discussed.

Fall 2019 Course Schedule							
CE 4200-001/D01: Professional Engineering Practice Issues							
Mtg No.	Date	Day	Topic	BOK3E	Instructor	Assignment	Due
1	26-Aug	M	ASCE Body of Knowledge/ Course Introduction		Lawson	Assign 1 (100 pts)	4-Sep
2	28-Aug	W	Trust and Trustworthiness in Engr-Client Relations	19	Lawson	Bonus 1 (25 pts)	4-Sep
	2-Sep	M	Labor Day Holiday				
3	4-Sep	W	Attitudes Beneficial to Civil Engineering	19	Lawson		
4	9-Sep	M	Early Career Guidance	19	Lawson	Assign 2 (100 pts)	16-Sep
5	11-Sep	W	Engineering Licensure	20	Lawson	Assign 3 (100 pts)	23-Sep
6	16-Sep	M	NCEES Fundamentals of Engineering (FE) Exam	20	Lawson		
7	18-Sep	W	Engineering Job Fair: Lubbock Civic Center	20	ENG OP CTR		
8	23-Sep	M	FE Exam Performance	MFE 20	Lawson	Mock FE (200 pts)	09/23 10/04
9	25-Sep	W	FE Exam Preparation	MFE 20	Lawson		
10	30-Sep	M	Qualifications Based Selection	MFE 20	Lawson	Bonus 2 (25 pts)	7-Oct
11	2-Oct	W	No lecture (Mock FE)	MFE 20			
12	7-Oct	M	Leadership in Civil Engineering	17	Lawson	Assign 4 (100 pts)	16-Oct
13	9-Oct	W	Diversity & Inclusion	17	Lawson		
14	14-Oct	M	Ted Talks: Leadership Excellence	17	Online	Bonus 3 (25 pts)	21-Oct
15	16-Oct	W	Project Management: Introduction	9	Lawson		
16	21-Oct	M	Guest Lecture: REAL Project Management	9	TBD/Guest	Bonus 4 (25 pts)	28-Oct
17	23-Oct	W	Project Management: Traditional Topics	9	Online	Quiz 1 (50 pts)	30-Oct
18	28-Oct	M	Guest Lecture: Civil Engineering Business	9	TBD/Guest		
19	30-Oct	W	Project Management: Lessons Learned	9	Lawson		
20	4-Nov	M	Engineering Judgment	8	Lawson	Assign 5 (100 pts)	13-Nov
21	6-Nov	W	Why Critical Thinking?	8	Lawson		
22	11-Nov	M	Critical Thinking - Selected Readings	8	Online	Bonus 5 (25 pts)	18-Nov
23	13-Nov	W	Critical Thinking Case Study: Gold King Mine	8	Lawson		
24	18-Nov	M	Engineering Failures in Critical Thinking	8	Online	Bonus 6 (25 pts)	25-Nov
25	20-Nov	W	Social Science and Civil Engineering	3	Lawson		
26	25-Nov	M	Guest Lecture: Public Policy in Civil Engineering	3	TBD/Guest		
	27-Nov	W	Thanksgiving Holiday				
27	2-Dec	M	Professionalism	3	Lawson	Quiz 2 (50 pts)	4-Dec
28	4-Dec	W	Course Evaluation, Semester Review		Lawson		
	5-Dec	TR	Individual study day				
29	6-Dec	FRI	Final Exam: 1:30pm-4:00pm		Lawson	FINAL (200 pts)	6-Dec

Figure 3. CE 4200 Course Schedule, Updated and Current, Fall 2019

In addition to the direct measures, four sets of “indirect” assessment data are presented, and these are student evaluation of the course and instructor, faculty evaluation relative to ABET General Criterion 3 student outcomes, student evaluation relative to ABET’s discipline-specific Program Criteria, and detailed student assessment of the course design.

Direct Measures of Student Achievement

Direct measures offer insight on the extent to which students actually achieve the learning goals of the course. And most students do perform well in CE 4200, which is not unexpected for mature undergraduate students in an upper-division course. From inception through 16 semesters of instruction, the percentage of students who “passed” the course with a grade of “C” or better varied from 90% to 100%, average 97%. The overall course grade breakdown per semester was “A”: 19% to 78%, average 47%; “B”: 15% to 66%, average 41%; “C”: 0% to 16%, average 10%; “D”: 0% to 7%, average 1%; and “F”: 0% to 7%, average 1%.

