The Impact of EAC-ABET Program Criteria on Civil Engineering Curricula

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Abstract

Civil engineering programs accredited by the Engineering Accreditation Commission of ABET (EAC-ABET) must comply with program criteria developed by the American Society of Civil Engineers (ASCE). Requirements stipulated in the program criteria are limited to the areas of curricular topics and faculty qualifications. There is a perception that innovation, flexibility, and creativity in civil engineering curriculums are stifled by the EAC-ABET program criteria. The goals of this study are to determine if the civil engineering program criteria (and indirectly ASCE's Body of Knowledge) have 1) hindered innovation and 2) standardized civil engineering curriculums.

A curriculum study was performed of 86 EAC-ABET accredited civil engineering programs in the United States. The study included programs from all 50 states; small and large; public and private; and research and teaching focused. For uniformity in the study and because the majority of civil engineering programs use a semester credit hour system, only programs with semester credit hours were analyzed. A database of graduation requirements was created that indexed courses in categories corresponding to the EAC-ABET civil engineering program criteria.

Innovation in civil engineering curriculums was addressed by examining the required number of credit hours in civil engineering electives, technical electives, civil engineering courses not linked to the program criteria, and math and science electives. The degree of standardization of civil engineering curriculums was investigated by comparing the 86 civil engineering programs to a benchmark civil engineering program of study derived from 2002 ABET data. Since 2002, the average number of credit hours required for a civil engineering degree decreased from 130.4 to 128.6 and the number of elective engineering credit hours increased from 11.0 to 19.0. The study concluded that civil engineering programs use unique methods and courses to meet the EAC-ABET program criteria, and during the period 2002-2017, the nation's civil engineering programs gravitated further from a standardized curriculum.

Introduction

Discipline-specific engineering program curriculums have evolved since the establishment of formal training for entry into the engineering profession. During the creation of civil engineering programs over one hundred years ago, content became more focused on modern engineering mechanics and design methods. To date the engineering profession continues to engage in a pattern of continual evaluation and change.

Within the past twenty years, there have been a significant number of factors affecting civil engineering programs. The three primary factors are the creation of ASCE's Civil Engineering Body of Knowledge, NCEES's changes in testing methods for the fundamentals of engineering (FE) exam, and EAC-ABET's changes to civil engineering program criteria (CEPC). Due to these influential changes over a relatively short period of time, this study was initiated to gauge their impact on civil engineering curricula. The goal of this study was to analyze current civil

engineering curriculum requirements and determine if there are significant variations among programs. Two questions were addressed: have the ASCE BOK2, the NCEES changes in FE exam testing methods, and EAC-ABET's changes to the civil engineering program criteria 1) hindered innovation in civil engineering curriculums and 2) resulted in a standardized civil engineering curriculum.

Background

The year 2018 marks the 100th anniversary of the Mann Report [1], a fundamental engineering program analysis that helped shape the civil engineering profession. The portion of the Mann report dedicated to curriculum and specialization made specific curriculum recommendations:

- The number of required credit hours per week should be less than 18 and preferably 16.
- College students do their best work when the number of different subjects studied at a given time is not greater than five.
- The first two years of study should include contact with real engineering projects and practical experiences.
- There is a need for interrelation between the concrete and the abstract throughout the entire curriculum.

The Mann report recommended a common core made up of three distinct parts: science (mathematics, chemistry, physics and mechanics), mechanic arts (drawing and shop) and humanities (English and foreign languages). "In addition to this explicitly recognized core of common material it is customary at present to require civil engineers, for example, to take brief courses in mechanical and electrical engineering, since it is necessary that a road or a railroad builder know something of steam machinery, turbines, electric machinery, and gas engines" [1].

Throughout the twentieth century, civil engineering programs continued to evolve and add more science and engineering courses and less mechanical arts. Russell and Stouffer conducted a survey of 90 of the nation's 218 undergraduate civil engineering programs using data from each programs most recent accreditation under the 2002-2003 EAC-ABET criteria [2]. Their findings indicated that the average number of semester credit hours required for a civil engineering degree was 130.4. The survey revealed that civil engineering curriculums were in a state of flux regarding which engineering classes should be taken outside the discipline. Many fundamental engineering topics courses that most programs required decades before had been eliminated by 2002. Dynamics was required in 70% of curricula, an electrical engineering course was required in 57% of curriculums and thermodynamics was required in 55% of curriculums. Civil engineering programs appeared to be streamlining their curriculum and making it civil centric.

