Designing a New Civil Engineering Curriculum to Prepare Tomorrow's Engineer

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Abstract

Today, the infrastructure challenges civil engineers face are complicated not only by accelerating technological progress, rapidly evolving societal needs and expectations, and complex global environmental challenges, but also by swiftly changing demographics. Changing demographics require inclusive perspectives both in the formulation of engineering solutions and the recruitment and training of an increasingly diverse pool of aspiring engineers. The development of diverse civil engineers, as stewards of technology, the natural and built environments, and public health, who are as well versed in professional skills as they are in technical skills is the challenge we face as engineering educators.

This paper describes a new civil engineering curriculum designed to meet these challenges. Our new curriculum, that was the result of a multi-year effort, is centered around a "design spine". The design spine, series of eight courses, is expected to improve the development of professional skills, improve fluency with data analysis and computing skills, improve critical thinking skills, and integrate systems thinking through project-based learning. The design spine helps connect and integrate the separate subdiscipline courses typical of most civil engineering curricula as a system of systems.

The courses in the design spine were developed using feedback and input from faculty, students, alumni, and employers as well as considering ASCE's Civil Engineering Body of Knowledge, 3rd Edition, ABET criteria, and our College of Engineering's Complete Engineer ® competencies. All of this was done while reducing the credit hours for the degree from 130 to 126. We began offering the new design spine courses in fall 2022. This paper describes our path to the new curriculum.

Introduction

Why change a curriculum? Change is hard so the need to change a curriculum needs to be compelling. One answer to the need for curriculum change is that our world is constantly changing. We need to make change to keep our curriculums from becoming outdated, to keep up with changes in how information is accessed, to keep our students engaged, and to keep up with a changing world. In our faculty discussions, the University of Nebraska-Lincoln Civil & Environmental faculty recognized that today, the infrastructure challenges civil engineers face are complicated not only by accelerating technological progress, rapidly evolving societal needs and expectations, and complex global environmental challenges, but also by swiftly changing demographics. Changing demographics require inclusive perspectives both in the formulation of engineering solutions and the recruitment and training of an increasingly diverse pool of aspiring engineers. The development of diverse civil engineers, as stewards of technology, the natural and built environments, and public health, who are as well versed in professional skills as they are in technical skills is the challenge we face as engineering educators. All of this led the UNL CEE department to redesign its civil engineering curriculum. This paper describes the goals for the new curriculum and how it was designed to meet these goals.

Previous curriculum

The previous curriculum at the University of Nebraska-Lincoln that is now being replaced by the new curriculum starting Fall 2022 had served Nebraska students well for over 30 years. This old curriculum is shown in Table 1.

Table 1: Previous civil engineering curriculum

Semester (credits)	General Education		Math	Science	General Engineering	Civil Engineering Courses
1 (16)	History (3)		Calculus 1 (5)	Chemistry 1 (4)	Computer Programming (Python) (3)	Introduction to Civil Engineering (1)
2 (17)	Social Science (3)		Calculus 2 (5)	Physics 1 (4)		Civil Engineering Graphics (2) Geomatics for Civil Engineers (3)
3 (17)	Writing (3) Fine arts (3)		Calculus 3 (4)	Chemistry 2 or Physics 2 (4)	Statics (3)	
4 (15)	Communication Skills (3)		Differential Equations (3)		Dynamics (3) Mechanics of Elastic Bodies (3)	Introduction to Transportation Engineering (3)
5 (15)			Statistics (3)			Fluid Mechanics (3) Fluid Mechanics Lab (1) Intro. to Environmental Engineering (3) Environmental Engineering Lab 327 (1) Intro. to Structures (4)
6 (16)	Ethics (3)					Intro. to Geotechnical Engineering (4) Intro. to Water Resources (3) Materials of Construction (3) Professional Practice & Management in Civil Engineering (3)
7 (16)	Global Awareness (3)			Science Elective (4)		Civil Engineering Design Electives (6) Civil Engineering Technical Elective (3)
8 (18)	Free Elective (3)					Senior Design (3) Civil Engineering Design Elective (3) Civil Engineering Technical Electives (9)
130 credits	21 cr	3 cr	20 cr	16 cr	12 cr	58 cr

Note: The University of Nebraska-Lincoln requires a total of 30 credit hours of general education. The free elective is not part of the general education requirements. The additional 9 credit hours of general education are met through the required math and science courses and the civil engineering senior design.

