A Survey of Education in Civil Engineering

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A Survey of Education in Civil Engineering

Date:
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PREFACE

The motivation behind this paper is due to the author’s own curiosity towards education. The author, a senior undergraduate civil engineering student at the time of writing, was inspired by the Accreditation Board for Engineering and Technology (ABET) re-accreditation process underway for their program during their final year. This was furthered by changes to their program’s curriculum during their time as a student. These two events served to pique the author’s interest in the education of civil engineers, and how effective that education was.

This paper was originally intended to be split into two equal sections. The first section would be a comprehensive look at current education practices in civil engineering, while the second section would describe the impacts civil engineering education in the context of professional licensure and the Infrastructure Report Card. The main method of collecting data was to be an anonymous survey taken by academics in civil engineering to retrieve information about civil engineering programs such as students enrolled, classes offered, among other information. The survey would also allow the participants to share their own opinions on education in civil engineering.

It was necessary for the final paper to deviate from the original plan mentioned above. One reason for this was that the survey did not return as many responses as were expected. Out of several hundred surveys that were distributed, only twenty-three responses were received. To accommodate the low response count, data from published curricula of select civil engineering programs, chosen at random, were utilized to supplement the survey. Furthermore, over the course of writing the paper, the author’s interest shifted heavily towards education practices and requirements, especially at the undergraduate level. Thus, in relation to the proposed outline mentioned above, the first section was greatly emphasized, while the second section was greatly
diminished. Nevertheless, it is the hope of the author that this paper will provide some insights on the practice of education in civil engineering.

ABSTRACT

This paper provides an overview of the current education requirements in the field of civil engineering. This is achieved through means of an anonymous survey sent to civil engineering academics and data gathered from the published curricula of ten existing civil engineering programs. These ten programs were selected by means of a random number generator from the list of institutions the survey was sent to. Such an overview is important for gauging the effectiveness of civil engineering education for current and future students.

INTRODUCTION

Overview of Civil Engineering

Civil Engineering is the branch of engineering primarily concerned with public projects and infrastructure. People encounter the works of civil engineers every day. From bridges and roads, sewer and wastewater management, construction and structural design, civil engineers have a hand in some of the most important functions of society. There are six traditional disciplines of the profession: construction, environmental, geotechnical, structural, transportation, and water resources. However, these are by far not the only disciplines, and more are constantly emerging to help better serve the needs of the public.

Construction

Construction Engineering concerns the erection of structures in a timely and cost-effective way. Construction engineers are knowledgeable in multiple facets of engineering as well as economics, public policy, and project management. They are tasked with completing their projects on time, coordinating resources, and solving problems that arise during the construction itself.
Geotechnical

Geotechnical engineering focuses on soils and their impacts and engineers in this field are proficient in such areas as soil and fluid mechanics. Engineers in this field are responsible for designing building foundations, designing retaining walls, and performing tests to gauge the quality of soils. They may also analyze what happens to soils over time, such as in building settlement or erosion.

Environmental

Environmental engineering envelops the measures taken to manage and maintain the natural resources and ecosystems of the world. Environmental engineers are equipped with skills in chemistry and fluid mechanics to assist in solving problems in these areas. An engineer in this field may design a wastewater treatment plant, ensure that a city’s water is safe to drink, or help protect the natural environment from harm such as pollution.

Structural

Structural engineering is responsible for the planning, analysis, and maintenance of structures. Engineers in this field draw knowledge from mathematics, physics, and materials science to design structures that are safe and long-lasting. They may create plans for new structures, inspect existing ones, or specialize in certain areas, such as developing innovative building materials. Structural engineers work closely with architects, geotechnical engineers, and construction engineers.

Transportation

Transportation engineering entails connecting people and places safely and efficiently. An engineer in this field would design road and highway systems and analyze their effectiveness as
well as their safety. They may also carry out cost-benefit analyses related to creating and maintaining these systems and advise policy decisions based on these analyses.

Water Resources

Water resources engineering involves the transportation and management of water systems. Engineers in the field use knowledge of fluid mechanics to understand how to solve a variety of problems. Such tasks may include water distribution and collection systems, sewer systems, and flood mitigation and prevention.

Necessity of Education

It should be clear from the section above, that civil engineering is a dense and widely varied field. There is much to know, and the nature of the projects mean there is a lot at stake. Moreover, no discipline exists on its own, and everything is interconnected. Thus, is it imperative that anyone practicing this profession has a solid background in each area. This is the motivation of this paper. This paper will seek to analyze the standards for an education in civil engineering and attempt to discuss how this education shapes the practice.

STANDARDS AND GUIDELINES

At the nexus of education and engineering lies the Accreditation Board for Engineering and Technology (ABET). This board sets the standard for all engineering disciplines, and any aspiring engineer must graduate with a degree that abides by their guidelines. However, there exist other metrics for gauging the merit of degree in civil engineering. One such metric includes the Civil Engineering Body of Knowledge, Third Edition (CEBOK3) assembled by the American Society of Civil Engineers (ASCE). This collection of civil engineering knowledge serves as a guide for the skills necessary for an individual to become a successful professional in the field (CEBOK3). These two sources are key in shaping the landscape of education in civil engineering.
ABET

ABET is a coalition comprised of 36 individual member societies with knowledge spanning a breadth of subjects in engineering and the sciences ("Member Societies"). Their purpose is to accredit college programs in these fields by setting standards and unifying the meaning of the degree ("About ABET"). ABET is nationally recognized and instrumental in the creation of engineering professionals. Possessing a degree granted by an ABET accredited institution is generally the only way to start the path of achieving a professional license.