As regards assignments, Figure 3 identifies that learning exercises for CE 4200 include five writing assignments, two quizzes, six bonus assignments, the Mock FE Exam, and the final exam. Three high-level observations are appropriate. First, the assignments are intended to provide opportunity for students to demonstrate facility with the content, usually by reading and reflection. This is strikingly different from the traditional problem sets and project-based learning exercises customary in undergraduate engineering instruction. Second, by virtue of the BOK3E’s presentation of cognitive and affective domain levels of achievement, students are continuously reminded to view their performance over the long term, relative to career success. It is not hard to make this connection. Third, the assignments are designed more to spark awareness, interest and passion for the topic than promote accumulation of deep knowledge. The quality of student submittals follows the expected range from “below average” to “excellent,” but it is gratifying to see students actively embrace one or more of the learning opportunities.

This performance summary indicates that most students achieve the learning goals and objectives of the CE 4200 course. In addition to the direct measures, four indirect measures provide further insight into student learning.

Student Evaluation of Course and Instructor

Students enrolled in formal courses at Texas Tech University complete an evaluation of the course and instructor each semester. Two survey questions are especially pertinent: (1) instructor effectiveness – *i.e.*, “overall, the instructor was an effective teacher,” and (2) valuable learning experience – *i.e.*, “overall, this course was a valuable learning experience.” Figure 4 presents the results from these Likert-type surveys for CE 4200. The survey response rate for traditional (face-to-face, instructor present) instruction ranged from 56 to 97, average 81 percent, and the survey response rate for distance instruction ranged from 43 to 79, average 63 percent.

Focusing on the traditional delivery modality, ‘instructor effectiveness’ ratings varied from about 4.0/5 to 5.0/5, average 4.4/5. In contrast, the ‘course value’ rating began at a modest 3.5/5, but within three semesters had stabilized at about 4.5/5 and remained consistently at this level until F2016. As noted in the description of course design, about that time CE curriculum

changes were under way relative to the FE Exam review course, and the distance learning modality was added to CE 4200 (S2016). These and other factors resulted in the ‘course value’ rating lapsing into a slump (3.5/5) which extended through F2018. Within a year the curriculum issues were resolved, and a significant course redesign for CE 4200 was implemented and “dialed in” (S2019). The present status is that the CE 4200 ‘course value’ rating is again achieving about 4.5/5 for traditional instruction.

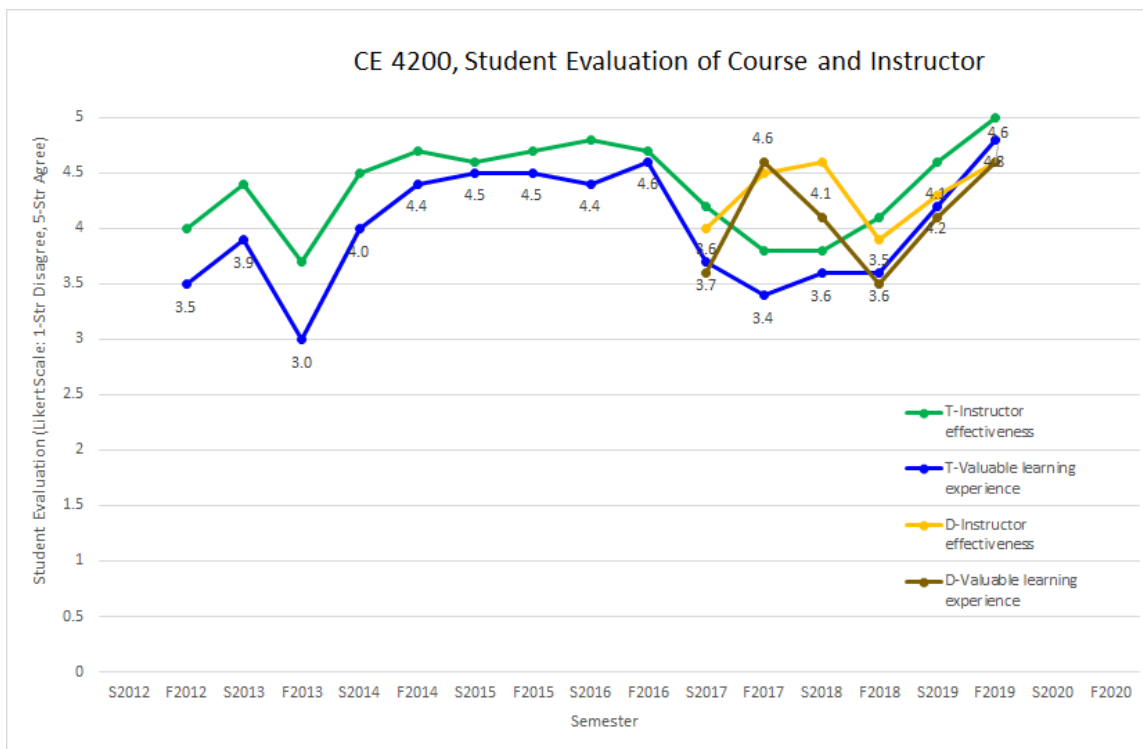


Figure 4. Student Evaluation of Course and Instructor, CE 4200, Traditional and Distance Modalities, F2012-F2019

Student ratings for the distance learning modality of CE 4200 have been more erratic, and generally a little lower than for traditional instruction. The ‘instructor effectiveness’ rating varied from about 3.9/5 to 4.6/5, average 4.3/5. In contrast, the ‘course value’ rating for the distance course varied from 3.5/5 to 4.6/5, average 4.1/5, with the most recent year (2019) showing a stabilized average score of 4.4/5.