Strengths & weaknesses

One of the strengths of the previous curriculum was the flexibility it allowed students in selecting courses in civil engineering beyond the required third-year discipline specific courses. If students wanted to, they could take all but one of their design electives and their civil engineering technical electives in one discipline of civil engineering. For example, a student could choose to take 5 of their 6 3-credit courses from structural engineering courses with the sixth course taken from some other area such as geotechnical engineering. Alternatively, a student could choose to take an elective course in each civil engineering discipline as well as one course from an allowed technical area outside of civil engineering such as math or community & regional planning.

This previous curriculum had several weakness. Students during their first two years often only had a civil engineering faculty member teaching one 1-credit course during their first two years

as the civil engineering graphics and geomatics for civil engineers courses have been typically taught by faculty from other departments. This lack of belonging to their declared major is known to lead to students leaving engineering [1, 2, 3]. Additionally, about half of the students delayed taking the introductory transportation engineering course until later in their career to either repeat a course they had failed in their first two years or to reduce the number of credits they were taking each semester.

Another weakness stemmed from compartmentalizing much of the professional skills in the curriculum into two courses, professional practice & management in civil engineering and senior design. Based on student evaluations and exit interviews, most students felt the skills presented in these courses were not meaningful as they did not see the connection to what they were learning in their other civil engineering courses.

The development of fluency with computing and data analysis skills suffered in our previous curriculum because even though students took computer programming, CAD, and geomatics, the skills and tools they learned in these courses were not used much if at all until their last semester in senior design. Students had to get themselves back up to speed with these skills and tools while working on their senior design project. This led the senior design projects to be scaled back to allow time to build back up the skills and tools needed to complete senior design.

Another concern with the previous curriculum is that there was a general feeling from the faculty that Nebraska graduates were good, competent engineers but needed more development of critical thinking skills. The faculty wanted them to better understand how civil engineering projects are systems of systems. The faculty wanted them to be able to think through how an environmental catastrophe isn't just an environmental engineering problem. That it's often also a water resources and geotechnical engineering problem. That addressing just one aspect of the problem doesn't solve the problem. So even though the old curriculum was producing good, competent engineers, the faculty thought we could do better.

Objectives of New Curriculum

The faculty recognized that to address the concerns about the old curriculum that a rethinking of our entire curriculum instead of continuing to do the small tweaks and changes that had been doing for over 30 years. As the faculty started designing the new curriculum, the overarching objective is to develop not only competent civil engineers but outstanding civil engineers. To do this the faculty set several goals: 1) Improve recruitment and retention, 2) Improve 4 & 6 year graduation rates, 3) Be more in-line with the rest of the college in credit requirements, 4) Improve development of professional skills & make professional skills more meaningful, 5) Improve fluency with data analysis & computing skills, 6) Improve critical thinking skills, 7) Retain and improve discipline strengths, and 8) Remain ABET accredited. These objectives and goals came from discussions by the entire faculty during discussions about student performance as part of the ABET continuous improvement process.

These eight goals came out of a close examination of the strengths and weakness of the previous curriculum. Goals 1 and 2 come out of knowing a good number of students didn't feel part of their major during their first two years in the major. The faculty wanted to improve retention to the major and help students connect what they were doing in their math and science courses to

their civil engineering degree. For Goal 3, reducing the number of credit requirements, the old civil engineering major, at 130 credit hours, was the second highest credit hour major in the college of engineering. It was also high in terms of credit hours in comparison to Nebraksa's peer institutions. This high credit hour requirement likely contributes to lower 4- and 6-year graduation rates as well as costing our students more in tuition.

Goals 4 through 6 aim at addressing our concerns with the development of professional skills, data analysis & computing skills, and critical thinking skills. Goal 7 came from a desire to keep as much flexibility as possible in the curriculum as well as retain and strengthen the introductory courses to the different disciplines within civil engineering. Goal 8 of making sure the new curriculum would meet ABET accreditation requirements was an absolute requirement.