To be eligible for accreditation, a college program must meet ABET’s definition of a program ("Program Eligibility"), the criteria for which are discussed below. Prospective programs must also be housed in a degree-granting institution, have at least one graduate, have an appropriate name, and fall under the purview of one of ABET’s four Accreditation Commissions. The program must also complete a separate process known as a Readiness Review if it would be their institution’s first ABET-accredited program.

There are eight criteria all engineering programs are required to fulfill in order to become accredited by ABET ("Criteria"). These criteria govern not just the content of the program, but also how the program itself is governed, and often require documented proof of each step. For example, a consistent standard pathway through the program must be well documented and utilized, and students’ progress through the program must be recorded with their performances. The program must also feature competent faculty, appropriate facilities, and proper support from the institution’s administration. There must also be evidence that the program is self-evaluating and improving over time.
Among the criteria are two metrics for tracking a student’s achievement (“Criteria”). One such metric is a set of guidelines for the program curriculum, which can be found in Table 1. The other is a set of student outcomes meant to support such guidelines, which can be found in Table 2. Note the difference between the two set of guidelines. While the curriculum guide provides a path for relevant coursework a student must complete, the student outcomes go further. The outcomes take the knowledge gathered over the course of the program and coalesce them into a concentrated skill set that each student should possess once they finish the program.

The criteria described so far apply to all engineering programs accredited by ABET. However, there are two additional criteria for civil-specific programs (“Criteria”). The first consists of additional specifications for the curriculum. This criterion includes specifying mathematics courses up to differential equations and statistics, specifying natural science courses of physics and chemistry, requiring knowledge of at least four disciplines of civil engineering, and classes involving conducting experiments, among additional topics. The second criterion emphasizes that the faculty must be properly qualified, and that there is a sufficient number of faculty involved in the program.

Table 1: ABET curriculum guidelines for engineering degrees (“Criteria”).

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program.</td>
</tr>
<tr>
<td>2</td>
<td>A minimum of 45 semester credit hours (or equivalent) of engineering topics appropriate to the program, consisting of engineering and computer sciences and engineering design, and utilizing modern engineering tools.</td>
</tr>
<tr>
<td>3</td>
<td>A broad education component that complements the technical content of the curriculum and is consistent with the program educational objectives.</td>
</tr>
<tr>
<td>4</td>
<td>A culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work</td>
</tr>
</tbody>
</table>
The Civil Engineering Body of Knowledge is a publication produced by ASCE that outlines the skills they deem necessary for a professional civil engineer to possess (CEBOK3). The purpose of this document is to provide guidelines to prepare engineers for the challenges faced by the profession, with consideration for how these challenges will evolve over time. This is the third such document published by ASCE and will be referred to in this paper as CEBOK3.

CEBOK3 contains a collection of 21 outcomes categorized into four groups, with each outcome representing a necessary skill that a professional civil engineer should possess (CEBOK3). The outcomes are broken down into components based on Bloom’s Taxonomy. For

### Table 2: ABET student outcomes for engineering programs (“Criteria”).

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.</td>
</tr>
<tr>
<td>2</td>
<td>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.</td>
</tr>
<tr>
<td>3</td>
<td>An ability to communicate effectively with a range of audiences</td>
</tr>
<tr>
<td>4</td>
<td>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</td>
</tr>
<tr>
<td>5</td>
<td>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</td>
</tr>
<tr>
<td>6</td>
<td>An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions</td>
</tr>
<tr>
<td>7</td>
<td>An ability to acquire and apply new knowledge as needed, using appropriate learning strategies</td>
</tr>
</tbody>
</table>
each level of Bloom’s Taxonomy, an associated level of ability is associated, as well as a typical pathway to achieving that level. CEBOK3 considers four pathways: undergraduate education, graduate education, mentored experience, and self-experience. See Table 1 for a typical breakdown of one of the outcomes. For a list of all 21 outcomes, see Table 2.

Note that at first glance ABET and CEBOK3 seem similar in their content, however, they are not equivalent. While CEBOK3 recognizes that ABET provides the minimum standards for education in civil engineering, it maintains that it has broader applications, and should be used as a basis for future curricula, not a requirement for the present (CEBOK3).

Table 3: Breakdown of the mathematics outcome based on Bloom’s Taxonomy (CEBOK 3).

<table>
<thead>
<tr>
<th>Cognitive Domain Level of Achievement</th>
<th>Demonstrated Ability</th>
<th>Typical Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember (remember previously learned material)</td>
<td><strong>Identify</strong> concepts and principles of mathematics, including differential equations and numerical methods.</td>
<td>Undergraduate education</td>
</tr>
<tr>
<td>Comprehend (grasp the meaning of learned material)</td>
<td><strong>Explain</strong> concepts and principles of mathematics, including differential equations and numerical methods.</td>
<td>Undergraduate education</td>
</tr>
<tr>
<td>Apply (use learned material in new and concrete situations)</td>
<td><strong>Apply</strong> concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering problems.</td>
<td>Undergraduate education</td>
</tr>
<tr>
<td>Analyze (break down learned material into its component parts so that its organizational structure may be understood)</td>
<td><strong>Select</strong> appropriate concepts and principles of mathematics to solve civil engineering problems.</td>
<td></td>
</tr>
<tr>
<td>Synthesize (put learned material together to form a new whole)</td>
<td><strong>Develop</strong> mathematical models to solve civil engineering problems.</td>
<td></td>
</tr>
<tr>
<td>Evaluate (judge the value of learned material for a given purpose)</td>
<td><strong>Assess</strong> mathematical models used to solve civil engineering problems.</td>
<td></td>
</tr>
</tbody>
</table>
Table 4: The 21 ASCE outcomes (“Criteria”)

