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From Disciplinary to Multidisciplinary Programs: Educational Outcomes, BOK's, and Accreditation

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Abstract

Over the last several decades, and in response to a variety of drivers, departments of civil engineering at universities across the United States have expanded and many now support multiple degrees. Over the same time period, ABET's Engineering Criteria 2000 introduced outcomes-based assessment to the accreditation process for engineering degree programs[1]. In today's environment, many departments of civil engineering face the challenges of: (a) supporting multiple, interdisciplinary degree programs, (b) updating and keeping their programs current with ASCE's latest Body of Knowledge (BOK) and (c) managing the continuous assessment and improvement activities associated with ABET accreditation. *We believe that civil engineering departments will continue to evolve into multi-disciplinary, sustainable infrastructure programs, and that a new vision for a multi-disciplinary BOK is needed*. While a complete vision for a new multi-discipline BOK is beyond the scope of this work, some characteristics of such a vision are developed and presented. This paper presents a case study from The University of Alabama Civil Engineering Department from 2005 through 2015. During this period, the department and its programs were expanded and transformed. Among the most important lessons we learned were: (1) design definitions vary across disciplines and departments need to explicitly develop design guidelines across all programs offered, (2) significant efficiency can be gained by developing one set of Program Education Objectives and Outcomes encompassing all programs offered, and (3) capstone design classes will need much attention to detail if a single class is for multiple degree programs

Introduction

Over the last several decades, and in response to a variety of drivers, departments of civil engineering at universities across the United States have expanded and many now support multiple degrees. Over the same time period, ABET's Engineering Criteria 2000 introduced outcomes-based assessment to the accreditation process for engineering degree programs[1]. During first six year cycle of ABET Engineering Criteria 2000 assessment, The America Society of Civil Engineers (ASCE) released their first Body of Knowledge (BOK) in 2004 [2]. Engineering professions and professional societies develop Bodies of Knowledge (BOKs) or similar documents to define the knowledge, skills, and attitudes needed to successfully enter professional practice. BOKs also are used by professional societies to inform and develop ABET accreditation standards for engineering education. Therefore, they influence how collegiate engineering curricula are developed and assessed.

In today's environment, many departments of civil engineering face the challenges of: (a) supporting multiple, interdisciplinary degree programs, (b) updating and keeping their programs current with ASCE's latest BOK, and (c) managing the continuous assessment and improvement

activities associated with ABET accreditation. *We believe that civil engineering departments will continue to evolve into multi-disciplinary, sustainable infrastructure programs, and that a new vision for a multi-disciplinary BOK is needed*. The transition from discipline-focused objectives to multi-disciplinary objectives presents significant challenges to academic departments. This is especially true given that each degree program will be separately accredited using what is likely to be a single discipline approach.

We present a case study from The University of Alabama Civil Engineering Department from 2005 through 2015. During this period, the department and its programs were expanded and transformed through: (a) adopting a new set of Program Educational Objectives (PEOs) and Student Outcomes, (b) the addition of three more undergraduate degrees, (c) the development of a single set of harmonized PEOs and learning outcomes for four programs, (d) the development of shared capstone design classes across multiple degree plans, and (e) the use of an integrated, multiple program ABET Self Study Report. As we present this case study, we will analyze common challenges, extract lessons, and make recommendations

While a complete vision for a new multi-discipline BOK is beyond the scope of this work, we will develop and present some characteristics of such a vision. We recommend characteristics of a new civil engineering discipline BOK that will support a multi-disciplinary infrastructure BOK. Several lessons will be presented from our case study in developing a single set of outcomes supporting four degree programs.

Background

As we consider multi-disciplinary programs in sustainable infrastructure, we will focus on the disciplines of Civil Engineering (CE) and its sub-disciplines of: Construction Engineering (ConE), Architectural Engineering (ArchE), and Environmental Engineering (EnvE). The University of Alabama is managing a set of B.S. degrees in these four program areas with a single faculty and a single set of outcomes. According to the ABET , as of January 2015, there are 240 universities and colleges in the United States offering accredited programs in civil engineering. There are also 16 accredited programs in Construction Engineering, 17 in Architectural Engineering, and 68 in Environmental Engineering[3]. There are 77 U.S. universities that offer two of these four degree programs, and currently 12 that offer three. Figure 1 indicates how the number of universities offering multiple degrees in the infrastructure area has grown since the start of accreditation and Table 1 lists those universities offering three of the four accredited programs in the "infrastructure engineering disciplines."[3] As of January 2015, no university offers all four of these accredited programs, and we believe the University of Alabama will be the first after we proceed through ABET evaluation and achieve accreditation in 2017.

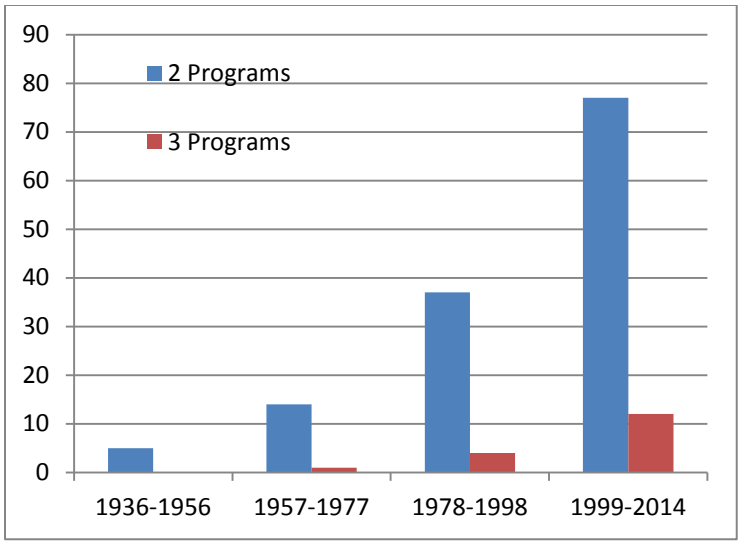


Figure 1. Growth in Universities with Multiple Programs in CE, ConE, ArchE, or EnvE [3]

Table 1 Initial Accreditation Dates for Infrastructure-Related ABET/EAC Accredited Programs[1]

	CE	ConE	ArchE	EnvE
California Polytechnic State University, San Luis Obispo	10/01/1973		10/01/1975	10/01/1971
North Carolina State University at Raleigh	10/01/1936	10/01/1958		10/01/1993
Pennsylvania State University	10/01/1936		10/01/1936	05/01/2000
Purdue University at West Lafayette	10/01/1936	10/01/1984		10/01/2012
San Diego State University	10/01/1964	10/01/2008		10/01/2002
Texas A&M University - Kingsville	10/01/1980		10/01/2009	10/01/2011
University of Central Florida	10/01/1982	10/01/2007		10/01/1972
University of Colorado at Boulder	10/01/1936		10/01/1936	10/01/2001
University of Miami	10/01/1960		10/01/1962	10/01/1997
University of Oklahoma	10/01/1936		10/01/1960	10/01/1995
Drexel University	10/01/1936		10/01/1989	10/01/2000
Missouri University of Science and Technology	10/01/1936		10/01/2004	10/01/2005