Since 2002, a number of changes have occurred that have impacted civil engineering curriculums.

- Between 2002 and 2017, the number of EAC-ABET accredited civil engineering programs in the United States increased by 12% to 244 [3]. More universities added civil engineering programs leading to the possibility that newer schools may be taking different approaches to meeting program criteria.

- Several changes were made to the EAC-ABET civil engineering program criteria (CEPC) between 2002 and 2017. This required programs to re-evaluate their approach to maintaining accreditation.
- The American Society of Civil Engineers (ASCE) published their first Body of Knowledge for the civil engineering profession (BOK1) in 2004 and their second Body of Knowledge (BOK2) in 2008 [4].
- ASCE created the Civil Engineering Program Criteria Task Committee (CEPCTC) in 2012. The CEPCTC reviewed the BOK2 outcomes and recommended changes to the CEPC. The recommendations were approved by ABET for implementation in the 2016-2017 accreditation cycle. These actions by ASCE and ABET illustrate the close link between the BOK and the EAC-ABET CEPC. The CEPCTC provided a commentary for civil engineering programs [5].
- The National Council of Examiners for Engineering (NCEES) changed to a computerized FE exam in January 2014 and dropped some subject areas from the civil engineering exam, most notably chemistry, material science, electrical circuits, and thermodynamics.

EAC-ABET Program Criteria

The EAC-ABET program criteria contain specific requirements for mathematics, natural sciences, civil engineering technical areas, design content, experimentation, sustainability, and a series of other topics related to business, management, public policy, leadership, professional ethics, and licensure (Table 1). Every civil engineering program has the discretion to determine how they will meet these criteria. Each program determines the degree requirements, including the total number of credit hours, the number of required civil engineering courses, the number of technical elective courses, and the organization of the design courses.

Table 1. EAC-ABET Civil Engineering Program Criteria [6]

Curriculum	2017-2018	2002-2003
	Mathematics through differential equations	Mathematics through differential equations
	Calculus-based Physics	Calculus-based Physics
	Chemistry	Chemistry
	3rd science	
	Probability and statistics to address uncertainty	Probability and statistics
	At least 4 technical areas appropriate to CE	Proficiency in at least 4 CE areas
	Experiments in at least 2 CE areas	Experiments in more than 1 CE area
	Design in at least 2 CE contexts	Design throughout CE curriculum
	Sustainability in design	
	Basic Concepts: project management, business, public policy, leadership	Professional Practice Issues: Procurement of work, bidding vs QBS, design/construct interaction
	Professional ethics	
	Professional licensure	Professional Licensure and continuing education

Table 1 summarizes the changes made to the EAC-ABET civil engineering program criteria between 2002 and 2017 [6]. Since 2002, new curriculum requirements include a third natural

science (other than physics and chemistry), sustainability in design, basic concepts in project management, business, public policy, leadership, and professional ethics.

ASCE BOK2 Outcomes

ASCE's BOK2 increased the number of outcomes in BOK1 from 15 to 24 to add clarity, and they adopted Bloom's Taxonomy to describe cognitive levels of achievement for each outcome [4]. Estes et.al compared the ASCE BOK2 outcomes and the EAC-ABET criteria, concluding that several gaps exist between the BOK2 outcomes and the EAC-ABET criterion 3, criterion 5, and the CEPC [5]. Table 2 indicates that 10 of the BOK2 outcomes are explicated in the CEPC.

Table 2. ASCE Body of Knowledge 2 Outcomes and EAC-ABET CE Program Criteria [4], [5]