The identified ups and downs in the student ratings are consistent with the instructors’ own observations. The responses reflect the various challenges associated with creating a new course, and then substantially revising its design, as well as preparing new lectures, identifying the right assignments to facilitate learning, and establishing reasonable and valid assessment measures.

Faculty Evaluation of ABET General Criterion 3, Student Outcomes

As part of the CE Department’s effort toward continuous program improvement, the Instructor of Record (IOR) annually evaluates CE 4200 relative to student achievement of course

learning objectives expressed by ABET’s General Criterion 3, “Student Outcomes” [6]. This evaluation began with the “a through k” student learning outcomes that were used from the origin of the course (Fall 2012) through Spring 2019, and recently transitioned to the current “1 through 7” student learning outcomes that took effect in Fall 2019 [10]. Table 1 identifies the General Criterion 3 Student Outcomes as they have been applied to the CE 4200 course, with the former “a through k” outcomes mapped to the current “1-7” outcomes. Outcomes which are “shaded” in the table do not feature significantly in the CE 4200 instructional design.

Table 1. Identification of Criterion 3, “General Program Outcomes” for CE 4200 Course

Criterion 3 Outcome (2012-2019)	Learning Objectives Engaged	Effective Course Emphasis	Criterion 3 Outcome (2019-2020)	Learning Objectives Engaged	Effective Course Emphasis
(a) an ability to apply knowledge of mathematics, science, and engineering	2/4	5/5	(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (a, e)	0/3	0/5
(e) an ability to identify, formulate, and solve engineering problems	2/4	5/5			
(c) an ability to design a system, component, or process to meet desired needs	0/4	0/5	(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (c, h)	2/3	3.5/5
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context	0/4	0/5			
(g) an ability to communicate effectively	0/4	0/5	(3) an ability to communicate effectively with a range of audiences (g)	0/3	0/5
(f) an understanding of professional ethical responsibility	2/4	5/5	(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (f, j)	3/3	4/5
(j) a knowledge of contemporary issues	0/4	0/5			
(d) an ability to function on multi-disciplinary teams	0/4	0/5	(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (d)	0/3	0/5
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	0/4	0/5	(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (b)	1/3	3/5
(i) a recognition of the need for, and an ability to engage in life-long learning	2/4	5/5	(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies (i, k)	2/3	4/5
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	2/4	3/5			

CE 4200 was designed to engage five of the General Criterion 3 “a through k” student learning outcomes, and within these outcomes the emphasis of instruction via course learning objectives also varied. Thus, the potential contribution of CE 4200 relative to ABET General Criterion 3 student outcomes was weighted based not only on student achievement of course objectives but also the extent to which the student learning outcomes are emphasized in the course design. This approach is reflected in the “effective course emphasis” column.

Figure 5 charts the IOR’s assessment of the extent to which CE 4200 achieved the ABET General Criterion 3 student outcomes by academic year, from 2012 through 2019. While changes and adjustments to instructional design are captured, data are available only for the ABET “a through k” student learning outcomes, as the current “1 through 7” student learning outcomes have not yet been assessed. The dashed line above each set of histogram bars identifies the criterion-specific standard associated with each student outcome.