<table>
<thead>
<tr>
<th>Foundational</th>
<th>Engineering Fundamentals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td>Materials Science</td>
</tr>
<tr>
<td>Natural Sciences</td>
<td>Engineering Mechanics</td>
</tr>
<tr>
<td>Social Sciences</td>
<td>Experiment Methods and Data Analysis</td>
</tr>
<tr>
<td>Humanities</td>
<td>Critical Thinking and Problem Solving</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical</th>
<th>Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>Communication</td>
</tr>
<tr>
<td>Engineering Economics</td>
<td>Teamwork and Leadership</td>
</tr>
<tr>
<td>Risk and Uncertainty</td>
<td>Lifelong Learning</td>
</tr>
<tr>
<td>Breadth in Civil Engineering Areas</td>
<td>Professional Attitudes</td>
</tr>
<tr>
<td>Design</td>
<td>Professional Responsibilities</td>
</tr>
<tr>
<td>Depth in a Civil Engineering Area</td>
<td>Ethical Responsibilities</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
</tr>
</tbody>
</table>

**THE EDUCATION REQUIREMENT**

This section explores data gathered from the survey combined with information gathered from the undergraduate curricula of ten institutions chosen at random. This will be accomplished by breaking down each program into its requirements and electives, comparing the information from both sources to ABET criterion and CEBOK3 outcomes, presenting the opinions of academics in the field, and include a brief discussion of cooperative education.

**Curricula**

Out of 21 survey responses, 19 responses indicated the number of credits required for their program. Combined with data gathered from the ten sampled programs, this suggests that civil engineering programs require on average 134 credits for graduation. The majority of programs considered require between 120-129 credits, with 16 programs falling in this category. The second
highest grouping was 131-139 credits, which describes an additional 8 programs. These numbers are illustrated in Figure 1. Note that the ≥140 credits bar of Figure 1 describes four programs, however while one program in that category requires 144 credits, the other three range from 180-192 credits.

For each sampled program, the number of required courses and elective courses were tallied for each of the six standard disciplines of civil engineering, as well as for surveying, mathematics, and computing (CAD/Coding). General education and general engineering courses (i.e. “Introduction to Civil Engineering”) have been omitted. Any course involving planning and economics was listed under construction. Statics and dynamics courses were listed under structural. Statistics courses were listed as mathematics. Fluid mechanics courses were listed under water resources. Graphical breakdowns of this data and lists of courses considered under each category can be found in Appendix B.

Of the ten sampled schools, the lists of required courses follow similar patterns. First, each program requires several mathematics courses. Second, the most represented discipline in each case tends to be structural engineering. Aside from this, the other disciplines of civil engineering are generally evenly represented, though this is not true for every case. The number of electives offered varies by program. Some schools offer several electives, while others offer fewer. Furthermore, with the exception of structural engineering tending to remain the most represented, the number of electives offered per discipline also differs by program. Examples of this include...
George Mason University (Figure 14, Appendix B) offering relatively more construction courses, and University of Colorado, Boulder (Figure 18, Appendix B) offering relatively more water resources courses.

There are noticeable absences in the data which must be addressed. An absence of courses of a particular discipline may indicate that the school has a separate degree for that discipline. However, this is not true in all cases, as can be seen with Drexel University (Figure 12, Appendix B), which does not offer any transportation engineering classes. Furthermore, Drexel University and University of Miami both offer and require electives, however, neither school has posted a list of electives that meet this requirement (Drexel, Miami). Finally, The Citadel has no elective requirements (The Citadel).

Data gathered from the survey support the data from the sampled programs. According to the survey, the required courses from the represented programs also tend to evenly distribute courses across the disciplines. A higher concentration of structural engineering classes can also be found in the survey responses, though this is less common than from the sampled programs. Note that differences between the two data sources may arise depending on how each participant chooses to categorize courses, and with some survey responses only mentioning required “upper-level” (junior/senior) coursework. Additionally, data from the survey is generally vague regarding electives offered. The number of electives required, generally 2-4, are given, as well as a number of courses offered, but no response delineates these electives by discipline.

Figure 2 regards the opinions of the survey takers regarding their own curricula. Most responses conveyed positive outlooks on the programs, with few mixed responses and no responses of dissatisfaction. The positive responses tend to praise their program’s ability to effectively prepare students for careers as civil engineers. Even the mixed responses tend to be
mostly positive, and usually include minor complaints, such as needing a change in the number of credits required or adding or dropping a course. In addition to the opinions mentioned above, each participant was given the opportunity to share any changes they would make to their curriculum if they had the power. The most common response to this prompt was a call for more electives and greater flexibility in the curriculum. Others include wanting more requirements for non-STEM classes, wanting more applied mathematics courses compared to pure mathematics, and wanting to add CAD and computing classes.

The results of the survey also allowed a look at whether there is any correlation between the number of students enrolled, the number of full-time faculty present, and the number of elective courses offered. Figure 3 and Figure 4 show the number of students enrolled compared to the number of electives offered and the number of faculty present to the number of electives offered, respectively. In both cases, a positive trend is hinted, but the data is too scattered to draw any definitive conclusions. However, when student population is plotted against the number of full time faculty, there
appears to be a stronger argument for correlation based on the data gathered. This can be seen in Figure 5.

Cooperative Education

Cooperative education, also referred to as “Co-op,” is a hands-on educational experience common to many engineering programs. In this setting a student would take some time, typically in one-semester increments, to work as an intern at an engineering firm. These “courses” may or may not be used for class credit depending on the academic program. The goal is to provide the student with real-world work experience to supplement the material they were learning in their classes.

Figure 6 shows the programs considered that offer co-ops. This figure includes both the schools from which curricula were sampled, as well as data pulled from the survey. While they are not universal, the data gathered shows that co-ops in civil engineering are present in many programs. Note that some programs that do not offer options called co-ops still support other forms of internship.
The participants of the survey were given the opportunity to share their opinions of co-ops if they were offered by their institutions. The responses from those who answered this prompt were overwhelmingly positive, with only minimal negative responses, as can be seen in Figure 7. The positive responses lauded the hands-on and professional development aspects of their co-op programs, while the negative responses were answered with little or no reason why.