ABET Accreditation General Criterion 3: Student Outcomes

All ABET/EAC accredited programs, including the four of interest here (CE, ConE, ArchE, and EnvE) must meet the same General Criterion 3 Student Outcomes as shown in Table 2 below.[5] The program specific criteria are developed for ABET by a lead agency, sometimes with the assistance of cooperating agencies. The American Society for Civil Engineers (ASCE) is the lead agency for the Program Specific Criteria for Civil Engineering, Construction Engineering, and Architectural Engineering. The American Academy of Environmental Engineers and Scientists (AAEES) is the lead agency for the Environmental Engineering Program Specific Criteria. The program specific criteria only address curricula and faculty. It is the program criteria for curricula that are of critical importance to crafting Program Educational Objectives (PEOs) and for developing the assessable outcomes for each degree program.

Table 2 EAC/ABET General Criterion 3(a) through (k) Student Outcomes [5]

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

History and Development of the Civil Engineering Body of Knowledge

ASCE published the first edition of the *Civil Engineering Body of Knowledge for the 21st Century*[2] (BOK1) in 2004. The BOK1 presented 15 outcomes that defined the knowledge, skills, and attitudes envisioned for future entry into the practice of civil engineering at the professional level. The BOK1 was the basis for changes to the ABET/EAC Civil Engineering Program Criteria (CEPC) effective for the 2008/2009-accreditation cycle. Recognizing ABET's six-year accreditation cycle, all civil engineering now have been evaluated for accreditation under the BOK1-informed ABET criteria.

In 2008, ASCE published the second edition of the *Civil Engineering Body of Knowledge for the 21st Century*[4] (BOK2). The BOK2 increased the number of outcomes from 15 to 24. Some outcomes from the BOK1 were split into 2 or more outcomes for the BOK2, while other outcomes were new additions to the BOK. In 2012, ASCE organized the Civil Engineering Program Criteria Task Committee (CEPCTC) with a charge to develop and propose new Civil

Engineering Program Criteria. The CEPCTC completed this charge in the summer of 2014 with proposed new CEPC[4] now available for public comment through ABET. Following ABET/EAC procedures, the proposed CEPC, once approved on second reading by the ABET, would go into effect for the 2016/2017-accreditation cycle.

Since the BOK defines the knowledge, skills, and attitudes envisioned for future entry into the professional practice of civil engineering, it is recognized that the BOK must be regularly reviewed and, as necessary, updated. To address how this should be done in an effective and fair manner, ASCE created a BOK-Accreditation Strategic Planning Committee. This committee released a report[6] in 2010 recommending "an eight-year cycle for the periodic review, revision (if necessary), and publication of the Civil Engineering Program Criteria." Each eight-year cycle would begin with a four-year focus on improvements to the Civil Engineering Body of Knowledge, followed by a four-year focus on the Civil Engineering Program Criteria." Given the new Civil Engineering Program Criteria based on the BOK2 are set to go into effect for 2016/2017, the recommended eight-year cycle then implies a new BOK committee will be established in 2016 with a target publishing date of 2019[7].

Expanding from One to Two degrees

In 2005, the University of Alabama, Department of Civil Engineering, offered one undergraduate degree: a BS in Civil Engineering that had been continuously accredited since 1931. The department civil engineering learning outcomes are shown in Table 3. This set of student outcomes was influenced primarily by ABET, but also through a member faculty's participation in ASCE's BOK. The department not only wanted to comply with minimum criteria expressed in ABET but to embrace and foster some of the more aspirational aspects of the original BOK. Note that the year 2005 outcomes used the ASCE BOK convention of Bloom's Taxonomy to indicate learning level. Also, the EAC/ABET Criteria 3(a) through 3(k) are restated when appropriate to convey the context of the civil engineering program and to merge smoothly with the program specific outcomes.

In 2005, a program of construction engineering was established with approval of the Alabama Commission on Higher Education and the University of Alabama Board of Trustees. An initial self-study report was submitted in 2009 for the 2009/2010 accreditation cycle. This self-study report used a separate set of construction engineering program outcomes that was parallel to but different from the original set of department outcomes only covering civil engineering. The construction engineering program received accreditation (with a retroactive date of October 2007) through September 2012. A reaccreditation report was submitted in June 2011 to address shortcomings identified in the final statement of the 2009-2010 report. The program then received accreditation through September 2014, at which point it was on schedule with all the programs in the College of Engineering (including the original CE program).

Table 3 CE Program Outcomes in 2005

Upon completuion of the program, graduates of the University of Alabama Bachelor of Science in Civil Engineering program will be able to:	
Technical Outcomes	
Outcome T1:	**Solve** problems in mathematics through differential quations, probability, and statistics, calculus-based physics, and general chemistry. (Level 4)
Outcome T2:	**Select** and conduct civil engineering experiments to meet a need, and analyze and evaluate the resulting data. (Level 3)
Outcome T3:	**Apply** relevant knowledge, techniques, skills, and modern engineering tools to identify, formulate, and solve engineering problems in at least four technical areas appropriate to civil engineering. (Level 4)
Outcome T4:	**Design** a system or process in more than one civil engineering context to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability. (Level 5)
Outcome T5:	**Predict** possible global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution. (Level 5)
Outcome T6:	**Function** effectively as a member of a multidisciplinary team (Level 3)
Outcome T7:	**Define** key aspects of at least one traditional or emerging area of advanced specialization appropriate to civil engineering.(Level 1)
Professional Outcomes	
Outcome P1:	**Analyze** a situation involving multiple conflicting professional and ethical interests determine an appropriate course of action. (Level 4)
Outcome P2:	**Organize** and deliver effective written, verbal, graphical and virtual communications (Level 4)
Outcome P3:	**Demonstrate** the ability to learn through independent study, without the aid of formal instructions (Level 3)
Outcome P4:	**Demonstrate** the ability to incorporate contemporary issues, into the identification, formulation, and solution of an engineering problem (Level 3)
Outcome P5	**Explain** the importance of licensure, and basic concepts in engineering management, business, public policy, and leadership (Level 3)

As a result of expanding the department's programs and the necessary new program accreditation, the department adopted an informal philosophy to help it accomplish its mission statement and PEOs. It is this philosophy which developed in the 2007 time-frame that informs all programmatic activity in the department to this day. The philosophy is simple, "one department, one faculty, (x) degrees." Informed by this underlying value and philosophy, the faculty decided that there would only be ONE set of PEOs and ONE set of student learning outcomes for all of the accredited programs in the department. This decision was made to enhance the already strong sense of cohesion and cooperation of the department and to increase the efficiency of maintaining multiple accredited programs.