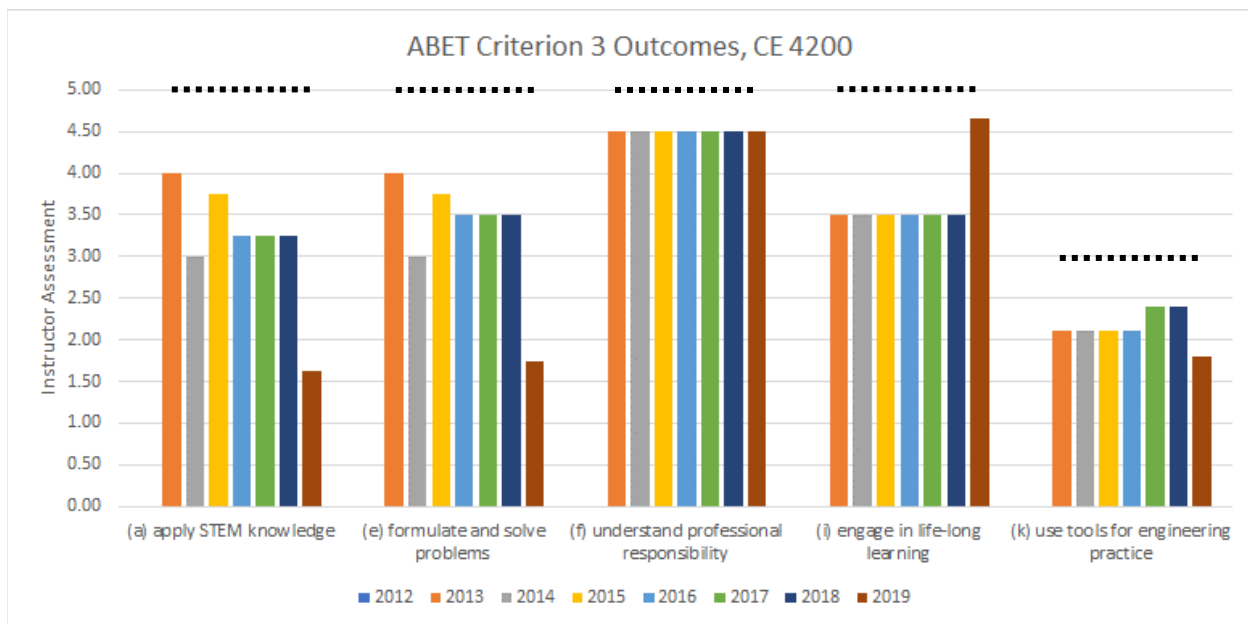


Figure 5. Achievement of ABET General Criterion 3 Student Outcomes in CE 4200, AY2012-AY2019

Figure 5 identifies the IOR’s perspective that CE 4200 has consistently helped students understand their professional responsibility – Outcome 3(f). However, the FE topic reviews per the original course design – Outcomes 3(a) and 3(e) – achieved only mixed effectiveness. Further, CE 4200 has been only marginally successful in promoting lifelong learning per Outcome 3(i). Fostering student ability to use the techniques, skills, and modern engineering tools necessary for engineering practice – Outcome 3(k) – was identified as only a limited focus of the course, and CE 4200 achieved correspondingly limited success.

Turning to the current (new) ABET General Criterion 3 student outcomes (1) through (7) per Table 1 [10], the present instructional design for CE 4200 will be most strongly positioned to help students develop “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of

engineering solutions in global, economic, environmental, and societal contexts” [Outcome 3(4)] and the “ability to acquire and apply new knowledge as needed, using appropriate learning strategies” [Outcome 3(7)]. To a lesser extent CE 4200 should help students “apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors” [Outcome 3(2)] and “develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions” [Outcome 3(6)].

Student Evaluation of ABET Discipline-Specific Program Criteria

The discussion of curriculum under ABET’s discipline-specific “Program Criteria” requires that graduates must be able to “...explain basic concepts in project management, business, public policy, and leadership... and explain the importance of professional licensure” [5]. Graduating seniors provide their assessment on achievement of the discipline-specific program criteria each semester in response to a question on the CE Department Chair’s “Senior Exit Survey and Questionnaire.” Figure 6 presents the results, with the number of respondents varying from 22 to 64, average 42 per semester, noting that three semesters of data are missing.