**ABET Revisited**

Between both the sampled programs and the data collected through the survey, 27 out of 31 programs are ABET accredited at the time of writing, as can be seen in Figure 8. Programs that were not ABET accredited were either working to attain accreditation or did not respond to the corresponding prompts on the survey. Each of the ten sampled programs featured at least 30 credits of mathematics and basic science, at least 45 credits of engineering coursework, a senior-level design class, and a general education component. Thus, they fulfilled the general requirements for engineering degrees put forth by ABET (ABET D). Furthermore, each program requires courses involving differential equations and statistics. Experiment-based laboratory classes as well as chemistry, physics, and other natural science classes are present in each curriculum. Project management and topics in leadership and economics are also present in each degree plan. Thus, the additional requirements for civil engineering degrees
set forth by ABET are fulfilled in each of the ten sample programs. This is true even for the programs that are not yet ABET accredited.

Data gathered from the survey provided opinions from the participants about ABET, its practices, and its effectiveness. The responses were mostly positive, with a few mixed and negative responses returned. This can be seen in Figure 9. Most of the positive results returned were simply affirmations that the criteria of ABET were effective, with no additional detail given. The mixed reviews were equally sparse on details, as the respondent typically answered along the lines of having no opinion either way. Only two responses were objectively negative, with one accusing ABET of losing focus on fundamental courses, and another unhappy with the amount of pure math and science courses mandated.

CEBOK3 Revisited

In addition to ABET compliance, it remains to be seen how the programs studied compare to CEBOK3 outcomes. Recall that CEBOK3 is not a standard for a program, nor is it a list of requirements, and it should not be used as such. However, it is still worthwhile to discuss its outcomes in this context.

The first group of student outcomes outlined by CEBOK3 are foundational outcomes, and include mathematics, natural sciences, social sciences, and humanities (CEBOK3). Generally, the social sciences and humanities outcomes are fulfilled by a program’s general education requirements. Chemistry, physics,
and one other area of science are present in each of the ten sampled programs, suggesting that the natural science outcome is fulfilled. The mathematics outcome suggests that students should be able to apply mathematics up to differential equations, which all programs fulfill. However, it is also recommended that students are exposed to numerical methods, which few of the programs offer for civil engineering students. The outcome details additional mathematics courses that may be of interest to civil engineers such as multivariable calculus and linear algebra, which are occasionally present in the curricula discussed here.

The second group of outcomes are engineering fundamentals, and include materials science, engineering mechanics, experimental methods and data analysis, and critical thinking and problem solving (CEBOK3). Nine out of ten of the sampled programs requires a class on engineering materials, often with an accompanying laboratory section. The engineering mechanics outcome is fulfilled in each program, as shown by the presence of statics, mechanics of materials, and fluid mechanics classes. Likewise, all programs contain laboratory-based classes in two or more civil engineering disciplines, fulfilling the undergraduate requirements of the experimental methods and data analysis outcome. However, this outcome also suggests that prospective engineers should be able to analyze experimental methods at the graduate level, which is not accomplished by any of the programs studied in this paper. By nature of engineering programs, student will develop appropriate critical thinking skills as they progress, thus fulfilling the undergraduate portion of the critical thinking outcome. This outcome also suggests an ability to analyze and synthesize these skills with the aid of mentored experience. This part of the outcome may be fulfilled in undergraduate education should a student participate in co-op or internship education as mentioned above.
The third category of outcomes describe technical skills and include project management, engineering economics, risk and uncertainty, breadth in civil engineering areas, design, depth in a civil engineering area, and sustainability (CEBOK3). Each of these outcomes, aside from depth in a civil engineering area, is fulfilled by a combination of undergraduate education and mentored experience. The undergraduate requirements may or may not be fulfilled depending on the outcome. For example, each of the ten sampled programs requires classes from at least four disciplines of civil engineering, as recommended for the breadth in civil engineering areas outcome. However, courses involving project management or sustainability are not always required, or even available. The depth in a civil engineering area also contains undergraduate and mentored experience components, but also mandates a depth of knowledge consistent with graduate level education, which is not present in the programs studied. As mentioned above, the mentored experience aspects may or may not be fulfilled during undergraduate education depending on a student’s ability and willingness to pursue co-op education.

The final category of outcomes involves professional skills which include communication, teamwork and leadership, lifelong learning, professional attitudes, professional responsibilities, and ethical responsibilities (CEBOK3). Each of these outcomes is also split between fulfillment at the undergraduate level and with mentored experience. Pertaining to the undergraduate fulfillment, these outcomes represent skills that are not simply taught in class but are practiced throughout the degree. This includes general education public speaking courses, engineering ethics courses, and senior design projects, among others. Examples of these outcomes can be found throughout most curricula. Just like above, mentored experience at the undergraduate may come with potential co-ops.
It remains to mention that some of the outcomes mentioned above include guidelines for self-development (CEBOK3). Such outcomes include sustainability and each professional outcome. The points on self-development emphasize the importance of internalizing and reflecting on why each of the relevant outcomes are necessary to civil engineering. While these are not as pertinent to a discussion on education, these points remain an important part of the CEBOK3 vision.

BEYOND THE REQUIREMENTS

Often, obtaining an undergraduate degree is only the first step in preparing a civil engineer for their career. The path most advertised to students as they leave college is professional licensure. This path along with another, graduate school, will be discussed in this section. This section will follow up with a discussion of the Engineering Report Card, a metric published by ASCE detailing the state of infrastructure in the United States.