BOK2 Outcomes		EAC-ABET Criteria
1	Mathematics	Criterion 3 & 5
2	Natural Sciences	Criterion 3 & 5
3	Humanities	Criterion 5-Gen Ed
4	Social Sciences	Criterion 5-Gen Ed
5	Materials Science	
6	Mechanics	Criterion 5-Engr Topics
7	Experiments	Criterion 3 & 5
8	Problem Recognition and Solving	Criterion 5-Engr Topics
9	Design	Criterion 5-Engr Topics
10	Sustainability	CEPC
11	Contemporary Issues & Historical Perspectives	CEPC
12	Risk/uncertainty	CEPC
13	Project Management	CEPC
14	Breadth in Civil Engineering Areas	CEPC
15	Technical Specialization	CEPC
16	Communication	Criterion 3
17	Public Policy	CEPC
18	Business and Public Administration	CEPC
19	Globalization	Criterion 3
20	Leadership	CEPC
21	Teamwork	Criterion 3
22	Attitudes	Criterion 3 & 5
23	Lifelong Learning	Criterion 3
24	Professional and Ethical Responsibility	CEPC

BOK2 outcome 14 is titled, "Breadth in Civil Engineering Areas." BOK2 states that "Knowledge and breadth of coverage in at least four technical areas appropriate to civil engineering is necessary for individuals to solve a variety of civil engineering problems [4]." Traditional technical subject areas appropriate to civil engineering include construction engineering, environmental engineering, geotechnical engineering, surveying, structural engineering, transportation engineering, and water resources engineering. The development of BOK2 and the resulting changes to the EAC-ABET CEPC formalized curriculum requirements

that allowed civil engineering programs to move away from a requirement that students take at least one course in each of these seven civil engineering subject areas.

NCEES Fundamentals of Engineering Exam Changes

On October 26, 2013, NCEES conducted their last pencil and paper Fundamentals of Engineering (FE) Exam [7]. Beginning in January 2014, the new computer-based testing (CBT) FE exam was offered at Pearson VUE test centers across the country. The old pencil and paper FE exam was 8-hours long and consisted of a 120-question common morning section and either a 60-question common afternoon section or a 60-question discipline-specific afternoon section. The new CBT FE exam was reduced from 8 hours to 5 hours and 20 minutes. An additional 40 minutes are allotted for a tutorial, scheduled break, and a brief survey [8]. Examinees are asked to select one of seven individual FE exams that consist of 110 questions. Table 3 summarizes the changes that were made to the civil engineering FE exam.

Several changes were made to the FE exam content when it moved to a computerized format. Some subject areas were eliminated from the civil engineering FE exam including chemistry, electrical circuits, thermodynamics, and materials science. Other areas were moved and combined such as computers, ethics, computer/numerical methods, and legal and professional aspects.

Study Methodology

The curriculum requirements of 100 different EAC-ABET accredited undergraduate civil engineering programs in the United States were reviewed. The programs were selected to obtain a diverse, representative sample of current civil engineering program requirements. At least one program was selected from every state and only universities that use semester credit hours were analyzed. This latter requirement eliminated 14 civil engineering programs originally selected for the study. The study included public and private universities, large land-grant universities and smaller universities that limited enrollment, and universities that had a significant research mission and universities that had only undergraduate students. Of the 86 universities selected, there were 17 civil engineering programs from private universities (19.8%) and 69 civil engineering programs from public universities (80.2%). This compares closely to national data. In the United States, 25.8% of all EAC-ABET accredited civil engineering programs are at private universities [3].

Data was obtained from each university's most recent undergraduate catalog and the program's published civil engineering curriculum. The data was compiled in a series of 54 categories that were organized in seven groups: mathematics and science, engineering mechanics, basic engineering courses, civil engineering courses, engineering electives, general education requirements, and other courses. Every required course was categorized and the number of credit hours was logged. Notes were recorded on credit hour requirements that were classified as electives.

Table 3. NCEES Fundamentals of Engineering Exam Subject Areas for Civil Engineering [8]

Subject	Average Percent 2002-2003	Average Percent 2017-2018
Mathematics	10	7.1
Electrical Circuits	5	-
Statics	5	7.1
Chemistry	4.5	-
Thermodynamics	4.5	-
Dynamics	3.5	4.0
Fluid Mechanics	3.5	4.0
Materials Science/Structure	3.5	-
Mechanics of Materials	3.5	7.1
Computers	3	*
Engineering Economics	2	4.0
Ethics	2	*
Computers/Numerical Methods	5	*
Environmental Engineering	5	6.0
Hydraulics/Hydrologic systems	5	7.9
Soil Mechanics & Foundations	5	9.1
Structural Analysis	5	6.0
Structural Design	5	6.0
Surveying	5	4.0
Transportation Facilities	5	7.9
Water Purification & Treatment	5	*
Construction Management	2.5	4.0
Legal & Professional Aspects	2.5	*
Probability and Statistics	-	4.0
Computational Tools	-	4.0
Civil Engineering Materials	-	4.0
Ethics and Professional Practice	-	4.0
Total	100%	100%

*Combined with other areas in the 2017-2018 format.
- Not Included

The total number of credit hours for each civil engineering curriculum was verified to ensure data accuracy. A statistical analysis was performed on the data from each category to allow civil engineering curriculums to be compared to determine similarities and variations. The average, range, and standard deviation of credit hours for each course were computed.