While the faculty embraced expansion into a second accredited program area, there were, of course, concerns about supporting two degrees and continuing to grow both undergraduate and graduate student populations as well as graduate research activities. The department faculty was

concerned that adding the second degree may increase faculty workload, especially with regard to accreditation activities of assessment and continuous improvement. By having ONE set of PEOs and outcomes, only one process was needed for accreditation and that would be supported by the entire faculty. This was deemed to be a more efficient way forward as well as supporting our core value of maintain faculty integrity as a single unit. From this point in time forward the department was committed to a single ABET Self Study Report and a single, department-wide ABET process.

In 2007, the faculty voted to integrate the new construction engineering student outcomes with the civil engineering outcomes to create a single, integrated and harmonized set of student outcomes for both programs. These outcomes were strongly influenced by ASCE's BOK, and of course by the EAC/ABET Criteria 3(a)-3(k) general criteria and program-specific curriculum criteria. As, the construction engineering profession (represented in ABET by ASCE's Construction Institute's Education Committee) does not have a separate BOK, it is not surprising that the structure of the departments' outcomes echoes that of the ASCE BOKI with its introduction of foundational outcomes and continued refinement of Bloom's Taxonomy. The primary assessment mechanism for these outcomes is the use of a student generated graduation portfolio that displays and explains the student's accomplishment of the outcomes through the use of example work from classes.

In 2009 and 2010 the faculty (with the support of the department's external board of visitors) made a number of changes in the departmental PEOs, outcomes and curricula to accommodate : (a) the release of ASCE BOK II, (b)a change of credit hours 132 to 125 in response to the University of Alabama lowering the "full-time load" for students to 16 hours/semester, (c) increasing numbers of students, (d) to communicate program specific criteria more explicitly, and (e) to reflect lessons learned during the departmental assessment of outcomes using student portfolios. Table 4 shows the single set of departmental outcomes for both the CE and ConE program introduced in 2010. Note that when the program specific criteria need to be reflected in a degree, the words "civil engineering" or "construction engineering" are used. A careful comparison of Table 4 to each of the ABET program specific criteria indicates that there are places where the joint outcomes move beyond what one or the other single program specific criteria state. For example, ASCE changed the civil engineering criteria to include the phrase "one additional area of natural science." Such a parallel phrase is not found in the construction-engineering criteria. However, the faculty decided that having uniform curricula in the first two years of each degree program was of sufficient value to require the additional science for both programs.

ABET Review of the Newly Added Second Degree Program (ConE)

In 2010, the faculty approved several changes to the BS ConE curricula largely as a result of the initial ABET evaluation of this new degree. The changes focused around changing a number of elective courses in this program to required courses in order in insure that all ConE students met all of the ABET criteria in the specific context of the practice of construction engineering.

This evaluation raised the issue that different disciplines and programs housed within a single department may view design differently. Even though design may be appropriately included the department's shared outcomes, when assessed in a single-discipline context, it might not be of

the type a PEV trained in a particular program evaluation may be expecting. This contextual nature of the subtle difference in design definition from program to program became an area of preparation before the 2013/2014 ABET cycle and will be discussed below.

Table 4 Single Set of Department Outcomes for CE and ConE Programs 2010

Foundational Outcomes

- F1 (Level 3): **Solve** problems in mathematics through differential equations, probability and statistics, calculus-based physics, general chemistry, and one additional area of science.
- F2 (Level 3): **Explain** the importance of (1) humanities, literature, and fine arts, and (2) history and social and behavioral science.

Technical Outcomes

- T1 (Level 4): **Analyze** and **solve** problems in material science and engineering mechanics.
- T2 (Level 4): **Select** and **conduct** program relevant civil or construction engineering experiments to meet a need, and **analyze** and **evaluate** the resulting data.
- T3 (Level 3): **Appl**y relevant knowledge, techniques, skills, and modern engineering tools to **identify**, **formulate**, and **solve** engineering problems, including:
  BSCE – problems in at least four technical areas appropriate to civil engineering.
  BSConE –problems in construction processes, communications, methods, materials, systems, equipment, planning, scheduling, safety economics, accounting, cost analysis and control, decision analysis, and optimization.
- T4 (Level 3): **Explain** the impact of historical and contemporary issues on civil or construction engineering.
- T5 (Level 3): **Develop** solutions to well-defined project management problems within civil or construction engineering.
- T6 (Level 5): **Develop** a system or process in more than one program-relevant civil or construction engineering specialty field to meet desired needs, including sustainability and within other realistic constraints such as economic, environmental, social, political, ethical, health and safety, and constructability.
- T7 (Level 2): **Explain** key aspects of at least one traditional or emerging program-relevant area of advanced specialization.

Professional Practice Outcomes

- P1 (Level 4): **Analyze** a situation involving multiple conflicting professional, legal, and ethical interests to **determine** appropriate course of action.
- P2 (Level 4): **Organize** and **deliver** effective written, verbal, graphical and virtual communications.
- P3 (Level 3): **Demonstrate** the ability to learn through independent study, without the formal aid of instruction.
- P4 (Level 3): **Demonstrate** attributes supportive of the professional practice of engineering; **apply** leadership principles to direct efforts of a small group to solve a relatively constrained problem, and **function** effectively as a member of a multidisciplinary team to solve open-ended engineering problems.
- P5 (Level 2): **Explain** the importance of licensure, and basic concepts in engineering management, business, law, public administration, public policy, and globalization as related to the professional practice of civil or construction engineering.

ABET Evaluation of Both CE and ConE Programs in the 2013/2014 Cycle

A single ABET report for the 2013/2014 accreditation cycle was written for both the CE and ConE programs. It included the single set of PEOs and outcomes (listed in Table 3). However,

the single report was clerically split into separate reports one for each program at the request of the PEVs. As the faculty prepared for the 2013/2014 visit, after submitting the initial report, several actions were taken to improve the department's assessment process.

In the Fall of 2013, the faculty submitted requests for establishing new programs in Architectural and Environmental Engineering to the Board of Trustees. The Board approved the request to submit a proposal and the State of Alabama Commission of Higher Education started the process of approving these programs. As part of preparing for the addition of these new degrees, the faculty did one more restructuring of the department's single set of integrated outcomes (Table 5).