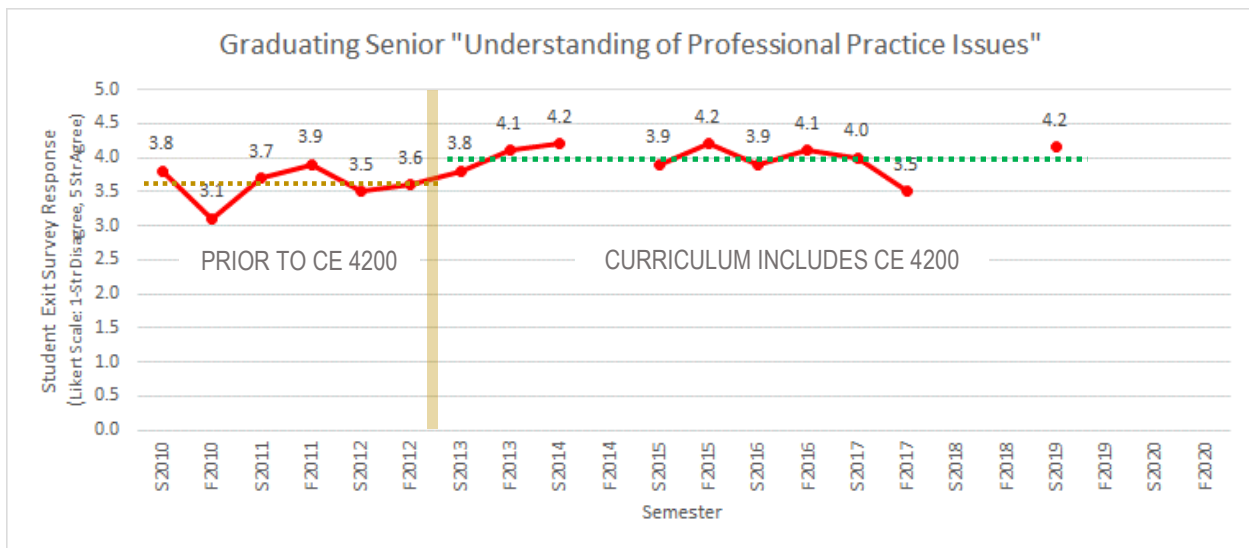


Figure 6. Student Evaluation of Achievement of ABET Discipline-Specific Program Criteria

The language of the actual survey item is unwieldy, namely, “Understanding of professional practice issues such as: procurement of work, bidding versus quality-based selection processes, how the design professionals and the construction professions interact to construct a project, the importance of professional licensure and continuing education, and/or other professional practice issues” – and the question has since been revised. However, interpretation of the meaning is clear. Prior to Spring 2013 *before* our graduating seniors took CE 4200, the average response to this question was 3.6/5. But since Spring 2013, the data show an average response of 4.0/5, with the before/after difference (improvement) being statistically significant at the 95% confidence level.

Detailed Student Assessment of CE 4200 Course

As noted in the discussion of Figure 4, student evaluations since the course re-design (S2019, F2019) suggest students find CE 4200 a “valuable learning experience.” To explore this finding in more detail, all students were invited to complete a detailed, comprehensive survey wherein they answered 43 questions with Likert-type responses [5-point scale: anchors 1-strongly disagree/ 5-strongly agree] about each aspect of course including lectures and assignments. The survey also included three short answer/ open-ended questions about course design. Survey participation was incentivized by offering limited bonus credit, and the survey response rates (combined traditional and distance sections of the course, undifferentiated) were 86 percent (S2019) and 80 percent (F2019). Table 2 provides summary-level average results.

Table 2. Student Assessment of CE 4200 Course Design, Instruction and Assessment, by Topic, S2019-F2019

CE 4200 Instructional Topic	Min	Max	Average
ASCE Body of Knowledge Overview	3.98	4.55	4.31
Attitudes Beneficial to Civil Engineering	4.25	4.50	4.35
Engineering Licensure	4.09	4.77	4.38
Leadership in Civil Engineering	3.96	4.24	4.11
Project Management	3.59	4.52	4.10
Critical Thinking	3.90	4.33	4.15
Social Science	3.70	4.30	4.07
Overall Course Assessment	4.20	4.79	4.49

The lower ratings tended to coincide with non-interactive instruction such as assigned readings and stylized instructional videos, or non-interactive assessments such as online proctored quizzes. Higher ratings often accompanied interesting-yet-challenging written assignments, guest lectures, and strong practice-oriented interactive lectures.

Preliminary analysis of student comments consisted of qualitative summarization, categorization, and ranking of open-ended responses. The findings suggest that at a high level, the aspect of the course students *liked best* was how the instructor delivered the content, what they *liked least* were technological glitches such as malfunctions associated with distance instruction or online quiz proctoring, and the *one thing* they would change to improve the course was... “nothing.”

Mapping BOK3E Outcomes onto the CE Curriculum

The “CEBOK vs. CE Degree Program” Assignment

This paper focuses on implementation of the CEBOK into the CE curriculum at Texas Tech University, and in particular the course re-design that emphasized BOK3E outcomes. It is

therefore appropriate to address this fundamental aspect of course instruction. The detailed student assessment survey included five questions specifically about the CEBOK, identified in Table 3.

Table 3. Student Assessment of CEBOK Instruction in CE 4200, S2019-F2019

Student Assessment of CEBOK Instruction	S2019 Mean	F2019 Mean
I know why the BOK is used in this course.	4.50	4.52
The BOK vs CE Degree Program assignment helped me learn about my degree program.	4.20	4.55
The BOK vs CE Degree Program assignment was beneficial.	4.14	4.48
The BOK topics highlighted (discussed) in this course are important to my career as a Civil Engineer.	4.25	4.41
My overall assessment of the ASCE BOK document is favorable.	4.10	3.98
Overall BOK Assessment	4.24	4.39

The CEBOK assignment mentioned in Table 3 was introduced to help students comprehend – in both breadth and detail – the relationship between civil engineering skills/outcomes identified in the BOK3E and the program of study represented in the undergraduate CE curriculum at Texas Tech University. This understanding was accomplished by providing students with is a 1-page form entitled “Compare CE Degree Program vs. ASCE Body of Knowledge Outcomes.” This form identified all courses in the undergraduate civil engineering program – consisting of 48 courses totaling 129 credit hours (rows) and all 21 outcomes in the BOK3E (columns). Refer to Figure 7.

