Civil Engineering Curriculum

A redesign proposal

Undergraduate Curriculum Committee

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Motivation

Built environments that are well designed, constructed, and maintained improve the quality of life for God's children on His earth. These built environments face threats and challenges that change rapidly: natural hazards, climate change, population growth, and global economic and political conditions all at times threaten human happiness and well-being. The mission of the Civil Engineering program at Brigham Young University should be to develop students of faith, intellect, and character who are capable of meeting and solving challenges to built environments now and in the future.

BYU's civil engineering program has historically succeeded in generating high-quality, well-trained graduates. But as the field of civil engineering changes, the skills students need to address these challenges change as well. Further, graduating seniors have regularly commented on the inflexibility and inefficiency of our current program. This document describes a proposal for several changes to the requirements for a Bachelor of Science degree in Civil Engineering that we hope will better prepare our students with broad and highly flexible degree program.

In creating this proposal, the Undergraduate Curriculum Committee was deeply impressed by these two paragraphs from the Undergraduate – Depth section of Aims of a BYU Education:

> Depth does not result merely from taking many courses in a field. Indeed, excessive course coverage requirements may discourage rather than enhance depth. Depth comes when students realize "the effect of rigorous, coherent, and progressively more sophisticated study." Depth helps students distinguish between what is fundamental and what is only peripheral; it requires focus, provides intense concentration, and encourages a "lean and taut" degree that has a "meaningful core" and a purposefully designed structure (Memorandum to the Faculty No. 13). In addition to describing carefully structured academic majors, this description applies to well-designed BYU courses of all kinds.
>
> The chief result of depth is competence. BYU's students should be "capable of competing with the best students in their field" (Mission Statement). Even so, undergraduate study should be targeted at entrance-level, not expert-level, abilities. The desire for depth should not lead to bachelor's degrees that try to teach students everything they will need to know after graduation. Students should be able to complete their degrees within about four years.

The specific proposals we include in the remainder of this document are made with the intent to

- Increase personal agency and personal investment for students in the program by offering meaningful course options at several places.
- Introduce students to discipline areas earlier in the program.
- Allow students to complete either a broad civil engineering degree or develop targeted skills based on their interests and desires.
- Decrease the number of credit hours required for a degree to approximately 120 credit hours.
- Develop a framework that allows for new discipline area courses (e.g., data science, construction engineering) to seamlessly enter the program in response to changing industry needs.

A flowchart with the proposed changes is given in Figure 1. This proposal reduces the required credit hours to 122 from 128. The remainder of this document presents the changes by class year, along with a set of informal learning outcomes for each year. Chapter 5 presents a series of "student stories" describing how a variety of students might approach a civil engineering degree in the new program, complete with individual flowcharts.