Licensure

Professional licensure is a milestone in the careers of most engineers, civil or otherwise. In the United States, licensure is granted on a state-by-state basis. Becoming a Professional Engineer carries many benefits. Most importantly, only Professional Engineers are permitted to seal and approve any engineering work (“Advantages of Licensure”). Furthermore, this title is necessary to manage the work of other engineers, or even to form a private practice. Additional benefits, including more career opportunities, generally higher salaries compared to non-Professional Engineers, and the esteem that come with professional status, make licensure worth pursuing.

The path to becoming a Professional Engineer begins with obtaining a bachelor’s degree, this case in civil engineering. Requirements vary by state, but most require or strongly encourage that the degree is granted by an ABET-accredited program (“Engineering Licensure”). Once
someone has obtained the degree, they can sit for the Fundamentals of Engineering Exam, produced by the National Council of Examiners for Engineering and Surveying (NCEES). Upon passing the exam, the individual can work under a Professional Engineer as an Engineer in Training, or equivalent title. The Engineer in Training must work under a Professional Engineer for a set amount of time, typically four years, before they can sit for the Principles of Engineering Exam also produced by NCEES. Generally, only by passing this second exam is an individual qualified to apply for Professional Engineer licensure.

Note that the process of becoming a Professional Engineer fulfills certain CEBOK3 outcomes. First, by requiring a fixed amount of time working under a Professional Engineer, the Engineer in Training is receiving exactly the mentored experience described in many outcomes. Furthermore, Professional Engineers must continuously educate themselves to keep their licensure (“Mandatory Continuing Education”). This can come in many forms such as seminars and online courses from approved sources, such as ASCE (“Continuing Education”). This continuous education fulfills the lifelong learning outcome from CEBOK3.

**Graduate Education**

While graduate education is not currently required for civil engineering practice, it is still a path worth mentioning in this discussion. Both master’s and doctorate programs are available in this field, with the master’s degree usually offered in two modes: a Master of Science and a Master of Engineering. For the distinction between the two master’s degrees, the Master of Engineering tends to focus more on coursework while the Master of Science usually features a research component and has the possibility of continuing to a doctorate program (Case).

The idea of requiring some amount of graduate education such as a master’s degree has been discussed for several years. In 2006, NCEES had recommended that all engineers should
hold a master’s degree to be eligible for licensure by 2020 (“Revised Approach”). However, by 2014 these recommendations were removed due to confusion over the fate of comity licensure. Others have also voiced support for this requirement, citing that deeper levels of education benefit not only the engineer, but the entire practice (Killgore, et al.). Also, note that some outcomes from CEBOK3 advise some level of graduate education. However, there are still no official requirements for this level of education for licensure as of this writing.

The Infrastructure Report Card

The Infrastructure Report Card is a report published every four years by ASCE to gauge the effectiveness of the infrastructure in the United States (“Making the Grade”). The report judges various facets of the infrastructure such as energy, water quality, and roads, on a letter-grade basis along with assigning a letter grade to the infrastructure as a whole. Each category is evaluated based off a number of factors including present condition, future need, funding, and public safety, among others (“What Makes a Grade?”).

The overall grade given to infrastructure in the United States has been either a D or a D+ since 1998 (“Report Card History”). This grade is reflected across all facets measured, with only rail systems earning a B in 2017, and every other aspect of the infrastructure earning a C+ or lower. A report published alongside the 2017 edition of the Report Card states that the largest contributor to the poor state of infrastructure is a lack of funding (“Infrastructure Report Card”). While the situations described by the Report Card are far from ideal, the existence of the Report Card highlights one aspect of a civil engineer’s education. The evident professionalism and sense of ethics required for a society like ASCE to judge its own profession are characteristics that are fostered in engineers beginning at the undergraduate level.
CONCLUSIONS

Recall that goal of this paper is to analyze the education requirement for civil engineers. In doing so, the first step was to present minimum standard requirements for undergraduate education in ABET, as well as a set of guidelines to strive for in CEBOK3. Following this, current educational practices were examined by means of surveys taken by academics in civil engineering and a study of ten civil engineering undergraduate curricula. Finally, these points were supplemented by glimpses of civil engineering beyond the degree.

The data gathered through both methods revealed that all programs considered met the curriculum requirements presented by ABET, even if they were not accredited. It was also demonstrated that most of the programs represented here fulfilled many of the outcomes from CEBOK3, yet no program fulfilled all undergraduate outcomes. Thus, the data suggests that most civil engineering programs exceed minimum requirements and fall somewhere between these requirements and guidelines for the future. Moreover, it was shown that education in civil engineering continues past the undergraduate degree either formally, as in graduate school, or in terms of self-development to maintain licensure.

Clearly, civil engineering is a profession that is aware of its need to evolve in time. The programs with which its members are educated are not perfect, but there are systems in place to establish a uniform baseline while also providing room to grow. Furthermore, civil engineers are supported past the undergraduate level with multiple avenues to continue their education. Thus, it is clear that the education of civil engineers is sufficient to prepare its students for the industry today and, should the systems in place continue to hold, prepare its students for the ever-changing future.
APPENDIX A: Survey

Section I: Student and Program Information

1. How many students have enrolled in your undergraduate civil engineering program in each of the past five years? In your graduate program?

2. How many students are currently enrolled in your civil engineering undergraduate and graduate programs?

3. Does your school provide cooperative education opportunities to its students? If so, what is the typical distribution of cooperative education assignments among the fields of civil engineering?

4. How many civil engineering students have graduated from your undergraduate program in each of the past five years? In your graduate program? What is the typical distribution of graduates among the fields of civil engineering?

5. How many total classes/credit hours are required for a student to graduate from your civil engineering program?

6. How many classes specific to each field of civil engineering are required for a student to graduate from your civil engineering program?

7. If your school is ABET certified, how many classes does your school offer beyond those required to meet ABET specifications?