Students were asked to use this form two times. First, they performed a *comprehensive assessment* wherein they identified all BOK3E outcomes that they thought were associated with each course in the curriculum. This step can yield multiple outcomes per course. Second, the students repeated the analysis, but this time they identified the *primary* BOK3E outcome associated with each course in the curriculum (only one outcome). The IOR also performed this same exercise.

Table 4 presents a summary of responses from S2019 and F2019 consisting of the raw mean and standard deviation for both the comprehensive (n = 99) and primary student assessments (n=96). The IOR perspective is also provided for comparison. The data are sorted in descending order based on student assessment of primary outcomes (Column 6 – *i.e.*, assigning one BOK3E outcome per course). A helpful way to interpret Table 4 is to think of the values in Columns 3, 5, 6 and 8 as being the number of undergraduate courses associated with each identified BOK3E outcome (row). For example, focusing on Outcome 2 “Natural Sciences”, senior CE students feel that 14.6 undergraduate courses *provide instruction* in natural sciences, whereas the IOR thinks only 6 courses do. In contrast, senior CE students think that 5.3 courses are *primarily devoted* to natural sciences, whereas the IOR thinks 4 courses are. Outcomes which are shaded are currently included in CE 4200 instruction.

INSRUCTOR- COMPREHENSIVE
COMPARE CE DEGREE PROGRAM
VS.
ASCE BODY OF KNOWLEGE OUTCOMES

Semester	Course Number	Credit Hours	Course Description	Mathematics	Natural Sciences	Social Sciences	Humanities	Materials Science	Engineering Mechanics	Experimental Methods and Data Analysis	Critical Thinking & Problem Solving	Project Management	Engineering Economics	Risk & Uncertainty	Breadth in Civil Engineering Areas	Design	Technical Depth	Sustainability	Communication	Teamwork & Leadership	Lifelong Learning	Professional Attitudes	Professional Responsibilities	Ethical Responsibilities	TOTALS
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
FRESHMAN (FALL)	Math 1451	4	Calculus I with Applications	1							1														2
	Chem 1307	3	Principles of Chemistry I		1																				1
	Chem 1107	1	Experimental Principles of Chemistry I		1					1															2
	EGR 1207	2	Engineering Graphics: Software B													1			1						2
	Hist 2300	3	History of the United States to 1877				1																		1
	Engl 1301	3	Essentials of College Rhetoric				1												1						2
CE 1130	1	Civil Engineering Seminar I												1										1	
FRESHMAN (SPRING)	Math 1452	4	Calculus II with Applications	1						1															2
	Chem 1308	3	Principles of Chemistry II		1			1																	2
	Chem 1108	1	Experimental Principles of Chemistry II		1			1	1																3
	Phys 1408	4	Principles of Physics I		1					1															2
	Engr 1315	3	Introduction to Engineering							1					1										2
	Engl 1302	3	Advanced College Rhetoric				1			1									1						3
SOPHOMORE (FALL)	Math 2450	4	Calculus III with Applications	1						1															2
	ECE 3301	3	General Electrical Engineering							1					1										2
	CE 2301	3	Statics						1	1															2
	COE 2302	3	Surveying							1	1					1									3
	CE 2201	2	Construction Materials Laboratory					1	1									1							3
	Pols 1301	3	American Government			1																			1
SOPHOMORE (SPRING)	Math 3350	3	Higher Mathematics for Engineers and Scientists I	1						1															2
	CE 3303	3	Mechanics of Solids						1	1															2
	IE 2324	3	Engineering Economic Analysis							1	1		1												2
	CE 3305	3	Mechanics of Fluids						1	1															2
	IE 3341	3	Statistics	1						1	1			1											4
	various		International Experience				1								1										2
JUNIOR (FALL)	CE 3309	3	Environmental Engineering							1				1			1								3
	CE 3171	1	Environmental Engineering Laboratory I						1					1											2
	CE 3354	3	Engineering Hydrology							1				1											2
	CE 3440	4	Structural Analysis I							1				1											2
	CE 3103	1	Mechanics of Solids Laboratory						1	1															2
	Hist 2301	3	History of the United States since 1877				1																		1
CE 3105	1	Mechanics of Fluids Laboratory						1	1															2	
JUNIOR (SPRING)	CE 3372	3	Water Systems Design							1						1									2
	CE 3341	3	Principles of Structural Design							1						1									2
	CE 3302	3	Dynamics						1	1															2
	CE 3321	3	Introduction to Geotechnical Engineering							1					1										2
	CE 3121	1	Geotechnical Engineering Laboratory							1					1										2
	Pols 2306	3	Texas Politics and Topics			1																			1
SENIOR (FALL)	CE 4200	2	Professional Engineering Practice Issues			1				1	1								1		1	1	1		6
	CE 4343	3	Design of Concrete Structures							1						1									2
	various	3	Design Elective ONE							1					1	1									3
	various	3	Oral Communication							1									1						2
	CE 4361	3	Transportation Engineering							1					1										2
	CE 4330	3	Design of Engineering Systems							1	1				1	1			1	1	1	1	1	1	9
SENIOR (SPRING)	various	3	Design Elective TWO							1					1	1									3
	ENGR 2392	3	Engineering Ethics and its Impact on Society				1												1			1		1	4
	various	3	Creative Arts/ Multicultural				1																		1
	various	3	Basic Science Elective		1																				1
	129		TOTALS	5	6	3	7	3	6	9	28	2	1	1	13	7	2	2	6	2	1	3	2	1	110