Table 5 showcases the "one department, one faculty, four degree" philosophy of this department. The use of Bloom's Taxonomy was now more common practice in BOKs and in ABET vernacular and is used throughout Table 5. Table 5 displays the unified graduation level outcomes for all four undergraduate degrees offered by the UA Department of Civil, Construction, and Environmental Engineering. Wording in this table is a careful blend of meeting each program's ABET criterion while trying to keep the aspirational components of the ASCE BOK II and the AAEES's BOK. The phrase "within the discipline" is used to indicate that the particular outcome is in the context of the specific program (CE, ConE, ArchE, or EnvE). The only separate mention of the individual program criteria is in Outcome T3 "Tools and Solving Problems" as each of the four programs has very specific language there. While Table 5 displays only the graduation level outcomes, Appendix 1 displays the full outcome rubric with formative (lower-level) outcomes as well as the summative outcomes (graduation level) and the graduate degree outcomes for completeness.

During a faculty retreat in the Fall of 2013 and prior to the latest ABET visit, the faculty prepared and approved three critical documents that were later used to guide the faculty, advising staff, and students in moving forward with the four degrees. The first document contained a set of design definitions in the context of each of the four degree programs. The faculty believe such a document, while it may need to be refined over time, is necessary as "design" means something different to every profession and to every ABET/EAC program-specific area. BOKs typically spend considerable time discussing design and, even in those disciplines without a formalized BOK (construction engineering), PEVs and the profession tend to have a tighter agreement about the nature of design than exists across all four program areas (CE, ConE, ArchE, and EnvE).

Table 5 Department-Wide Integrated Outcomes
Across the Four Bachelor Degrees 2013

Foundational Outcomes

- F1 (Level 3): **Solve** problems in (1) mathematics through calculus and differential equations; (2) probability and statistics; and (3) at least two areas of natural science.
- F2 (Level 3): **Explain** the importance of (1) humanities, literature, and fine arts; and (2) history and social behavior.

Technical Outcomes

- T1 (Level 4): **Analyze** and **solve** problems in engineering mechanics and materials.
- T2 (Level 4): **Select** and **conduct** engineering experiments, and analyze and evaluate the resulting data.
- T3 (Level 3): **Apply** relevant knowledge, techniques, skills, and modern engineering tools to **identify**, **formulate**, and **solve** engineering problems, including problems in:

  BSCivE – environmental, water resources, transportation, structural, construction, and geotechnical
  BSArchE – building structures, building mechanical systems, building electrical systems, and construction engineering and management
  BSConE – project controls, construction methods, materials, and safety
  BSEnvE – air, land, and water systems, and associated environmental health impacts
- T4 (Level 3): **Explain** the impact of historical and contemporary issues on engineering practice.
- T5 (Level 3): **Develop** solutions to well-defined project management problems.
- T6 (Level 5): **Design** a system or process in more than one area within the discipline to meet desired needs, including sustainability, and within other realistic constraints such as: environmental, economic, social, political, ethical, health and safety, and constructability.
- T7 (Level 2): **Explain** key aspects of at least one traditional or emerging area of area of advanced specialization within the discipline.

Professional Practice Outcomes

- P1 (Level 4): **Analyze** a situation involving multiple conflicting professional, legal, and ethical interests, and determine an appropriate course of action.
- P2 (Level 4): **Organize** and **deliver** effective written, verbal, and graphical communications.
- P3 (Level 3): **Demonstrate** the ability to learn through independent study, without the aid of formal instruction.
- P4 (Level 3): **Demonstrat**e attributes supportive of the professional practice of engineering; **apply** leadership principles to direct the efforts of a small group to solve a relatively constrained problem; and **function** effectively as a member of a multidisciplinary team to solve open-ended engineering problems.
- P5 (Level 2) **Explain** the importance of professional licensure and basic concepts in engineering management, business, law, and globalization.

The faculty also prepared a portfolio guide to help guide the students in preparing their portfolio. This step was shown to be very useful during the latest ABET visit when portfolios (constructed before the guide) often did not have the most appropriate work to demonstrate a particular outcome, in particular The Design Outcome T6. This portfolio guide works in synergy with the design definition. Finally a "Student Guide to Senior Plan of Study Electives, Senior Design, Licensure, and Graduate School" was prepared to help students select the most appropriate and relevant electives for their program, their personal plan of study, and their professional future. All of these documents can be found on the department's website (http://cce.eng.ua.edu).

The last action that the faculty took was to investigate the use of a commercial product, "Livetext™" to aid the students in preparing, storing, and submitting their graduation portfolios. Over the ten year period (2005-2015) discussed in this paper, the department grew in both number of degrees and in number of undergraduate students. The undergraduate population in the department increased more than 160% as shown in Figure 2. The over 100 portfolios now generated per year were simply too large to handle using an antiquated hard copy process. The faculty now mandates the use of the LiveText™ system. Graduation outcomes have always been mapped to individual courses dating back to the single degree program in civil engineering. However, in response to comments during the last ABET evaluation; the faculty now explicitly link particular assignments/activities to graduation level outcomes that can then be used to populate graduation portfolios with the most appropriate work for each program.

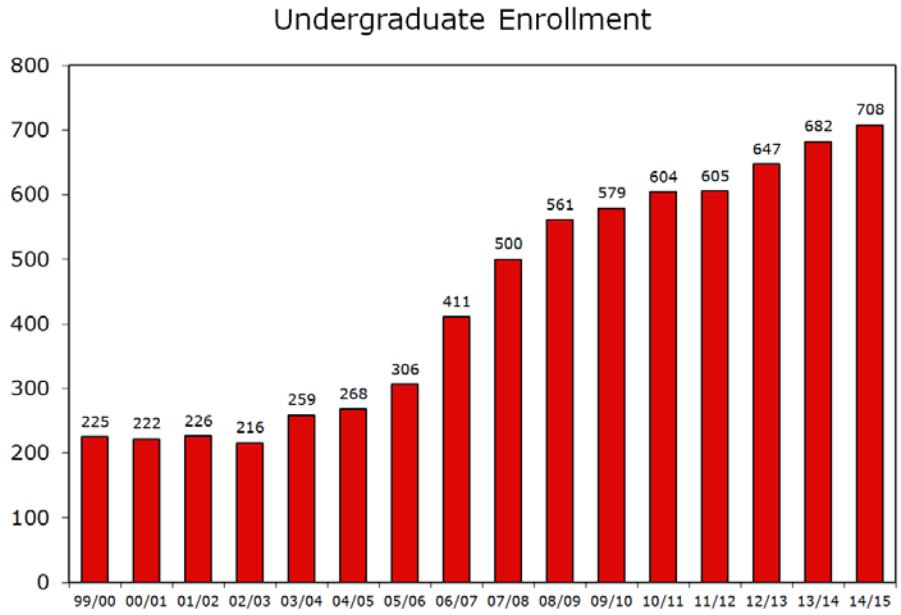


Figure 2: Growth in UA CCEE Department While Increasing the Number of Degree Programs Offered

Possible Issues Arising from New Degrees in ArchE and EnvE

Many of the major issues associated with adding new degrees to the department have been mitigated through the lessons learned when adding the ConE degree. However, certainly some issues must be expected. It is likely that our next ABET visit (for the new EnvE and ArchE degrees) will yield modifications such as were seen with the addition of specialty construction

engineering classes. Certainly expanding focus and coverage of the current two senior design classes (site design and building design), will be needed to meet the specific views of design espoused by the architectural and environmental engineering disciplines. We fully expect change and, in fact, see it as part of the process of growing our programs from a single multi-discipline set of outcomes.