The New Curriculum

The new curriculum that started in Fall 2022 is shown in Table 2. The major change to the curriculum is the new Design Spine. Passow and Passow [4] conducted a quantitative meta-analysis combined with a qualitative thematic analysis to determine what competencies undergraduate engineering programs should emphasize. Three of their findings were particularly influential in the decision to develop the Design Spine: engineering competencies are tied to the life-cycle of the product process, technical competence is inseparably intertwined with effective collaboration, and engineering practice requires coordinating multiple competencies to accomplish a goal. These findings along with the overriding objective and goals led to the development of the Design Spine. Other literature influencial in the development of the Design Spine included Brunhaver et al, Lattuca et al, and Huff et al [5, 6, 7].

The Design Spine serves several purposes. First, it provides students with a clear connection to their civil engineering major during the first two years. A goal with the design spine is to connect what is in the Design Spine to other courses that students are likely to be taking at the same time. During the first two years, the Design Spine courses will help students better connect what they are doing in their general education, math, and science courses to their civil engineering major. In their third year, the Design Spine courses will show how the different disciplines of civil engineering work together to solve infrastructure problems and how civil engineering is a discipline of systems of systems. And in the fourth year, the Design Spine allows students to have a full year capstone experience which should help them be better prepared to address with skills developed and used throughout the Design Spine and the rest of their civil engineering courses. To fit in our new Design Spine, 6 credits were repurposed from our previous civil engineering technical electives.

Reduction of credit hours

The new curriculum has 4 fewer credits than the previous curriculum. Two things changed – first the math department reduced Calculus II from 5 credits to 4 credits, and second, a 3 credit free elective was removed. Removing the free elective allows students the choice of whether they want to pay for these 3 credits or not instead of requiring them to pay for these 3 credits. In the old curriculum, some students used these 3 credits to pursue a minor. The reduction of credit hours should help improve the 4- and 6-year graduation rates as well as reduce the overall tuition for students.

Table 2: New Curriculum

Semester (credits)	General Education	Math	Science	General Engineering	Design Spine	Civil Engineering Courses
1 (16)	Communication Skills (3)	Calculus 1 (5)	Chemistry 1 (4)		CIVE 101: Introduction to Civil Engineering (3)	
2 (17)	Writing (3)	Calculus 2 (4)	Physics 1 (4)	Computer Programming (Python) (3)	CIVE 102: Geomatics for Civil Engineers (3)	
3 (17)	History (3)	Calculus 3 (4)	Chemistry 2 or Physics 2 (4)	Statics (3)	CIVE 201: Civil Eng. Analysis I (2)	
4 (15)	Social Science (3)	Differential Equations (3)		Dynamics (3) Mechanics of Elastic Bodies (3)	CIVE 202: Civil Eng. Analysis II (2)	Materials of Construction (3)
5 (15)		Statistics (3)			CIVE 301: Civil Eng. Synthesis I (1)	Fluid Mechanics (3) Fluid Mechanics Lab (1) Intro. to Structures (4) Intro. to Transportation Eng. (3)
6 (16)	Fine arts (3)				CIVE 302: Civil Eng. Synthesis II (1)	Intro. to Geotechnical Engineering (4) Intro. to Water Resources (3) Intro. to Environmental Engineering (3) Environmental Engineering Lab (1)
7 (16)	Ethics (3)		Science Elective (4)		CIVE 401: Civil Eng. Design I (3)	Civil Eng. Electives (6)
8 (18)	Global Awareness (3)				CIVE 402: Civil Eng. Design II (3)	Civil Eng. Elective (3) Technical Electives (6)
126 credits	21 cr	19 cr	16 cr	12 cr	18 cr	40 cr

Note: The University of Nebraska-Lincoln requires a total of 30 credit hours of general education. The additional 9 credit hours of general education are met through the required math and science courses and the civil engineering design II course.

It also brings the curriculum more in-line with programs at peer institutions & other majors in the college. Table 3 shows the comparison to two of peer groups (the Big Ten and University of Nebraska Regents' Peers) as well as within the college. The reduction in credit hours places the civil engineering degree at the lower end of peer institutions and about in the middle of the other majors in the college.

ABET Considerations

Our Goal 8 for the new curriculum is that changes made do not cause problems with ABET accreditation. The new curriculum needs to satisfy Criterion 5 of the ABET Engineering Accreditation Commission 2023-2024 Criteria [8]. This criterion states that "the curriculum must include:

a) a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic science with experimental experience appropriate to the program.
b) 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.
c) a broad education component that complements the technical content of the curriculum and is consistent with the program educational objectives.

d) 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."