Figure 7. Comparison of CE Degree Program Courses vs. ASCE BOK3E Outcomes

Table 4. BOK3E Outcomes Represented in CE Courses, Comprehensive and Primary Analysis

BOK3E Outcome	BOK3E Classification	All Outcomes			Primary Outcome		
		Student Mean	Std Deviation	IOR Rating	Student Mean	Std Deviation	IOR Rating
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[6] Engineering Mechanics	Engr Fundamentals	15.0	7.5	6	5.5	3.4	4
[2] Natural Sciences	Foundational	14.6	7.8	6	5.3	2.2	4
[1] Mathematics	Foundational	26.2	10.4	5	5.0	1.5	4
[13] Design	Technical	11.9	6.6	7	4.5	2.6	4
[7] Experimental Methods and Data Analysis	Engr Fundamentals	12.4	7.1	9	3.8	2.4	5
[4] Humanities	Foundational	7.7	3.6	7	2.9	1.9	4
[3] Social Sciences	Foundational	8.0	4.2	3	2.9	1.8	2
[12] Breadth in Civil Engineering Areas	Technical	14.5	8.6	13	2.7	2.7	10
[16] Communication	Professional	11.7	8.2	6	2.2	1.4	4
[8] Critical Thinking & Problem Solving	Engr Fundamentals	24.0	12.0	28	2.1	2.6	0
[5] Materials Science	Engr Fundamentals	12.0	7.7	3	1.8	1.6	1
[14] Technical Depth	Technical	11.8	8.1	2	1.8	2.2	2
[21] Ethical Responsibilities	Professional	7.7	10.7	1	1.2	0.6	1
[18] Lifelong Learning	Professional	11.9	13.3	1	1.0	1.3	0
[17] Teamwork & Leadership	Professional	11.9	6.3	2	1.0	1.6	0
[10] Engineering Economics	Technical	3.4	3.7	1	1.0	0.4	1
[20] Professional Responsibilities	Professional	7.9	8.0	2	0.8	0.7	1
[15] Sustainability	Technical	7.6	7.4	2	0.7	1.0	0
[9] Project Management	Technical	9.2	7.4	2	0.5	0.7	0
[11] Risk & Uncertainty	Technical	6.4	7.1	1	0.5	0.6	1
[19] Professional Attitudes	Professional	7.9	8.2	3	0.4	0.6	0

The data in Table 4 are inclusive of CE 4200 instruction. While data scatter is wide, overall the table suggests several BOK3E outcomes are either *not* represented, are *underrepresented*, or are only *indirectly* represented in the CE curriculum at Texas Tech University. On the face of it, these outcomes include professional attitudes [outcome 19], risk and uncertainty [outcome 11], project management [outcome 9], sustainability [outcome 15], professional responsibility [outcome 20], engineering economics [outcome 10], teamwork and leadership [outcome 17], lifelong learning [outcome 18], and ethical responsibility [outcome 21].

Of these not-so-highly-represented outcomes, CE 4200 is designed to address professional attitudes [outcome 19], project management [outcome 9], professional responsibility [outcome 20], and teamwork and leadership [outcome 17]. Further, CE 4200 also addresses social sciences [outcome 3] and critical thinking and problem solving [outcome 8], these being outcomes that see expression through other courses in the program but which benefit from more focused, CE-specific treatment.

This interpretation means that, even with CE 4200 devoted to instruction on six BOK3E outcomes, there are still five outcomes that could use further emphasis in the undergraduate program – risk and uncertainty [outcome 11], sustainability [outcome 15], engineering economics [outcome 10], lifelong learning [outcome 18], and ethical responsibility [outcome 21]. Conversations about where to invest instructional effort are ongoing and represent a continuous challenge per ABET’s General Criteria for Baccalaureate Level Programs, Criterion 5 – curriculum [11]. For now the finding is that the CE 4200 course is helping to meet the need and provides a means for further refinement and filling out of the undergraduate curriculum.