The approach that we are implementing is building from a central set of outcomes (originally derived from expanding CE outcomes to meet additional program criteria) and then refining curricula of each program to support these unified outcomes rather than starting from separate outcomes and trying to move together.

Table 1 lists twelve universities that have three accredited programs in the "infrastructure disciplines" of CE, ConE, ArchE, and EnvE. A review of the current websites of these universities reveals an interesting trend. Almost all of these programs have separate PEOs and Student learning Outcomes for each degree program, indicating a different implementation pathway than used at the University of Alabama. Only University of Oklahoma has a single set of PEOs and outcomes for all three programs. Of course, several of these universities offer these three programs across multiple departments or even multiple colleges, which complicates a unified approach. But even in the case of two programs in a civil engineering department and a third offered in a separate department, the civil department often has two sets of PEOs and outcomes.

Summary of Findings

Developing the next generation of civil engineering departments that attempt to cover the multi-disciplinary breadth of infrastructure engineering will be challenging. However, as Table 1 and Figure 1 attest, civil engineering programs are naturally moving in this direction. We believe that an effective approach is to develop a unified set of PEOs and Outcomes. Assessment tools and data presentation can then be devised and segmented as necessary to meet a single-disciplined approach to accreditation.

As ASCE moves forward with BOKIII[7], it may be useful to think about a future with unified or at least highly linked PEOs and outcomes across infrastructure programs. Based on our experiences, we find that the interpretation of the concept or definition of design is one of the major challenges. ASCE has invested heavily in its BOK process and may be the best positioned of any of the engineering societies to help foster true multi-disciplinary programs of the future. ASCE's BOK has been somewhat of a model for others including the Environmental Engineering AAEES BOK. Also ASCE houses the lead "agencies" for program-specific criteria for Architectural Engineering, Civil Engineering, and Construction Engineering. These agencies are the Civil Engineering Program Criteria Task Committee (CEPCTC) for Civil Engineering, the ASCE Construction Institute Education Committee for Construction Engineering, and the ASCE Architectural Institute Education Committee for Architectural Engineering. If CEPCTC considers it worthwhile to help foster multi-disciplinary programs in sustainable infrastructure, then it is very possible some of the approaches detailed herein will prove useful to other Departments of Civil Engineering.

References

1. Koehn, Enno. *Professional program criteria for civil engineering curriculums* . Journal of Professional Issues in Engineering Education and Practice, 2010 Vol 126, No. 4, pg 174-179.
2. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*. American Society of Civil Engineers, 2004.
3. Finding Accredited Programs. (http://main.abet.org/aps/Accreditedprogramsearch.aspx), accessed October 30, 2014.
4. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, Second Edition*. Reston, VA: American Society of Civil Engineers, 2008.
5. *Criteria for Accrediting Engineering Programs 2015-2016* (http://www.abet.org/eac-criteria-2015-2016/). ABET, 2014.
6. BOK-Accreditation Strategic Planning Committee. *Final Report.* American Society of Civil Engineers, 2010.
7. Ressler, S. J. and D.R. Lynch. *The Civil Engineering Body for Knowledge and the Accreditation Criteria: A plan for Long-term Management of Change*. American Society of Engineering Education Annual Conference and Exposition, Vancouver, British Columbia, 2011.

Appendices

Appendix 1: Student Learning Outcome Levels of Achievement Rubric

Appendix 2: UA Department of Civil, Construction, and Environmental Engineering Undergraduate Degree Flowcharts

Civil ■ Construction ■ Architectural ■ Environmental

Student Learning Outcome Levels of Achievement Rubric – This table provides the outcome statement for each student learning outcome at each level, including the level expected at graduation (bolded). Outcomes statements are also included for the MS and PhD degrees, but you only need to document your achievement of the BS graduation outcomes.

Outcome ID	Outcome Name	Level 1 Knowledge	Level 2 Comprehension	Level 3 Application	Level 4 Analysis	Level 5 Synthesis	Level 6 Evaluation
F1	Math and Science	Define key factual information related to (1) mathematics through calculus and differential equations; (2) probability and statistic; and (3) at least two areas of natural science.	Explain key concepts and problem-solving processes in (1) mathematics through calculus and differential equations; (2) probability and statistics; and (3) at least two areas of natural science.	**Solve** problems in (1) mathematics through calculus and differential equations; (2) probability and statistics; and (3) at least two areas of natural science. **(BS)**			
F2	Humanities and Social Behavior	Define key facts from (1) humanities, literature, and fine arts; and (2) history and social behavior.	Discuss the key facts of (1) humanities, literature, and fine arts; and (2) history and social behavior.	Explain the importance of (1) humanities, literature, and fine arts; and (2) history and social behavior. **(BS)**			
T1	Materials and Mechanics	Define key factual information related to engineering mechanics and materials.	Explain key concepts and problem-solving processes in engineering mechanics and materials.	Solve problems in engineering mechanics and materials.	Analyze and solve problems in engineering mechanics and materials. **(BS)**		
T2	Experiments and Data Analysis	Identify the procedures and equipment necessary to conduct engineering related experiments.	Explain the purpose, procedures, equipment, and practical applications of engineering related experiments.	Conduct engineering related experiments according to established procedures, and report the results.	Select and conduct engineering experiments, and analyze and evaluate the resulting data. **(BS)**	Specify or design an experiment to meet a need, conduct the experiment, and analyze and explain the resulting data.	Evaluate the effectiveness of a designed experiment and the implications of the resulting data. **(PhD)**