Table 3 Comparison by Credit Hours with Peer Civil Engineering Programs

Credit Hours	Big Ten Civil Engineering Programs	UNL Regents' Peers Civil Engineering Programs	UNL College of Engineering Majors
132	Purdue, Iowa	-	-
131	Ohio State	-	Chemical Engineering
130	**UNL Civil Engineering Previous Curriculum**	**UNL Civil Engineering Previous Curriculum**, Colorado State	**UNL Civil Engineering Previous Curriculum**
129	-	Iowa State	Architectural Engineering (BS only)
128	Michigan, Michigan State, Rutgers, Illinois, Northwestern	Kansas, Kansas State, CU Boulder	Mechanical Engineering
127	Penn State	-	Biological Systems Engineering
126	**UNL Civil Engineering New Curriculum**	**UNL Civil Engineering New Curriculum**, Missouri	**UNL Civil Engineering New Curriculum**, Computer Engineering
125	Minnesota	-	Construction Engineering
124	-	-	Electrical Engineering, Software Engineering
123	-	-	Agricultural Engineering
122	Maryland	-	-
121	-	-	Data Science
120	-	-	Computer Science

Table 4 shows the courses for ABET Criterion 5a. In the new curriculum there are 35 credit hours for this criterion which exceeds the ABET minimum requirement of 30 credit hours. Table 5 shows the engineering topics for the new curriculum. There are 72 such credit hours which exceeds the ABET minimum requirement of 45 credit hours. For ABET Criterion 5c, our curriculum includes UNL's Achievement Center Education (ACE) requirement of 30 credit hours of general education. Table 6 shows the courses in the civil engineering curriculum. ABET Criterion 5d is met with the two course sequence of CIVE 401 – Civil engineering design I and CIVE 402 – Civil engineering design II.

Table 4: Courses for ABET Criterion 5a

Course	Credits
Calculus I	5
Calculus II	4
Calculus III	4
Differential Equations	3
Statistics	3
Chemistry I (with lab)	4
Physics I (with lab)	4
Chemistry II or Physics II (with lab)	4
Science elective (with lab)	4
Total Credits in Adopted CIVE curriculum	**35**

Table 5: Courses for ABET Criterion 5b

Course	Credits	Course	Credits
CIVE101-Introduction to Civil Engineering	3	CIVE378-Materials of Construction	3
CIVE102-Geomatics for Civil Engineering	3	CIVE310-Fluid Mechanics	3
CIVE201-Civil Engineering Analysis I	2	CIVE319-Fluid Mechanics Lab	3
CIVE202-Civil Engineering Analysis II	2	CIVE361-Introduction to Transportation Engineering	3
CIVE301-Civil Engineering Synthesis I	1	CIVE341-Introduction to Structural Engineering	4
CIVE302-Civil Engineering Synthesis II	1	CIVE334-Introduction to Geotech. Engineering	4
CIVE401-Civil Engineering Design I	3	CIVE352-Introduction to Water Resources Eng.	3
CIVE402-Civil Engineering Design II	3	CIVE321-Introduction to Environmental Eng.	3
CSCE101-Fund. of Computer Science (Python)	3	CIVE321L-Environmental Engineering Lab	1
MECH223-Engineering Statics	3	Civil Engineering Electives	9
MECH325-Mechanics of Elastic Bodies	3	Technical Electives	6
MECH373-Engineering Dynamics	3	**Total engineering topics credits in New Civil Engineering curriculum**	**72**

Table 6: Courses for ABET Criterion 5c

Course	Credits	Courses in the Civil Engineering Curriculum
ACE 1: Written communications	3	Student's choice
ACE 2: Communication skills (non-written)	3	Student's choice
ACE 3: Mathematical or computational reasoning	3	Calculus I
ACE 4: Scientific Methods	3	Chemistry I
ACE 5: Historical perspectives	3	Student's choice
ACE 6: Social sciences	3	Student's choice
ACE 7: Fine arts	3	Student's choice
ACE 8: Ethics	3	Student's choice
ACE 9: Global awareness or human diversity	3	Student's choice
ACE 10: Capstone experience	3	CIVE 402 – Civil Eng. Design II

Development of Design Spine Courses

The previous sections described the broad overview of the new curriculum and verified how it continues to meet the ABET accreditation requirements. This section focuses on the development of the design spine. The relevant goals of the curriculum redesign for the design spine are:

2) Improve 4 & 6 year graduation rates,
4) Improve development of professional skills & make professional skills more meaningful,
5) Improve fluency with data analysis & computing skills,
6) Improve critical thinking skills, and
7) Retain and improve discipline strengths.