Benchmark Study Results

A previous study that was performed by Russell and Stouffer was used as a baseline program for comparison purposes [2]. The Russell and Stouffer study was selected for four reasons. In 2002

- The initial impact of the 1996 ABET EC2000 accreditation criteria on engineering curriculums was in the process of being documented [9]. ABET's 2006 report on the impact of EC2000 during the period 1994-2004 indicated that improvements in student learning had occurred as a result of changes in engineering program curricula, teaching methods, faculty practices, and student experiences in the classroom [9].
- ASCE had not yet published a Body of Knowledge.
- Civil engineering curriculums had not yet been impacted by the 2008 and 2016 changes to the CEPC.
- The FE exam covered 23 topics and was offered twice a year as a pencil-and-paper exam.

The Russell and Stouffer data was collected from civil engineering programs in 2002 [2]. This coincided with the beginning of a 15-year period of change that was initiated independently by ASCE, NCEES, and ABET; these changes directly impacted civil engineering program curriculums.

The benchmark data for a typical civil engineering program in 2002 is shown in Table 4. The average number of credit hours to obtain a civil engineering degree in 2002 was 130.4 for universities on a semester system. The average number of math and science credits was 35.2 and the average number of general education credits was 26.7. These two categories constituted 47.5% of the program credits. Engineering topics consisted of 66.4 credits or 51% of the required credits. Of these engineering credits only 16.6% were electives or 11.0 credits.

Table 4. Comparison of Benchmark Civil Engineering Curriculum to Study Data

	2002[2]		2017	
Subject	Average Credits	Percent	Average Credits	Percent
Math and Science	35.2	27.0	34.6	26.9
General Education	26.7	20.5	24.2	18.8
Other	2.1	1.5	3.4	2.7
Total Engineering Topics	66.4	51.0	66.4	51.6
Required Engr Topics	55.4	83.4	47.4	71.4
Elective Engr Topics	11.0	16.6	19.0	28.6
Total	130.4		128.6	

In 2017, the average number of credit hours required for a civil engineering degree had decreased 1.4% to 128.6. The average credits for math and science decreased slightly to 34.6 and the number of general education credit hours decreased to 24.2. The total number of credit hours in the engineering topics category remained the same at 66.4 credit hours, but the number of elective engineering credit hours increased noticeably from 11.0 to 19.0, a 72.7% increase.

Civil Engineering Curriculum Study Results

Mathematics and Science

All of the civil engineering programs in the study require students to take calculus, physics, and chemistry courses, but the range of required credit hours for chemistry is between 3.0 and 10.0 and the range for physics is between 3.0 and 12.0. Every program required at least 8.0 credits of calculus and the average was 11.4 credits. Over 95% required differential equations, although only 34.9% included a math or science (chemistry or physics) elective. Linear algebra was not required in most curriculums, and it had the highest standard deviation (2.09 credits) of mathematics and science credits required. Only 88.4% required a third natural science course, and only 87.2% required a probability and statistics course despite both of these being requirements in ABET's CEPC (Table 5).

Table 5. Mathematics and Science Requirements in 2017 Study

	CE Programs Requiring	CE Programs Elective	CE Programs Requiring Course			
Subject	Course	Course	Average Credit	Standard Deviation	Maximum Credits	Minimum Credits
Calculus	100.0%	0.0%	11.4	0.65	14.0	8.0
Differential Equations	95.3%	3.5%	3.2	0.35	6.0	1.5
Probability and Statistics	87.2%	2.3%	3.0	0.65	4.0	1.0
Linear Algebra	29.1%	15.1%	2.2	2.09	3.0	1.0
Physics	100.0%	0.0%	7.3	1.78	12.0	3.0
Chemistry	100.0%	0.0%	5.3	0.89	10.0	3.0
3rd Natural Science	88.4%	4.7%	3.3	1.39	6.0	3.0
Math/Science Elective	34.9%	**	3.6	0.71	6.0	2.0

** Not Applicable

Engineering Topics

All civil engineering programs in the study required a course in statics and a course in mechanics of materials; the average numbers of credits were 2.9 and 3.2, respectively. Only 69.8% of the programs required dynamics, but another 19.8% included it as an elective (Table 6). Most required a course in fluid mechanics (96.5%).