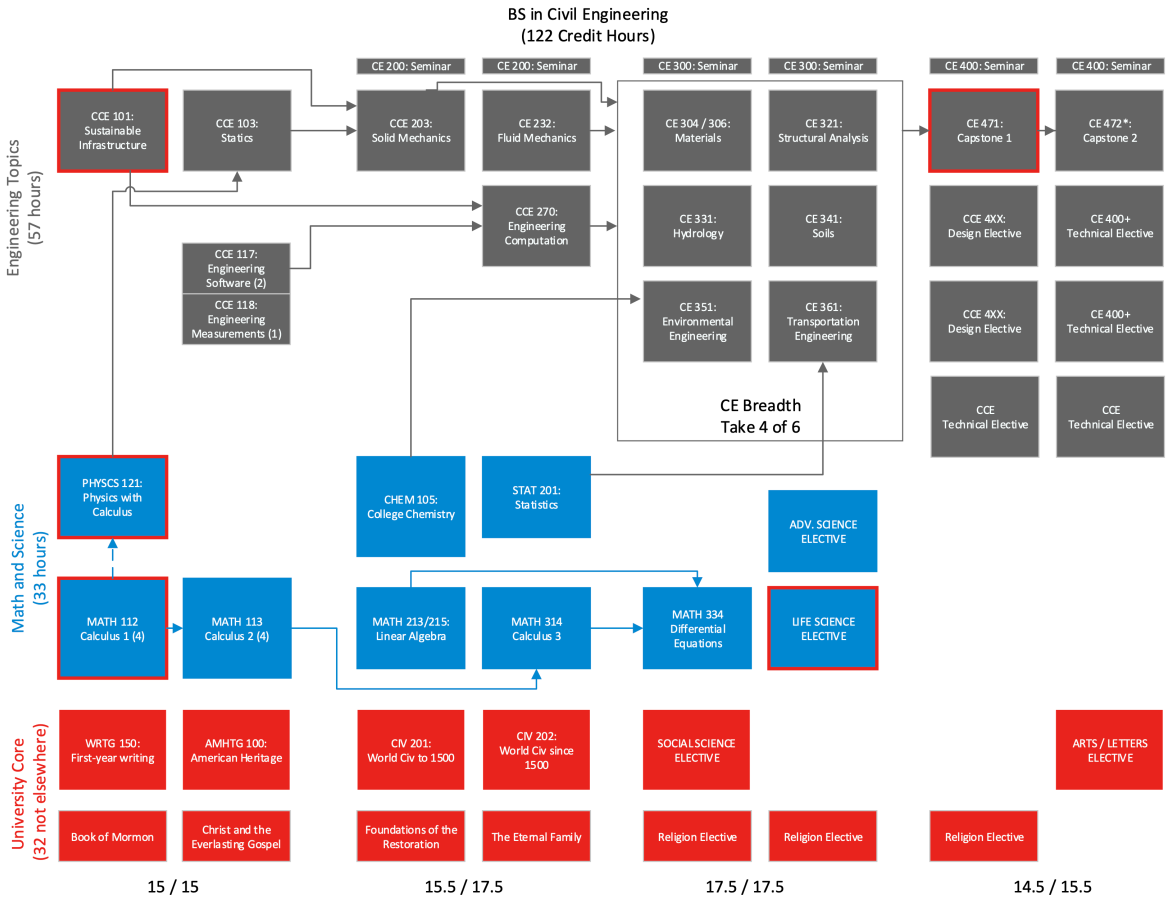

Figure 1: Proposed program flowchart (right-click to open larger in new tab).

1 Freshman Year

The learning outcomes for this year are for students to:

1. Feel belonging as a student in our discipline, regardless of their personal background and future career goals.

2. Describe how designing and constructing civil infrastructure benefits society and how the tools of our disciplines can solve challenges to humanity.
3. Apply mathematics and basic physics to solve basic problems related to optimization and forces on static bodies.
4. Obtain meaningful business and engineering skills that could be useful in part-time research or internships.

1.1 CCE 101: Sustainable Infrastructure

> **ℹ Proposed Change**
>
> Create a new CCE 101 (3 credit hours) by combining many learning outcomes from CCE 101 (1), CCE 201 (2), and CCE 231 (3)

The existing CCE 101 course is designed to *tell* students about the different employment and study paths available to them as civil engineers and construction managers. We desire to make this a class that *shows* how designing and building civil infrastructure benefits society through interactive case studies and a lens of stewardship.

The objective of this course is not to bring in all the learning outcomes of all three courses it replaces. Rather, we hope to create a targeted, "lean and taut" course that looks at global challenges to human prosperity and happiness, potential solutions to these challenges using built environments, and the responsibility of trained Latter-day Saints to find and implement solutions to these challenges. We hope that this class will set a tone for all the subjects students will encounter through their programs. Proposed learning outcomes include:

1. Describe how civil infrastructure and the built environment can foster (or inhibit) a sustainable society, including efforts to achieve United Nations Sustainable Development Goals.

2. Apply the principle of time value of money to identify financially sustainable infrastructure investment decisions.
3. 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. (ABET Student Outcome 4)
4. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. (ABET Student Outcome 5)

We intend that this course will qualify for the Global and Cultural Awareness University Core requirement (focused on the global challenge of sustainability), or as an Explorations: Science and Technology in the proposed GE. We also expect this change to enhance recruiting of undecided majors across campus and begin generating interest in civil engineering and construction disciplines students will explore later.