8. How many civil engineering related student groups are present at your school?

9. How many undergraduate students are conduction research at your school? Graduate students?
Section II: Personal Opinions

1. What is your opinion of your school’s civil engineering curriculum? Do you think it adequately prepares your students to prepare for the challenges facing civil engineers today?

2. What would you change about your school’s civil engineering curriculum if you had the power to do so?

3. If your school is ABET accredited, to what extent do you agree with ABET recommendations? Do you believe they prepare your students for the challenges facing civil engineers today?

4. If your school offers a cooperative education program, do you feel that the exposure to professional practice is beneficial to your student’s education?

5. What are your opinions on the state of research at your school?

6. Please share any other thoughts you may have related to the civil engineering program at your school.
APPENDIX B: Sampled Curricula

CALIFORNIA STATE UNIVERSITY, FRESNO
www.fresnostate.edu

*Denotes Laboratory sections paired with another class. Not tallied under these circumstances.

Required Courses:

Construction:
- Construction Engineering I
- Project Design

Environmental:
- Environmental Engineering
- Environmental Engineering Laboratory*

Geotechnical:
- Soil Engineering
- Soil Engineering Laboratory*

Structural:
- Engineering Mechanics: Statics
- Mechanics of Materials
- Mechanics of Materials Laboratory*
- Concrete Laboratory
- Theory of Structures
- Reinforced Concrete Design
- Design of Steel Structures
- Engineering Mechanics: Dynamics

Transportation:
- Transportation Planning and Design

Water Resources:
- Civil Engineering Hydraulics
- Engineering Hydraulics Laboratory*

Surveying:
- Engineering Surveying
- Engineering Surveying Laboratory*

Mathematics:
- Calculus I
- Calculus II
- Calculus III
- Elementary Differential Equations with Linear Algebra

CAD/Coding:
- Computer Applications in Civil Engineering

Elective Courses:

Construction:
- Boundary Controls and Legal Principles

Environmental:
- Design of Water Quality Control Processes
- Design of Wastewater Management Systems

Geotechnical:
- Geotechnical Engineering Design
- Foundation Design

Structural:
- Design of Timber Structures
- Intermediate Theory of Structures
- Seismic Analysis of Building Structures

Transportation:
- Pavement Design
- Introduction to GIS
- Transportation Geographic Information System
- Traffic Operations and Control
- Transportation Engineering Materials

Water Resources:
- Water Resources Engineering
- Urban Stormwater Management
- Hydrology

Surveying:
- Computer-Aided Mapping

CAD/Coding:
- Engineering Graphics
- Computer-Aided Construction Detailing

Figure 10: Relevant required and elective courses at California State University, Fresno.
**Required Courses:**

**Environmental:**
- Environmental Engineering I: Fundamentals
- Environmental Engineering Laboratory*

**Geotechnical:**
- Introduction to Soil Mechanics
- Soil Mechanics Laboratory*
- Introduction to Foundation Engineering

**Structural:**
- Materials for Civil Engineering
- Materials for Civil Engineering Laboratory*
- Analytical Mechanics I (Statics)
- Analytical Mechanics II (Dynamics)
- Structural Analysis I
- Reinforced Concrete Design I
- Mechanics of Deformable Bodies

**Transportation:**
- Transportation Safety and Stability
- Transportation Engineering

**Water Resources:**
- Fluid Mechanics
- Engineering Hydraulics

**Surveying:**
- Surveying and Mapping
- Surveying and Mapping Laboratory*

**Mathematics:**
- Calculus I
- Calculus II
- Calculus III
- Applied Mathematics I
- Probability and Statistics in Civil Engineering

**CAD/Coding:**
- Computer Programming and Civil Engineering
- Computer Programming and Civil Engineering Laboratory*
- Engineering Design Graphics
  or Engineering Design Graphics – AutoCAD

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**Elective Courses:**

**Environmental:**
- Fundamentals of Groundwater Flow and Contaminant Transport
- Environmental Engineering II: Unit Processes
- Environmental Systems Design

**Geotechnical:**
- Retaining Wall and Slope Stability
- Introduction to Geotechnical Earthquake

**Structural:**
- Structural Steel Design
- Timber Design
- Structural Analysis II
- Seismic Design
- Mechanical Properties of Materials Laboratory

**Transportation:**
- Highway Design
- Highway Design Laboratory*
- Highway Engineering Materials
- Highway Engineering Materials Laboratory*
- Traffic Engineering
- Traffic Engineering Laboratory*

**Water Resources:**
- Hydrology and Water Resources Engineering
- Hydraulic Engineering Design I
- Hydraulic Engineering Design I Laboratory*
- Fluid Mechanics Laboratory

**Surveying:**
- GIS Laboratory for Civil Engineers
**DREXEL UNIVERSITY**
drexel.edu

**Required courses:**

**Construction:**
Engineering Economic analysis

**Environmental:**
Introduction to Environmental Engineering

**Geotechnical:**
Soil Mechanics I
Soil Mechanics II

**Structural:**
Fundamentals of Materials
Construction Materials
Structural Analysis I
Structural Design I
Structural Material Behavior
Statics
Dynamics
Mechanics of Materials I

**Water Resources:**
Introduction to Fluid Flow
Hydraulics
Hydrology

**Mathematics:**
Calculus I
Calculus II
Multivariate Calculus
Statistical Analysis of Engineering Systems

**CAD/Coding:**
Introductory Programming for Engineers
or Programming for Engineers
Linear Engineering Systems
Dynamic Engineering Systems

**Elective Courses:**
Drexel University requires elective courses but does not list the courses that can be used to meet this requirement.