Outcome ID	Outcome Name	Level 1 Knowledge	Level 2 Comprehension	Level 3 Application	Level 4 Analysis	Level 5 Synthesis	Level 6 Evaluation
T3	Tools and Engineering Problems	Identify the techniques, skills, and modern engineering tools that are necessary for engineering practice.	Explain how relevant techniques, skills, and modern engineering tools are used in engineering practice, including key concepts and problem-solving processes.	Apply relevant knowledge, techniques, skills, and modern engineering tools to identify, formulate, and solve engineering problems, including problems in:	Identify, formulate, and solve complex relevant engineering problems by selecting and applying appropriate tools and techniques. **(MS)**	Synthesize and explain the solution to complex, relevant engineering problems, including the use of appropriate tools and techniques.	Verify and justify the solution to a complex relevant engineering problem, including the use of appropriate tools and techniques. **(PhD)**
				BSCivE – environmental, water resources, transportation, structural, construction, and geotechnical **(BS)**	BSArchE – building structures, building mechanical systems, building electrical systems, and construction engineering and management **(BS)**	BSConE – project controls, construction methods, materials, and safety **(BS)**	BSEnvE – air, land, and water systems, and associated environmental health impacts **(BS)**
T4	Impacts of Historical and Current Events	Define the impacts of specific historical and contemporary issues on engineering practice.	Discuss the impact of historical and contemporary issues on engineering practice.	Explain the impact of historical and contemporary issues on engineering practice. **(BS)**			
T5	Project Management	List key principles of project management.	Explain what a project is and the key aspects of project management.	Develop solutions to well-defined project management problems. **(BS)**			

Outcome ID	Outcome Name	Level 1 Knowledge	Level 2 Comprehension	Level 3 Application	Level 4 Analysis	Level 5 Synthesis	Level 6 Evaluation
T6	Design	Define engineering design; list the major steps in the engineering design process; and list constraints that affect the process and products of engineering design.	Describe the engineering design process, and explain how real-world constraints affect the process and products of engineering design.	Apply the engineering design process to a component to meet a well-defined set of requirements and constraints.	Illustrate the engineering design process for a basic engineering system or process to meet a well-defined set of requirements and constraints.	Design a system or process in more than one area within the discipline to meet desired needs, including sustainability and within other realistic constraints such as environmental, economic, social, political, ethical, health and safety, and constructability. **(BS)**	
T7	Specialization	Define key aspects of at least one traditional or emerging area of advanced specialization within the discipline.	Explain key aspects of at least one traditional or emerging area of area of advanced specialization within the discipline. **(BS)**	Apply specialized knowledge to solve problems in a traditional or emerging area of advanced specialization.	Analyze complex system of process in a traditional or emerging area of advanced specialization.	Synthesize advanced technical knowledge in a traditional or emerging area of specialization. (**MS)**	Develop and evaluate new, advanced technical knowledge in a traditional or emerging area of specialization. **(PhD)**
P1	Professional, Ethical, and Legal Aspects	List the professional, legal, and ethical responsibilities of an engineer.	Describe the professional, legal, and ethical responsibilities of an engineer.	Apply standards of professional, legal, and ethical responsibility in a relatively clear-cut situation to determine an appropriate course of action.	Analyze a situation involving multiple conflicting professional, legal, and ethical interests, and determine an appropriate course of action. **(BS)**		
P2	Communication	List the characteristics of effective verbal, written, and graphical communications.	Describe the characteristics of effective verbal, written, and graphical communications.	Apply rules of grammar, composition and appropriate graphical standards to deliver verbal, written, and graphical communications.	Organize and deliver effective written, verbal, and graphical communications. **(BS)**	Synthesize and explain the relevance and application of new, advanced technical knowledge in both technical and non-technical terms. **(PhD)**	

Outcome ID	Outcome Name	Level 1 Knowledge	Level 2 Comprehension	Level 3 Application	Level 4 Analysis	Level 5 Synthesis	Level 6 Evaluation
P3	Independent Study	Define life-long learning.	Explain the need for life-long learning and describe the skills required of a life-long learner.	Demonstrate the ability to learn through independent study, without the aid of formal instruction. **(BS)**			
P4	Attributes, Leadership, and Teaming	Describe attributes supportive of the professional practice of engineering, and key aspects of leadership and teamwork.	Discuss attributes supportive of the professional practice of engineering, leadership principles, and the principles of collaborative teaming.	Demonstrate attributes supportive of the professional practice of engineering; apply leadership principles to direct the efforts of a small group to solve a relatively constrained problem; and function effectively as a member of a multidisciplinary team to solve open-ended engineering problems. **(BS)**			
P5	Licensure, Business, and Globalization	List key concepts of licensure, engineering management, business, law, and globalization.	Explain the importance of professional licensure and basic concepts in engineering management, business, law, and globalization. **(BS)**				

Department of Civil, Construction, and Environmental Engineering

Bachelor of Science in Civil (BSCivE & BSCivE Pre-Law) • Construction (BSConE) • Architectural (BSArchE) • Environmental (BSEnvE)

FRESHMAN YEAR

Fall — 15 Hours

	CE 121 Intro to CCEE (1)	
	MATH 125 Calculus I MA (4)	PH 105 MATH 126
	ENGR 103 Engrg Foundations (3)	AEM 201 ENGR 171
	EN 101 English Comp I FC (3)	EN 102
	CH 101 Chemistry I N (4)	CH 102 CE 320

Spring — 15 Hours

ENGR 103	ENGR 171 Engineering Graphics (1)	CE 260
MATH 125	MATH 126 Calculus II MA (4)	MATH 227 GES 255 AEM 250 AEM 264 ME 216
MATH 125	PH 105 Gen. Physics w/ Calculus I N (4)	PH 106 AEM 201
EN 101	EN 102 English Comp II FC (3)	
	HI/SB[1] Elective HI/SB (3)	

SOPHOMORE YEAR

Fall — 16 Hours

ENGR 171 MATH 115	CE 260 Surveying (2)	CE 350
ENGR 103 MATH 125 PH 105	AEM 201 Statics (3)	AEM 250 AEM 264 AEM 311 CE 262
MATH 126	MATH 227 Calculus III MA (4)	MATH 238 AEM 311
GES 103 MATH 126 or Math 146	GES 255 Engineering Statistics (3)	CE 350 CE 420 CE 464
	Approved Natural Science Elective N (4)	

Spring — 16 Hours

AEM 201 AEM 250	CE 262 Civil & Const Engrg Mat'ls	CE 331 CE 340 CE 366
AEM 201 MATH 126	AEM 250 Mechanics of Materials (3)	CE 331 CE 340
AEM 201 MATH 126	AEM 264 Dynamics (3)	CE 378
MATH 126 MATH 227	MATH 238 Differential Equations MA (3)	ECE 320
CH 101	CH 102 Chemistry II N (4)	See naturalS cience Advice Notes
PH 105	or PH 106 Physics2 w/Cal2 N (4)	See NS advice / requir'd ECE320