1.2 CCE 117 / 118 Engineering Software and Measurements

> **Proposed Change**
>
> Proposed Change: Create a set of new courses introducing students to engineering software and measurements. Eliminate CCE 112 (3 credit hours) and CCE 214 (2 credit hours)

The list of practical skills that engineering students need is always expanding, with new software replacing formerly essential tools (e.g. the shift from manual drafting to CAD) or creating new ones (GIS). Rather than adding and shifting course requirements as tools become available – and retaining legacy classes that have been superseded – we propose a two-course series where individual sections focus on different software and measurement techniques.

CCE 117 is proposed as a two-credit hour software class. We anticipate a section focused on GIS and another on CAD, but others may be possible. Specific learning outcomes will vary by software, but all sections will require that students will:

1. Understand and explain software licensing models and how to install software.
2. Download technical files from web-based repositories, store the files onto local and shared computing networks, and open files in commercial engineering software.
3. Obtain useful guidance from software documentation and online help forums, including generative AI as appropriate.
4. Produce a visualization supporting an engineering design or analysis.

CCE 118 is proposed as a one-credit hour engineering measurements class. We anticipate potential sections on surveying, remote sensing, water quality measurements, and piezoelectric sensors. The proposed learning outcomes for all sections are that students will:

1. Describe the purpose of data collection in engineering projects.
2. Describe the challenge of measurement accuracy and tolerance.
3. Use modern techniques to record, store, and disseminate engineering data.
4. Construct basic visualizations of engineering data.

We recognize that many construction management students are likely to derive more benefit from BIM than GIS. If the construction management program elects to retain its three-credit hour CCE 113 BIM class, we would allow CE students to take that class as a substitute for CCE 117.

2 Sophomore Year

The learning outcomes for this year are for students to:

1. Apply advanced physics and mathematics to solve problems in solid and fluid mechanics.
2. Apply basic computational techniques – including writing functions, reading complex datasets, and optimization – to solve meaningful problems in all discipline areas of civil engineering.
3. Identify which discipline breadth classes to take in the junior year.

2.1 CE 232: Fluid Mechanics

> **Proposed Change**
>
> Convert CE 332 from a 300-level discipline area class into a 200-level mechanics class required for all students.

Fluid mechanics is an important prerequisite for many junior-level classes, including geotechnical engineering and environmental engineering. As a result, many engineering programs across the country require a fluid mechanics course prior to proceeding with discipline-specific classes. Moving fluid mechanics to a required sophomore-level class (1) naturally fills the void left by removing dynamics from our curriculum, (2) demonstrates to students that modeling of physical behavior is not limited to structural phenomena (3) better prepares students to take junior-level courses, and (4) enables students to explore topics in water engineering and soils engineering earlier in their program of study. Learning outcomes for this class will largely remain consistent with those of CE 332, which are

- Setup, perform, evaluate, and report on elementary hydraulic experiments;
- Use basic calculations to describe static pressures and forces in fluids;
- Understand and apply conservation of mass, momentum, and energy in flow analysis problems;
- Apply concepts of drag and lift to solve introductory problems of forces and dynamics;
- Employ and evaluate between standard methods to analyze and design pressure pipe systems;
- Understand basic elements of pump and turbine flow to analyze and select appropriate fluid pumps for basic pumping situations.

It is also anticipated that this change will breathe additional hope into students that currently may feel bogged down by two full years of solid mechanics prior to getting into alternative subject areas. This change is intended to improve retention for these students.

2.2 CCE 270: Engineering Computation

> **Proposed Change**
>
> Convert CCE 170 into a 200-level computation class with a higher level of computational tasks drawn from all discipline areas.