Only 7% of civil engineering programs required a materials science course and only 19.8% included it as an elective. Material science is not an EAC-ABET requirement, it is not included on the CPT FE exam, but it is listed as outcome number 5 in the BOK2 as shown in Table 2.

Table 6. Engineering Mechanics Requirements in 2017 Study

Subject	CE Programs Requiring Course	CE Programs Elective Course	CE Programs Requiring Course			
			Average Credit	Standard Deviation	Maximum Credits	Minimum Credits
Statics	100.0%	0.0%	2.9	0.39	4.0	2.0
Dynamics	69.8%	19.8%	2.9	0.62	3.0	1.0
Mechanics of Materials	100.0%	0.0%	3.2	0.82	6.0	1.0
Materials Science	7.0%	19.8%	2.7	0.53	3.0	1.0
Fluid Mechanics	96.5%	0.0%	3.5	0.50	5.0	3.0

The number of civil engineering programs that require electrical circuits and thermodynamics decreased substantially (Table 7). In their study, Russell and Stouffer found 55.6% of civil engineering programs required thermodynamics in 2002; this compared to 18.6% in 2017. Similarly, only 10.5% of civil engineering programs required students to take an electrical circuits course in 2017 compared to 58% in 2002 [2]. This trend is in sharp contrast to the recommendations in the 1918 Mann report that concluded that civil engineering students benefitted from taking courses in mechanical engineering and electrical engineering [1]. Numerical methods is rarely required or offered as an elective, and computer programing is only required in about half of the programs.

Table 7. Thermodynamics, Electrical Circuits and Computer Programming Requirements in 2017 Study

Subject	CE Programs Requiring Course	CE Programs Elective Course	CE Programs Requiring Course			
			Average Credit	Standard Deviation	Maximum Credits	Minimum Credits
Thermodynamics	18.6%	44.2%	2.9	1.00	3.0	1.0
Electrical Engineering Circuits	10.5%	43.0%	2.7	0.50	4.0	1.0
Computer Programming	52.3%	7.0%	2.7	0.72	4.0	1.0
Numerical Methods	5.8%	1.2%	3.0	0.55	4.0	3.0

General Education Courses

In 2017, the average number of required general education credits was 21.7; the range was 12 to 33 credits. This category had the largest standard deviation (4.03 credits) of any category reviewed in the study. General education content is not covered on the FE exam, but a general education component is required by the EAC-ABET program criteria, the CEPC, and BOK2. Almost half of the civil engineering programs required a technical writing course in 2017; this compared to 33.3% in Russell and Stouffer's 2002 data (Table 8) [2]. Free electives were available in only 20.9% of civil engineering curriculums confirming that there are few truly "free" or extremely flexible credits in most civil engineering programs.

Table 8. General Education Courses and Free Electives in 2017 Study

Subject	CE Programs Requiring Course	CE Programs Elective Course	CE Programs Requiring Course			
			Average Credit	Standard Deviation	Maximum Credits	Minimum Credits
General Education	100.0%	0.0%	21.7	4.03	33	12
Technical Writing	45.3%	7.0%	2.9	0.84	6	0
Free Electives	20.9%	NA	5.4	2.96	12	3

NA – Not Applicable to this category

Civil Engineering Topics

Data was obtained and summarized for twenty different civil engineering topics in Table 9. An introduction to engineering course was required in most curricula (91.9%) and had the second largest range of credits (1.0 to 6.0 credits). An additional four courses were required in at least 80% of the programs: structural analysis, soil mechanics, transportation engineering, and the capstone design course. Many civil engineering specialty courses, such as steel design, foundation design, hydrology/hydraulic systems, and water/wastewater were required in less than one third of the programs.