**Figure 12:** Relevant required courses at Drexel University.
**Fairleigh Dickinson University**

www.fdu.edu

**Note:** This program is not ABET-accredited. However, they will seek accreditation at their earliest opportunity.

**Required Courses:**

**Construction:**
- Construction Materials and Systems
- Managerial and Engineering Economic Analysis
- Project Management in Engineering and Technology

**Environmental:**
- Environmental Engineering
- Environmental and Land Use Planning

**Geotechnical:**
- Foundations
- Soil Mechanics

**Structural:**
- Statics
- Strength of Materials
- Dynamics
- Structural Analysis
- Concrete Structures
- Advanced Concrete Design
- Steel Structures
- Advanced Steel Design

**Transportation:**
- Transportation Engineering

**Water Resources:**
- Fluid Mechanics

**Surveying:**
- Surveying I

**Mathematics:**
- Calculus I
- Calculus II
- Calculus III
- Differential Equations
- Linear Algebra
- Engineering Statistics and Readability

**CAD/Coding:**
- Introduction to CAD
- Programming Languages in Engineering

**Figure 13:** Relevant required and elective courses at Fairleigh Dickinson University.

**Elective courses:**

**Construction:**
- Estimating I
- Contracts and Specifications

**Structural:**
- Bridge Design
- Engineering Materials I
- Stress and Vibration Analysis

**Transportation:**
- Signals and Systems I

**Surveying:**
- Surveying II
**Required Courses:**

**Construction:**
- Engineering and Economic Models in Civil Engineering
- Construction Systems
- Professional Practice and Management in Engineering

**Environmental:**
- Environmental Engineering and Science
- Ecological Applications

**Geotechnical:**
- Soil Mechanics

**Structural:**
- Statics
- Mechanics of Materials
- Structural Analysis

**Transportation:**
- Introduction to Transportation Engineering

**Water Resources:**
- Hydraulics
- Water Resources Engineering

**Surveying:**
- Geomatics and Engineering Graphics

**Mathematics:**
- Analytic Geometry Calculus I
- Analytic Geometry Calculus II
- Analytic Geometry Calculus III
- Elementary Differential Equations
- Probability and Statistics for Engineers and Scientists

**Elective Courses:**

**Construction:**
- Construction Administration
- Construction Cost Estimating
- Construction Planning and Scheduling
- Construction Safety and Risk Management
- Construction Planning and Scheduling

**Environmental:**
- Environmental Engineering Systems
- Water and Wastewater Treatment Processes
- Sustainable Water Resources Infrastructure in Developing Countries

**Geotechnical:**
- Foundation Design
- Engineering Geology

**Structural:**
- Structural Steel Design
- Reinforced Concrete Design
- Structural Modeling for Engineers

**Transportation:**
- Traffic Engineering
- Urban Transportation Planning
- Highway Design and Construction

**Water Resources:**
- Water Supply and Distribution
- Open Channel Flow
- Water Resources Planning and Design

**Surveying:**
- Remote Sensing in Civil Engineering

**CAD/Coding:**
- Building Information Modeling
- Construction Computer Application and Informatics

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**Figure 14:** Relevant required and elective courses at George Mason University.
**Required Courses:**

**Construction:**
Engineering Economics
Engineering Project Management

**Environmental:**
Environmental Engineering I

**Geotechnical:**
Soil Mechanics Lecture
Soil Mechanics Laboratory*

**Structural:**
Statics
Dynamics
Material Science
Mechanics of Materials Lecture
Mechanics of Materials Laboratory*
Basic Structural Analysis

**Transportation:**
Transportation Engineering

**Water Resources:**
Fluid Mechanics Lecture
Fluid Mechanics Laboratory*
Water Resources Engineering

**Mathematics:**
Calculus I
Calculus II
Calculus III
Probability and Statistics
Differential Equations

**CAD/Coding:**
Civil Engineering Software and Design

**Elective Courses:**

**Construction:**
Construction Project Managing

**Environmental:**
Unit Operations in Environmental Engineering
Transport Phenomena
Water and Wastewater Treatment
Aquatic Chemistry

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**Figure 15:** Relevant required and elective courses at Howard University.

<table>
<thead>
<tr>
<th>Standard Disciplines</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required</td>
<td>Elective</td>
</tr>
</tbody>
</table>

**Geotechnical:**
Foundation Engineering
Advanced Foundations
Introduction to Rock Mechanics and Tunneling
Forensic Geotechnical Engineering

**Structural:**
Reinforced Concrete Design
Structures Project Research
Steel Design
Special topics in Structural Engineering
Introduction to Structural Protection Systems

**Transportation:**
Traffic Engineering I
Traffic Engineering II
Advanced Traffic Engineering
Intelligent Transportation Systems

**Water Resources:**
Advanced Hydrology
Hydraulic Project Research

**Mathematics:**
Numerical Analysis
Required Courses:

Construction:
Construction Management

Environmental:
Environmental Engineering
Environmental Engineering Laboratory*

Geotechnical:
Soil Mechanics
Soil Mechanics Laboratory*
Foundation Engineering

Structural:
Statics
Dynamics
Strength of Materials
CE Materials
CE Materials Laboratory*
Structural Analysis
Design of Concrete Structures

Transportation:
Transportation Engineering

Water Resources:
Fluid Mechanics
Fluid Mechanics Laboratory*
Hydraulics Engineering

Surveying:
Introduction to Geomatics

Mathematics:
Analytic Geometry and Calculus I
Analytic Geometry and Calculus II
Multivariate Calculus
Elementary Linear Algebra
Differential Equations
Statistical Methods

Elective courses:

Construction:
Advanced Construction Management
Management of Organizations and People
Management Science
Urban Management Systems
Engineering Economics

Environmental:
Water and Wastewater Engineering
Solid Waste Management
Advanced Water Treatment Processes
Introductory Inorganic Chemistry
Organic Chemistry
Environmental and Urban Geology

Geotechnical:
Advanced Geotechnical Engineering
Structural Geology
Principles of Hydrogeology