To better expose students to the various disciplines of civil engineering, as well as to build on the momentum established in CCE 101, CCE 170 will be converted back into a sophomore-level class. Here, students will be asked to use computers and computation to solve discipline-specific problems. The intent of this class is to help students gain necessary computing skills while seeing they can solve interesting problems in a variety of discipline areas using computing. Based on this experience, students will be better prepared to select junior-level courses that best meet their interests. Learning outcomes for the class include

- Approach problems in mulitple civil engineering discipline areas from a programmatic mindset
- Apply intermediate spreadsheet skills to solve civil engineering problems in a variety of disciplines
- Create custom code in a modern programming language to automate redundant or otherwise intractable engineering processes
- Collaborate with a team to develop and present software of value to stakeholders

Recall that CCE 170 was originally taught as a sophomore-level class, but was moved to a freshman-level class to accommodate basic training in Excel necessary for some 200-level classes. Many of these prerequisite and basic skills in Excel will now be covered briefly in CCE 101.

2.3 Math Core

There is no proposed change here, other than we are electing to show the three-course math sequence on the flowchart, giving it primacy over the two-course sequence. Both sequences will remain acceptable in the new program.

3 Junior Year

The learning outcomes for this year are for students to:

1. Obtain a broad competence in multiple disciplines of civil engineering.
2. Prepare for technical and design electives, as well as a Capstone experience.

3.1 CE Breadth Core

> **Proposed Change**
>
> Require students to complete four of six discipline area classes, instead of all six courses.

Civil engineers must be trained to solve problems in multiple discipline areas. The ABET criteria for civil engineering programs states:

> The curriculum must prepare graduates to analyze and solve problems in at least four technical areas appropriate to civil engineering

The ASCE commentary (p. 11) on this criterion in part states:

> In response to emerging societal needs, civil engineering programs may need to develop non-standard technical areas. These breadth areas should be supported by constituent and stakeholder feedback, and connected to the Program Educational Objectives.

In our program, we have historically met this requirement with introductory discpline area classes at the 300-level. The requirement to take all courses is unnecessarily constraining to both the students and our program, however.

First, students who investigate the civil engineering major because it houses a discipline they have interest in are often deterred by the abundance of seemingly irrelevant courses. For example, students interested in urban transport or environmental mitigation look at our existing program and have the impression that it is a structural engineering degree with two or three elective courses relevant to their interests. These students — often women and minorities —

have frequently left or considered leaving our major to study mathematics, geology, geography, or plant and wildlife science instead of civil engineering. We believe that our discipline is poorer for losing their perspective.

Second, as new discipline classes are proposed (e.g., construction engineering, engineering data science, etc.), they require our faculty to reconsider anew where they will fit into our program. This proposed change sets the stage for sustainable flexibility in our core offerings as the disciplines of civil engineering evolve.

We anticipate some growing pains and objections to this proposal. These objections are reasonable, but we hope we can address them in the following ways

- *How will students know that they don't want to do X if they have never had a class in X?* We intend for the proposed changes to CCE 101 (Section 1.1) will help students first see the purpose of each discipline in improving the quality of life for God's children on His earth, and that improvements to CCE 270 (Section 2.2) will give meaningful exposure to questions and methods in all discipline areas, before students choose which junior core classes to pursue.
- *Won't students just take the courses that are easiest / the courses that their friends are taking?* This is a real possibility, but we believe that students must be accountable for their own intellectual development. We believe that the quality of course instruction will improve when the participating students have invested their agency in selecting courses.
- *Can you call yourself a civil engineer if you haven't had a class in X?* BYU would be far from the first university to not require specific discipline area classes in a civil engineering degree. At least Georgia Tech, Texas A&M, and UC Davis have degree programs without specific discipline area course requirements.
- *Will this have any ABET ramifications?* For civil engineering breadth, we are in good shape by requiring four discipline area classes. There is an additional requirement that students "conduct experiments in at least two discipline areas." To ensure that this requirement is met for all students, we will need to ask that at least four 300 level classes include an "experiment."
- *Will our students still pass the FE?* It is possible that depending on the courses students select and the specific makeup of their exams, students may encounter more or fewer problems that they are directly trained to solve. We anticipate that the FE review course will still be valuable.
- *Won't many of our students just want a well-rounded, all areas civil engineering degree?* The hope is that this proposal will allow students to choose for themselves what they would like to achieve in their education. Any 300-level courses beyond the four course breadth requirement would count as CCE technical electives, thus a student who wanted to take all discipline area classes for additional FE or career preparation could still do so. (see the student story in Figure 5.2).