Approved Natural Science (N) Electives

BSCivE	BSConE & BSArchE	BSEnvE
Required: CH 101, PH 105, and either CH 102 or PH 106 **Approved Electives**: BSC 114/115 Principles of Biology GEO 101 Dynamic Earth GEO 102 Earth Through Time GEO 104 Hazardous Earth GEO 105 Sustainable Earth GY 101 Atmospheric Processes GY 102 Earth Surface Processes Note: Natural Science Elective cannot be chemistry (CH) or physics (PH)	**Required**: CH 101, PH 105, and PH 106 **Approved Electives**: BSC 114/115 Principles of Biology CH 102 Gen Chemistry II GEO 101 Dynamic Earth GEO 102 Earth Through Time GEO 104 Hazardous Earth GEO 105 Sustainable Earth GY 101 Atmospheric Processes GY 102 Earth Surface Processes	**Required**: CH 101, CH 102, PH 105, and BSC 114/115 **Approved Electives** GEO 101 Dynamic Earth GEO 102 Earth Through Time GEO 104 Hazardous Earth GEO 105 Sustainable Earth GY 101 Atmospheric Processes GY 102 Earth Surface Processes Note: Natural Science Elective must be an "Earth" science

KEY

Prerequisites (must be taken before; C req'd) Prerequisites (may be taken concurrently)	Course ### Title (Credits)	Downward Dependencies (courses for which this course is a prerequisite)

Revision 2 March 1 2015

Advising Notes

[1]**HI/SB** = History & Social and Behavioral Science
[1]**HU/L/FA** = Humanities/Literature/Fine Arts
- CE 220 and EC 110 are recommended as SB electives
- Foreign language is recommended as HU electives

FC = Freshman Composition
MA = Mathematics
C = Computer Science
W = Writing

Department of Civil, Construction, and Environmental Engineering
Bachelor of Science in Civil Engineering (BSCivE)

JUNIOR YEAR

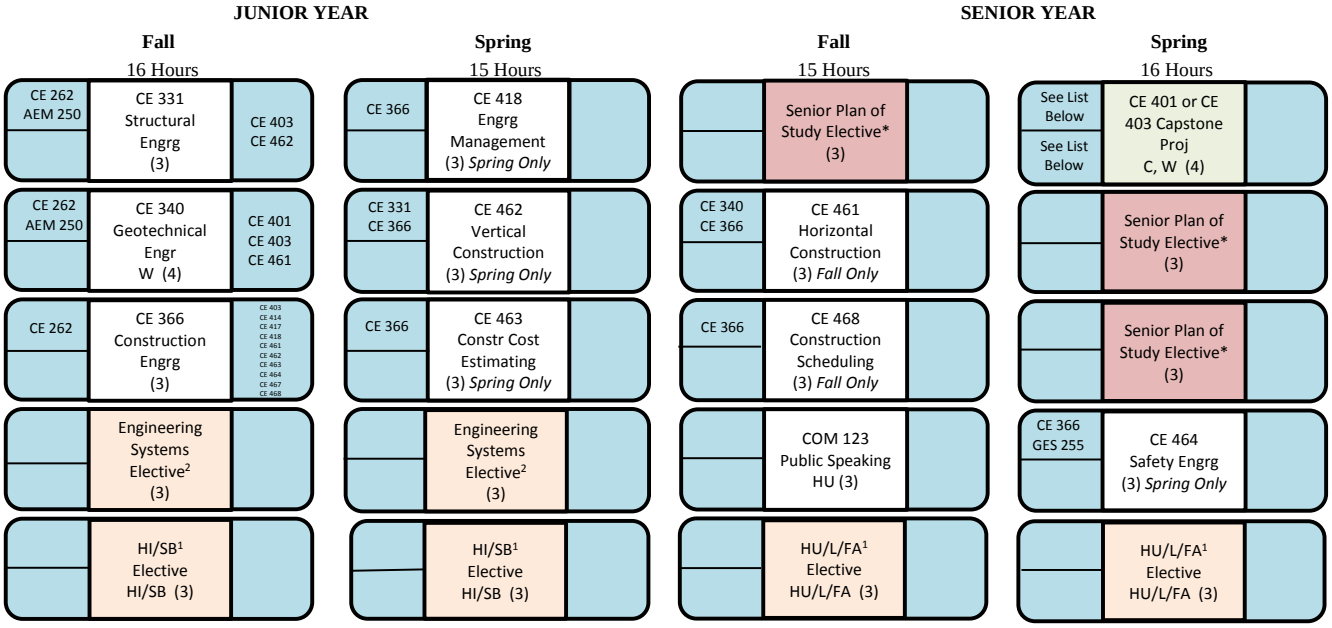
Fall (16 Hours)			Spring (15 Hours)		
CE 262 AEM 250	CE 331 Structural Engrg (3)	CE 403	CE 101 AEM 311	CE 320 Environmental Engrg (3)	CE 401
CE 262 AEM 250	CE 340 Geotechnical Engr	CE 401 CE 403	CE 262	CE 366 Construction Engrg	CE 403
CE 260 GES 255	CE 350 Transportation al Engrg	CE 401	AEM 264 AEM 311	CE 378 Water Resources (3)	CE 401
MATH 227 AEM 201 CE 320	AEM 311 Fluid Mechanics	CE 378		HI/SB[1] Elective HI/SB (3)	
	HI/SB[1] Elective HI/SB (3)		PH 106 MATH 238	ECE 320 Electr. Engrg (3)	
				or	
			MATH 126	ME 216 Thermal Engrg (3) *Spring Only*	

SENIOR YEAR

Fall (15 Hours)			Spring (16 Hours)		
	Senior Plan of Study Elective* (3)		See List Below See List Below	CE 401 or CE 403 Capstone Proj C, W (4)	
	Senior Plan of Study Elective* (3)			Senior Plan of Study Elective* (3)	
	Senior Plan of Study Elective* (3)			Senior Plan of Study Elective* (3)	
	COM 123 Public Speaking HU (3)			Senior Plan of Study Elective* (3)	
	HU/L/FA[1] Elective HU/L/FA (3)			HU/L/FA[1] Elective HU/L/FA (3)	

Advising Notes-Plan of Study	Senior Design Prequisite and Corequisite Requirements		Advising Notes
	CE 401 Capstone Project - Site Design	**CE 403 Capstone Project - Building Design**	
• *Please see the student guide to **Senior Plan of Study Electives** for a full list of electives and requirements. • All students my submit a **Graduation Portfolio**. Please see the student guide for further information. • All students are strongly encouraged to prepare for and take the **Fundamentals of Engineering (FE) Exam** during their senior year.	• CE 320, CE 340, CE 350, or CE 378 (C- or better required) • Six (6) credit hours of any 400- or 500-level CE courses (C- or better required) • Two of the following (may be taken concurrently with CE 401): CE 424/524, CE 425/525, CE 442/542, CE 451, CE 459/559, CE 475/575	• CE 331, CE 340, and CE 366 (C- or better required) • Six (6) credit hours of any 400- or 500-level CE courses (C- or better required) • Two of the following (may be taken concurrently with CE 403): CE 433, CE 434, CE 437/537, CE 438/538, CE 439, CE 444/544, CE 462/562, CE 563, CE 543	[1]**HI/SB** = History & Social and Behavioral Science [1]**HU/L/FA** = Humanities/Literature/Fine Arts • CE 220 and EC 110 are recommended as SB electives • Foreign language is recommended as HU electives **C** = Computer Science **W** = Writing