Structural:
Design of Steel Structures
Finite Element Analysis
Bridge Design
Advanced Structural Mechanics
Vibrations analysis

Transportation:
Urban Transportation Planning
Traffic Engineering

Water Resources:
Intermediate Fluid Mechanics

Surveying:
GIS for Public and Environmental Affairs
Land Surveying and Subdivision

Mathematics:
Applied Regression Analysis
**THE CITADEL, THE MILITARY COLLEGE OF SOUTH CAROLINA**
www.citadel.edu

**Required Courses:**

**Construction:**
- Engineering Management
- Construction Engineering
- Engineering Economy

**Environmental:**
- Water and Wastewater Systems
- Introduction to Environmental Engineering
- Environmental Engineering Laboratory*

**Geotechnical:**
- Introduction to Geotechnical Engineering
- Geotechnical Engineering Laboratory*
- Geotechnical Engineering II

**Structural:**
- Statics
- Dynamics
- Mechanics of Materials
- Materials Laboratory*
- Reinforced Concrete Design
- Structural Analysis
- Asphalt and Concrete Laboratory

**Transportation:**
- Transportation Engineering
- Highway Engineering

**Water Resources:**
- Fluid Mechanics
- Fluid Mechanics Laboratory*
- Hydrology and Hydraulics

**Surveying:**
- Surveying
- Surveying Laboratory*
- Geospatial representation
- Geomatics Laboratory*

**Mathematics:**
- Analytic Geometry and Calculus I
- Analytic Geometry and Calculus II
- Analytic Geometry and Calculus III
- Applied Engineering Mathematics I
- Probability and Statistics for Civil and Construction Engineering

**CAD/Coding:**
- Computer Application for Civil and Environmental Engineering
- Engineering Drawing

**Elective Courses:**
The Citadel does not require elective courses.

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**Figure 17:** Relevant required courses at The Citadel, The Military College of South Carolina.
**Required Courses:**

**Construction:**
Introduction to Construction

**Environmental:**
Fundamentals of Environmental Engineering

**Geotechnical:**
Geotechnical Engineering I

**Structural:**
Analytical Mechanics I
Analytical Mechanics II
Mechanics of Materials I
Structural Analysis

**Water Resources:**
Theoretical Fluid Mechanics
Hydraulic Engineering

**Surveying:**
Introduction to Geomatics

**Mathematics:**
Calculus I for Engineers
Calculus II for Engineers
Calculus III for Engineers
Introduction to Linear Algebra and Differential Equations
Probability Statistics and Decision for Civil Engineers

**CAD/Coding:**
Introduction to Engineering Computing
or Computing Elective
Civil Engineering Drawing
or Engineering Drawing

**Elective Courses:**

**Construction:**
Construction Engineering
Project Management I: Construction Project Planning
Project Management II: Construction Project Execution and Control

**Environmental:**
Water and Wastewater
Water Chemistry
Water Chemistry Laboratory*
Introduction to Applied Ecology
Hazardous and Industrial Waste Management

![Figure 18: Relevant required courses at University of Colorado, Boulder.](chart)

- **Standard Disciplines**
  - Required
  - Elective

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Required Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td>Introduction to Construction</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>Fundamentals of Environmental Engineering</td>
</tr>
<tr>
<td><strong>Geotechnical</strong></td>
<td>Geotechnical Engineering I</td>
</tr>
<tr>
<td><strong>Structural</strong></td>
<td>Analytical Mechanics I</td>
</tr>
<tr>
<td><strong>Water Resources</strong></td>
<td>Theoretical Fluid Mechanics</td>
</tr>
<tr>
<td><strong>Surveying</strong></td>
<td>Introduction to Geomatics</td>
</tr>
<tr>
<td><strong>Mathematics</strong></td>
<td>Calculus I for Engineers</td>
</tr>
<tr>
<td><strong>CAD/Coding</strong></td>
<td>Introduction to Engineering Computing</td>
</tr>
</tbody>
</table>

**Environmental:**

- Water and Wastewater
- Water Chemistry
- Water Chemistry Laboratory*
- Introduction to Applied Ecology
- Hazardous and Industrial Waste Management

**Geotechnical:**

- Geotechnical Engineering II
- Foundation Design
- Design of Earth Structures

**Structural:**

- Steel Design
- Reinforced Concrete Design
- Mechanics of Materials II
- Analysis of Framed Structures

**Water Resources:**

- Engineering Hydrology
- Ground Water Engineering’
- Modeling of Hydrologic Systems
- Groundwater Modeling
- Water Resources Engineering Design
Required Courses:

Environmental:
Introduction to Environmental Engineering

Geotechnical:
Geotechnical Engineering
Geotechnical Engineering Laboratory*
Foundations and Earth Retaining Systems

Structural:
Mechanics of solids I
Mechanics of Solids II
Structural Laboratory
Structural Analysis
Concrete Structures
Steel Structures

Transportation:
Transportation Engineering I
Transportation Engineering II

Water Resources:
Fluid Mechanics
Water Resources Engineering I
Water Resources Engineering II
Water Quality Control Systems

Surveying:
Introduction to Engineering II: Surveying
Geographic Information Systems for Engineers

Mathematics:
Calculus I for Engineers
Calculus II
Calculus III
Applied Probability and Statistics
Introduction to Ordinary Differential Equations

Elective courses:

Structural:
Advanced Design of Concrete Structures
Advanced Design of Steel Structures

Note: University of Miami requires several elective courses but does not post a list of all courses that can be used to meet these requirements.
APPENDIX C: References


“ Bachelor of Science in Civil Engineering.” Miami.edu. University of Miami. Web. 24 April, 2020002E


“Civil and Infrastructure Engineering, BS.” GMU.edu. George Mason University. 24 April 2020.