Also relevant is the overarching objective for the curriculum redesign to develop not only competent civil engineers but outstanding civil engineers. Incorporating the overarching objective and all these goals into eight courses is a daunting task that is aided by source such as ASCE's Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer (2019), the ABET Engineering Accreditation Commission's current Criteria for Accrediting Engineering Programs 2023-2024, what other civil engineering programs are doing in their curriculums, and the larger engineering education literature.

To do all of this, the faculty again looked to the findings of Passow & Passow [4] and to ASCE's Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer [9] as the primary guides. One of the sources reviewed by Passow & Passow [4] noted:

> All engineering is, of necessity, *both* technical and social…*Good* engineering (as in engineering which is effective) demand the thorough integration of these elements in ways that *transcend* conventional dichotomies. The knowledge mobilized in the course of engineering…is never "just technical" with "the social" bolted on. Rather, these two dimensions are in a very practical sense inseparable…Since the two are inseparable in everyday engineering practice, the boundaries drawn between them are inevitably arbitrary. [10, emphasis in original]

To bring the technical and social together in our curriculum's Design Spine, the demonstrated abilities developed in the undergraduate career as described in ASCE's Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer [9] were used to develop a plan for our design spine. Table 7 lists the level of skill and demonstrated abilities from the CE BOK3 and identifies those that have been incorporated into the Design Spine. Note that including skills and demonstrated abilities in the Design Spine does not preclude other courses in the curriculum from also including these skills and demonstrated abilities. In fact, this is encouraged to further strengthen these and to further demonstrate their importance in the context of civil engineering areas.

Table 7: CE BOK Demonstrated Abilities specifically developed in the Design Spine. X – demonstrated abilities developed in the undergraduate career. X – Integrated into the Design Spine

Area	Outcome	Level of Achievement					
		Cognitive Domain			Affective Domain		
		Remember	Comprehend	Apply	Receive	Respond	Value
Foundational Outcomes	Mathematics	X	X	X			
	Natural Sciences	X	X	X			
	Social Sciences	X	X	X			
	Humanities	X	X	X			
Engineering Fundamentals Outcomes	Materials Science	X	X	X			
	Engineering Mechanics	X	X	X			
	Experimental Methods and Data Analysis	X	X	X			
	Critical Thinking and Problem Solving	X	X	X			
Technical Outcomes	Project Management	X	X				
	Engineering Economics	X	X				
	Risk and Uncertainty	X	X	X			
	Breath in Civil Engineering	X	X	X			
	Design	X	X	X			
	Depth in a Civil Engineering Area	X	X				
	Sustainability	X	X	X	X	X	
Professional Outcomes	Communications	X	X	X	X	X	
	Teamwork and Leadership	X	X	X	X	X	
	Lifelong Learning	X	X	X	X	X	
	Professional Attitudes	X	X		X	X	
	Professional Responsibilities	X	X		X	X	
	Ethical Responsibilities	X	X		X	X	

Summary of Design Spine Courses

Eight courses make up the Design Spine. The course descriptions for each follow.

CIVE 101 – Introduction to Civil Engineering (3 credits; no prerequisites)

Introduction to engineering design process through hands-on projects supported by instruction of underlying engineering science and fundamentals, model development, and the required tools. Use of computer-aided design software to communicate engineering ideas. Dimensioning, 2- and 3-D model development, topographic mapping, and process layout with emphasis on Civil Engineering applications. Exploration of civil engineering disciplines and introduction to civil engineering profession with focus on ethics and professional skills.

CIVE 102 – Geomatics for Civil Engineers (3 credits-2 hr lecture+3 hr lab; Prereq.: CIVE 101)

Introduction to the theory and application of measurements and geospatial data for civil engineering. This includes error theory, measurements of elevation, distance, direction, and location using optical, mechanical, electronic, and global navigation satellite systems, and applications in geographic information systems (GIS). Project based.

CIVE 201 – Civil Engineering Analysis 1 (2 credits 1 hr lecture+3 hr lab; Prereq.: Introductory course in Python

Incorporating programming logic into spreadsheet solutions in the context of authentic civil engineering projects; emphasis on integrating professional skills, data analysis and management, and technical skills. Project based.