Department of Civil, Construction, and Environmental Engineering:
Bachelor of Science in Construction Engineering (BSConE)



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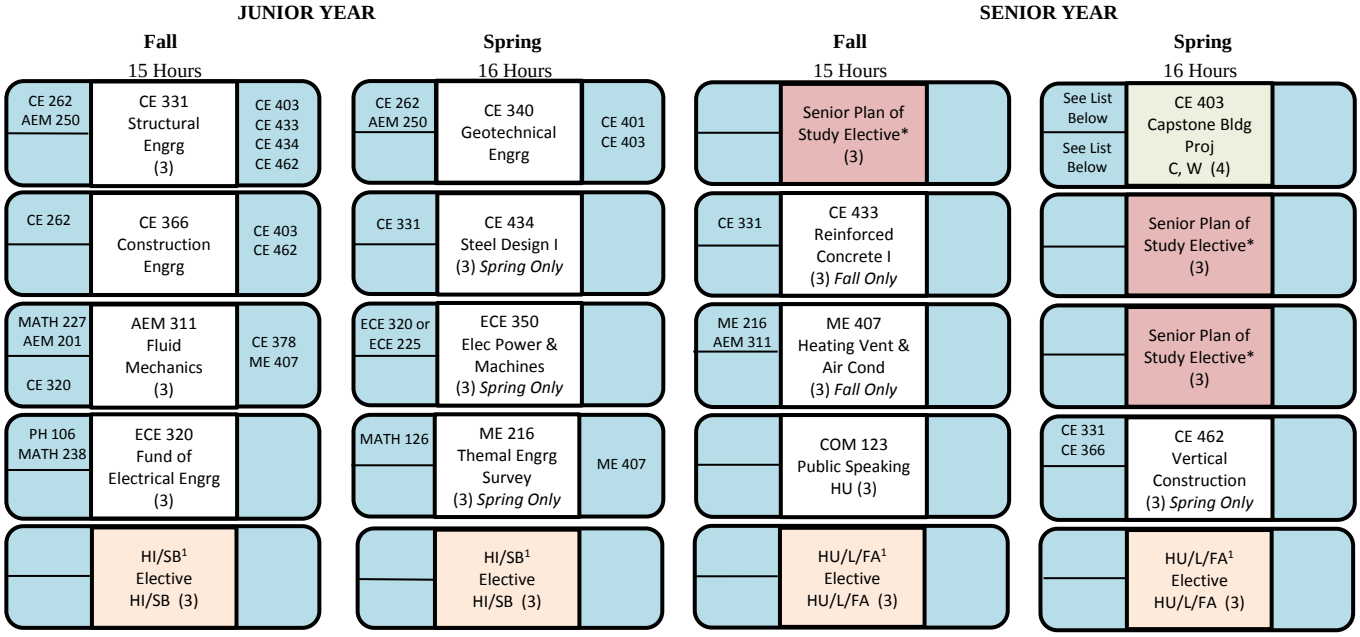
Department of Civil, Construction, and Environmental Engineering:
Bachelor of Science in Architectural Engineering (BSArchE)



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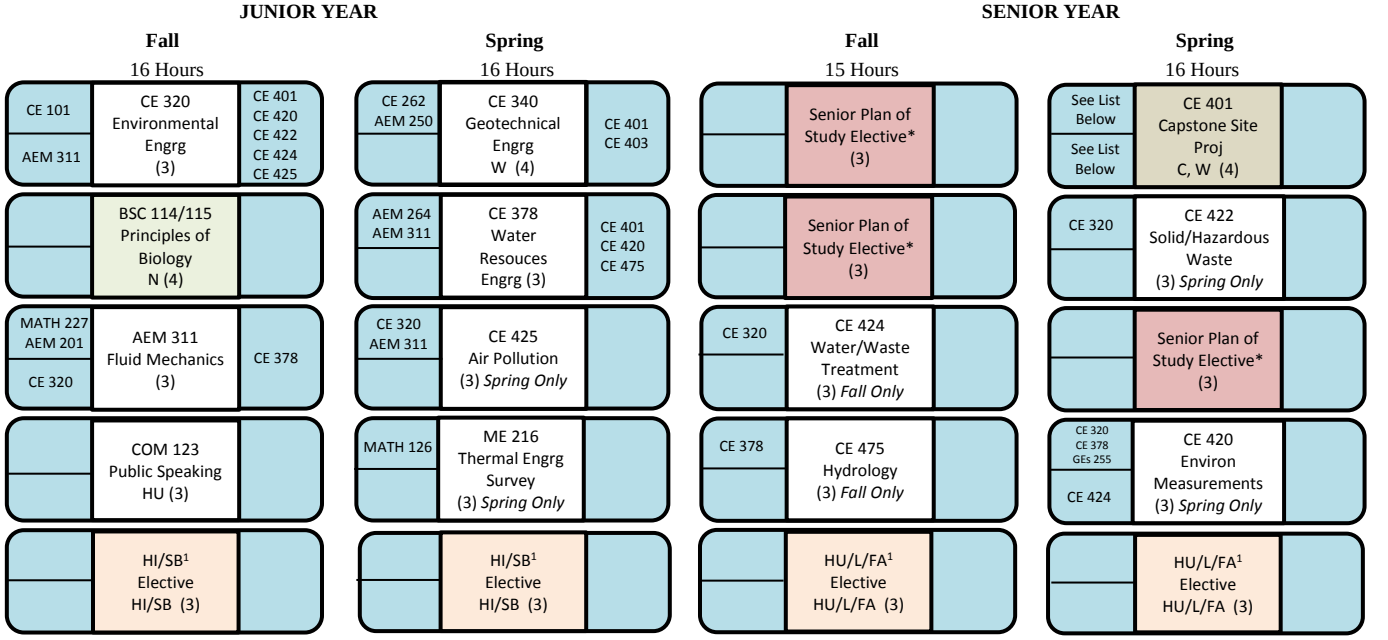
Department of Civil, Construction, and Environmental Engineering:
Bachelor of Science in Environmental Engineering (BSEnvE)



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