In his 2000 paper that examined the impact of ABET's 1997 civil engineering program criteria, Koehn found that practitioners favored civil engineering graduates who had courses in structural engineering, hydraulic engineering, and design integrated throughout the curriculum [10]. In the 2017 data, 89.5% of civil engineering programs required a structural analysis course, yet less than half the programs required students to take a reinforced concrete course (44.2%), a steel design course (32.6%) or an additional structural engineering elective (5.8%). In addition, only 58.1% of civil engineering curriculums required a hydraulic engineering course in addition to a course in fluid mechanics. This data is in sharp contrast to civil engineering practitioner preferences in 2000.

While many civil engineering courses are no longer required, the study revealed that most programs offered a diverse set of civil engineering electives. Of the twenty civil engineering topics in Table 9, fifteen are offered in at least 89% of the programs studied. Only civil engineering fundamentals, a civil engineering seminar, and sustainable design are offered in less than 50% of the programs. Topics in seminar and fundamentals courses were possibly combined with other course topics to reduce the number of credits in a program. Sustainability is a relatively new topic, although one that is in the ABET CEPC and the BOK2, but not a specific category on the FE exam (Table 2 & Table 3).

Engineering electives were grouped in three different categories in Table 10: CE core electives, technical electives, and design electives. Although the total number of required engineering topics courses changed little since 2002 (as shown in Table 4 and discussed in the Benchmark Study section), civil engineering curriculums were found to be trending toward offering degrees with an increased level of specialization within the civil engineering subject areas. The number of engineering topic elective courses grew from 11.0 credits in 2002 to 19.0 credits in 2017 which is now 28.6% of the total required engineering credits (Table 4).

Table 9. Civil Engineering Course Requirements in 2017 Study

Subject	CE Programs Requiring Course	CE Programs Elective Course	Offered in the Program	CE Programs Requiring Course			
				Average Credit	Standard Deviation	Maximum Credits	Minimum Credits
Introduction to Engineering	91.9%	1.2%	93.1%	2.7	0.32	6.0	1.0
Civil Engineering Fund	37.2%	3.5%	40.7%	2.4	1.05	5.0	1.0
Structural Analysis	89.5%	10.5%	100.0%	3.3	0.44	4.0	3.0
Steel Design	32.6%	67.4%	100.0%	2.9	0.43	4.0	1.5
Reinforced Concrete	44.2%	55.8%	100.0%	3.0	0.47	4.0	1.5
Structural Engineering Elect	5.8%	88.4%	94.2%	2.6	0.89	3.0	1.0
Soil Mechanics	89.5%	10.5%	100.0%	3.7	0.47	5.0	3.0
Foundation Design	24.4%	75.6%	100.0%	3.0	0.00	3.0	3.0
Transportation Engineering	81.4%	18.6%	100.0%	3.2	0.66	6.0	3.0
Hydraulic Engineering	58.1%	40.7%	98.8%	2.9	0.73	4.0	1.5
Hydrology/Hydrologic Sys	32.6%	67.4%	100.0%	2.6	0.83	4.0	1.5
Environmental Engineering	77.9%	17.4%	95.3%	3.3	0.55	6.0	3.0
Water/Wastewater	31.4%	67.4%	98.8%	3.1	0.75	4.0	1.0
Construction/Project Mgt	52.3%	37.2%	89.5%	3.0	0.55	6.0	1.5
Civil Engineering Materials	75.6%	18.6%	94.2%	3.0	0.76	4.0	1.0
Surveying	72.1%	11.6%	83.7%	2.8	0.75	4.0	1.0
Engineering Economics	57.0%	24.4%	81.4%	2.6	0.65	3.0	1.0
Sustainable Design	17.4%	31.4%	48.8%	2.7	0.72	3.0	1.0
Civil Engineering Capstone	86.0%	3.5%	89.5%	3.9	1.08	6.0	3.0
CE Seminar	39.5%	1.2%	40.7%	1.8	1.30	7.0	1.0

The data indicates that civil engineering programs support the specialization of civil engineering students with technical electives at the expense of a professional core. The civil engineering core electives approach is used in 48.8% of the programs and averages 11.0 credits with a range of 1.0 to 31.0. These core electives are typically based on taking a selection of the civil engineering courses shown in Table 9. Additionally, almost 95% of the civil engineering programs in the study required an average of 11.7 credit hours of technical electives. The specialization of course selection has been supported by ASCE's BOK2 [4] and the CEPC which define "breadth in civil engineering" as the ability to "analyze and solve problems in at least four technical areas appropriate to civil engineering." This flexibility within the CEPC has allowed civil engineering programs to use unique methods and courses to meet the program criteria and move further from a broad civil engineering curriculum.