CIVE 202 – Civil Engineering Analysis 2 (2 credits-1 hr lecture+3 hr lab; Prereq.: CIVE 201)

Expanding programming logic to data analysis & visualization, solution of linear systems of equations, and ordinary differential equations. Control of sensors and visualization of scientific data. Use of authentic civil engineering projects linking engineering mechanics and materials of construction. Emphasis on integrating professional skills, data analysis, and technical skills. Project based.

CIVE 301 – Civil Engineering Synthesis 1 (1 credit-3 hr studio; Coreq.: Fluid Mechanics or Intro. to Transpo. Eng. or Intro. to Structures)

Explores the co-disciplinary connections in civil engineering through authentic engineering projects; focus on synergies among fluid dynamics, transportation, and structures; emphasis on integrating professional skills, data analysis, and technical skills. Project based.

CIVE 302 – Civil Engineering Synthesis 2 (1 credit-3 hr studio; Coreq.: Intro. to Geotech. or Intro. to Water Resources Eng. or Intro. to Environ. Eng.)

Explores the co-disciplinary connections in civil engineering through authentic engineering projects; focus on synergies among geotechnical engineering, water resources, and environmental engineering; emphasis on integrating professional skills, data analysis, and technical skills. Project based.

CIVE 401 – Civil Engineering Design 1 (3 credits-2 hr lecture+3 hr studio; Prereq.-all required junior level civil engineering courses)

The first of two courses in the capstone sequence. Practical application of the engineering design process in a team project focused on an authentic and comprehensive civil engineering design project.

CIVE 402 – Civil Engineering Design 2 (3 credits-2 hr lecture+3 hr studio; Prereq.-CIVE 401)

The second of two courses in the capstone sequence. Practical application of the engineering design process in a team project focused on an authentic and comprehensive civil engineering design project.

Skill Development

Throughout the Design Spine, professional, technical, and computational skills will be developed (Figure 1). Additionally, all other courses in civil engineering are encouraged to use and develop these skills. While some of the computational skills are developed in specific Design Spine courses (CAD in CIVE 101, GIS in CIVE 102, Excel & VBA in CIVE 201, and Python in CIVE 202), the goal is to have all skills woven through the entire curriculum. This development of skills is closely tied to the UNL College of Engineering's Complete Engineer ® Program.

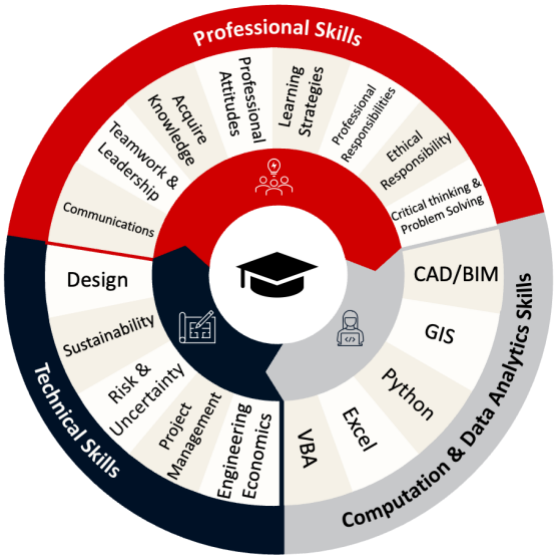

Figure 1: Professional, technical, and computational skills developed in the Design Spine

The CE BOK3 was used to help guide the progression of development of these skills through the Design Spine. The skill development progress was mapped on to the Design Spine. For example, Figure 2 shows this mapping for the technical skills.

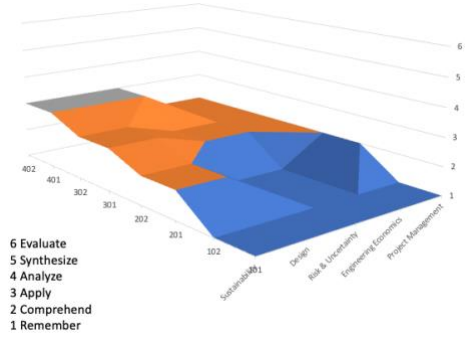

Figure 2: Progression of development of technical skills

Currently, the faculty are working at developing materials that can be used by all in all civil engineering courses although the focus is on how to effectively weave these skills through the design spine courses.