Discussion/ Lessons Learned

The account told herein of the creation of CE 4200, Professional Engineering Practice Issues, is intended to provide information and insight to other CE faculty who face similar challenges and needs in their own programs.

Our experience has taught us that there *definitely* is a place for a course like CE 4200 in the CE undergraduate curriculum. ABET’s discipline-specific “Program Criteria” for Civil Engineering Programs, ABET’s General Criteria for Baccalaureate Level Programs Criterion 3 student learning outcomes, and ASCE’s BOK outcomes coalesce to identify the knowledge, skills, and attributes that characterize the person who is prepared to practice civil engineering at the professional level. Entire courses and in some cases, multiple courses exist within the undergraduate civil engineering program to initiate and develop these competencies. But constraints on education are such that certain topics cannot and do not see expression as a stand-alone undergraduate course. By design, CE 4200 has helped to fill such gaps in the baccalaureate civil engineering program at Texas Tech University.

The educational framework for CE 4200 makes sense, but per ABET Criterion 5 it can be challenging to identify the right mix of BOK outcomes and topics for instruction. Program administrators often need to fit in more content than can be covered in one course. In the case of CE 4200, the course began with a split instructional design, half focused on the CE BOK and half devoted to review of selected FE topics. While evidence indicated the FE topic reviews were reasonably effective at improving student mastery of the content, the dual instructional emphasis was perennially difficult for students (and instructors) to manage and work through. In particular, the bifurcated approach made it tough to achieve systematic instruction on CE BOK topics beyond simple awareness levels of achievement.

Even when suitable course design – *i.e.*, identification of the “right” CE BOK outcomes – is clearly apparent, it is not necessarily an easy task to develop a harmonious blend of lecture, assignments, and assessment situated within tight syllabus constraints. Tailoring instruction to achieve the desired learning objectives not only takes time and communication, but also a commitment to continuous adjustment and refinement.

Another lesson that emerged with the publication of BOK3E was that, while students accepted and seemed to understand and appreciate the levels of achievement associated with the cognitive and affective learning domains, they still want practical application for the outcomes. For example, we noticed that the initial chapters of BOK2E were not retained when we re-

designed the course for BOK3E. A consequence of this change was that a key assignment on early career guidance – explicitly discussed in BOK2E Chapter 4, “Guidance for Faculty, Students, Engineer Interns and Practitioners” – was inadvertently demoted to “optional” status. That particular assignment turned out to be among the most successful and most highly-ranked learning exercises in the entire CE 4200 course, so both BOK2E Chapter 4 and the assignment were reinstated.

The genius of the CEBOOK is that it does “define the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level” [3]. With the ideal thus established, careful analysis of one’s undergraduate curriculum relative to acknowledged sets of student learning outcomes yields insight on which topics best serve to round out the program of study. CE 4200, and similar courses like it, have a place in delivering this instruction.

Conclusions

This paper describes observations and lessons learned from 2012 through 2020 during which time the authors introduced, taught, and assessed 16 semesters of an upper-division, undergraduate, 2-credit hour, required course on both the second and third editions the *CE Body of Knowledge*. The course is “CE 4200, Professional Engineering Practice Issues,” and is sequenced to be taken during the penultimate semester of a student’s program of study in civil engineering at Texas Tech University. As presently configured, the course features six BOK3E outcomes which are: professional attitudes, professional responsibilities, teamwork and leadership, project management, critical thinking and problem solving, and social sciences. These particular outcomes were selected with due attention to Texas Tech University’s 129-hour program in civil engineering, focusing on outcomes either not represented, indirectly represented, or otherwise underrepresented in the curriculum.

Course development has been a work in progress over the years, with academic influences and curriculum emphases affecting instructional design and learning activities. The lessons learned illustrate how the CEBOOK can be used to shape and polish the civil engineering curriculum relative to helping satisfy ABET program accreditation requirements, introducing students to topics about which they have limited awareness and yet are essential to professional success, placing the students’ education and learning within the framework of professional practice, and otherwise helping prepare civil engineering students for their professional careers.

Formative and summative in-class assessments, multiple survey instruments, and ABET assessments were used to capture instructional perspectives on course objectives, instructional design, and overall course effectiveness. With continuous improvement ongoing, the instructional design for CE 4200 may presently be considered “stable,” and the course rates as a “highly valuable” learning experience. Assessment data reveal both ups and downs over the years, and lessons learned highlight not only what has worked well with CEBOOK instruction, but also topics and learning activities that did not achieve their intended outcomes. From its origins, at present, and looking to the future, the CE 4200 course is a journey of “*being excellent*” [12] in civil engineering curriculum and instruction.

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