Except at a few universities (primarily small private universities in this study), the broad, rigid civil engineering curriculums of the past have been replaced by specialized tracks and concentrations. This is supported by the NCEES CBT model for civil engineers that removed electrical circuits, thermodynamics, material science, and chemistry from the Fundamentals of Engineering (FE) exam in 2014.

Table 10. Engineering Electives in 2017 Study

Subject	CE Programs Requiring Course	Average Credit	Standard Deviation	Maximum Credits	Minimum Credits
Civil Engineering Core Electives	48.8%	11.0	6.84	31.0	1.0
Technical Elective	94.2%	11.7	5.68	30.0	3.0
Design Electives	46.5%	5.7	2.40	12.0	3.0

To a much smaller degree, core civil engineering courses are being replaced by the option to take a wider variety of courses that address BOK2 and CEPC topics such as risk/reliability, GIS, business, ethics, and leadership (Table 11). With the exception of ethics, all of these courses are required in less than 12% of programs and are offered as electives in less than 24% of the programs. Almost three fourths of all civil engineering programs require a course in computer aided design.

Table 11. Other Required Courses in 2017 Study

Subject	CE Programs Requiring Course	CE Programs Elective Course	CE Programs Requiring Course			
			Average Credit	Standard Deviation	Maximum Credits	Minimum Credits
Computer Aided Design	73.3%	4.7%	2.3	0.72	3.0	1.0
Risk/Reliability	8.1%	14.0%	3.1	0.82	4.0	3.0
GIS	11.6%	23.3%	2.7	0.44	4.0	1.0
Business	7.0%	15.1%	3.3	0.43	4.0	3.0
Ethics	36.0%	10.5%	2.0	0.47	3.0	1.0
Leadership	3.5%	4.7%	1.3	0.89	2.0	1.0
ROTC	1.2%	7.0%	12.0	NA	12.0	0.0

Conclusions

A curriculum study of 86 civil engineering programs was performed and analyzed. The 2017 data was compared to a study performed using 2002 data. The following are the most significant findings:

- The total number of credits required in a civil engineering program has decreased from 130.4 in 2002 to 128.6 in 2017.
- The total number of credit hours in the engineering topics category remained unchanged at 66.4 credit hours, but the number of elective engineering credit hours increased noticeably from 11.0 to 19.0, a 72.7% increase.

- The engineering, math, and science courses required by all programs are calculus, physics, chemistry, statics, and mechanics of materials.
- The number of civil engineering programs that require electrical circuits and thermodynamics decreased significantly. The percent that require thermodynamics dropped from 55.6% to 18.6% and the percent that require an electrical circuits course dropped from 58% to 10.5%.
- Approximately 90% of programs require a structural analysis course, but steel design and reinforced concrete design courses are required in less than half the civil engineering curriculums.
- Less than 60% of civil engineering programs require a hydraulic engineering course.
- Civil engineering curriculums are trending toward offering degrees with an increased level of specialization within the civil engineering subject areas. The average number of engineering elective courses has grown to 19.0 credits, which is now 28.6% of the total engineering credits. The data indicates that civil engineering programs support the specialization of civil engineering students with technical electives and civil engineering core electives at the expense of a broad, professional required core of classes.
- The BOK2 outcomes, ABET CEPC, and the 2014 NCEES changes to the civil engineering FE exam have supported a higher degree of specialization in civil engineering curriculums and a move away from a standardized curriculum.

The study revealed that there is no single uniform civil engineering program of study. A few fundamental engineering topics courses such as statics, mechanics of materials, and fluid mechanics are universal, but the increase in the number of engineering electives reveals that civil engineering programs are using unique and creative ways to meet the EAC-ABET criteria. The data indicates that the current EAC-ABET criteria and CEPC have spurred increased civil engineering curriculum flexibility, innovation, and creativity.

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