Project based learning

All the Design Spine courses incorporate project-based learning. Project Based Learning (PBL) is a teaching method in which students learn by actively engaging in real-world and personally meaningful projects. Students work on a project over an extended period – from a week up to a semester – that engages them in solving a real-world problem or answering a complex question. They demonstrate their knowledge and skills by creating a public product or presentation for a real audience.

As a result, students develop deep content knowledge as well as professional skills (communication, teamwork & leadership, acquisition of knowledge, learning strategies, and ethical responsibilities), engineering fundamentals (data analysis and critical thinking & problem solving), and technical skills. PBL increases teamwork and communication skills, helps students relate course materials to the practice of engineering, and increases students' awareness and interest in a subject [11]. By incorporating PBL into our Design Spine we expect this to help with learning, development of skills, and retention from increased interest in the subject of civil engineering.

Breadth & Depth in Civil Engineering

The last consideration in redesigning our curriculum was to ensure that the curriculum still develops a breadth of understanding in civil engineering while also retaining the flexibility in the fourth-year technical electives that allows students to develop depth in areas of interest to them. The basic breadth has been and continues to be through the required junior level courses in fluid dynamics, principles of environmental engineering, introduction to geotechnical engineering, introduction to structural engineering analysis and design, principles of transportation engineering, and introduction to water resources engineering. All students are also required to take an addition three senior level courses in civil engineering – one in the "wet" side (environmental or water resources engineering), one in the "dry" side (geotechnical, transportation or structural engineering, and one additional course from either the "wet" or "dry" side. These "wet" and "dry" side courses are chosen from a list of ten courses and provide depth

in at least two areas. The curriculum also includes 6 credits of technical electives. The list of technical electives includes any senior level civil engineering courses not used to satisfy other requirements as well as a variety of courses from other STEM fields.

Timeline for New Curriculum Rollout

The new curriculum had an initial pilot in AY 2021-2022 with the curriculum being in place for students starting in AY 2022-2023 (Figure 3). By piloting our CIVE 101 in Fall 2021, the faculty have been able to stay one year ahead in the development of the Design Spine courses. These courses generally have two to four faculty working collaborative to develop and deliver them. Parallel to the Design Spine course development, a larger group of faculty have been working collaboratively to develop the professional and technical skill fabric through the Design Spine. As the Design Spine is rolled out, the faculty are committed to continually improving our curriculum.

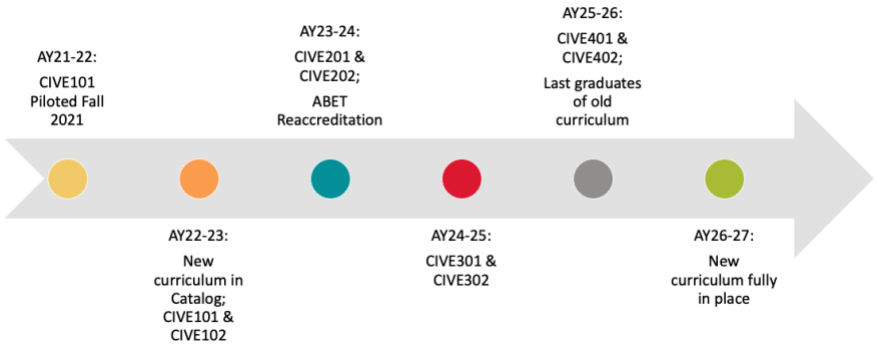

Figure 3: Timeline for new curriculum rollout

Conclusion

The curriculum change with the addition of the Design Spine has been a challenge. The effort has been worthwhile as it has allowed the faculty to improve the development of professional, technical, and computation skills in a meaningful way without increasing the number credits. By repurposing 6 credits for civil engineering courses, a Design Spine was developed. The credits needed for the degree were reduced by taking advantage of a reduction in the credits for a math course and eliminating a free elective. No longer will Nebraska students be disconnected from civil engineering. Instead, they will have the opportunity to develop as critical thinkers through project based learning and to develop facility with design and analysis tools throughout their undergraduate career while also becoming Complete Engineers ®. This new curriculum will help our students to meet the challenges that they will face in their careers and allow them to be stewards of technology, the natural and built environments, and public health, who are as well versed in professional skills as they are in technical skills.

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