3.2 CCE 331: Hydrology (Introduction to Water Resources)

> **ℹ Proposed Change**
>
> Convert CE 431: Hydrology into a 300-level junior core class.

Moving fluid mechanics to a sophomore-level mechanics class leaves the water resources group without a clear discipline area introduction class. We believe that the existing CE 431 course works better as an introductory discipline area class than as a design elective, and moving it to the 300 level is appropriate.

3.3 Social Science Elective

> **ℹ Proposed Change**
>
> Allow students to select a course for the Social Science University Core that most interests them.

Eliminating CCE 231 will necessitate that our students take a course that meets the social science requirements for the University Core. This also helps accomodate students who may have taken an appropriate GE class before entering the major. While any appropriate course could fill this box, we might informally recommended a list to students including:

- GEOG 110 Landscapes of Disaster: An Introduction to Natural Hazards
- EXSC 221 Science of Wellness
- ANTHR 101 Social/Cultural Anthropology
- ECON 110 Econ Principles & Problems
- HONRS 226 Unexpected Connections: Soc Sci-Ltrs
- PSYCH 111 Psychological Science
- SOC 112 Current Social Problems

3.4 Life Science Elective

> **ℹ Proposed Change**
>
> Require students to select a biological science University Core course from a list.

ABET requires classes in "calculus-based physics, college-level chemistry, and one additional area of basic science." Historically, this requirement has been met with PHYSCS 121, CHEM

105, and GEOL 330. But the University Core requires a course in biological science, which we represent on the present flowchart with Biology 100. We propose to use this course as the "one additional area of basic science" required by ABET, thus allowing students to take a second course in Physics or Chemistry later in the program (see Section 3.5). Courses that could be used to fill this requirement include:

- BIO 100 - Principles of Biology
- CELL 120 - Science of Biology
- HONRS 220 - Unexpected Connections: Biol-Letters
- MMBIO 121 - Gen Biology: Health & Disease
- PWS 150 - Environmental Biology

3.5 Advanced Math or Science Elective

> **i** Proposed Change
>
> Require an advanced science class from a list; GEOL 330 is no longer required for all students.

Many civil engineering students benefit from GEOL 330, but we believe that some students might elect to take a different advanced science course. This list might include:

- PHSCS 123 - Intro to Waves, Optics, and Thermodynamics
- PHSCS 137 - Energy, Climate, and the Environment
- PHSCS 220 - Electricity and Magnetism
- CHEM 285 - Introductory Bio-organic Chemistry
- CHEM 351 - Organic Chemistry 1
- GEOL 330 - Engineering Geology
- MATH 290 - Fundamentals of Mathematics
- MATH 355 - Graph Theory
- STAT 230 - Statistical Modeling 1

These classes would also count for up to one CCE technical elective.

4 Senior Year

4.1 CE 471: Capstone 1

Proposed Change

Develop CE 471 into a 3-credit hour course that counts as an Advanced Written and Oral Communication GE. Eliminates WRTG 316 (3)

Students currently take WRTG 316 Technical Writing to fulfil the Advanced Written and Oral Communication AWOC University Core requirement. While the instructors are well trained in writing pedagogy, they are not engineers, they are not consistent each semester, and they are trying to meet the needs of diverse academic departments. Student feedback over the years suggests that while some aspects of the course are valuable (such as writing methods), the instructors and learning activities do not relate well to their own disciplines, defeating many of the AWOC learning outcomes.

We propose to bring AWOC into the CE program as part of the Capstone experience. This is something that many programs on campus have done, with the aid and encouragement of the English department, and there is an application process already in place. The first Capstone semester would increase to 3 credits to accommodate the change. The AWOC learning activities would be specific to Capstone projects or senior thesis (see Section 4.2): proposal writing, oral presentations, literature reviews, resume preparation, interview skills, peer reviews, and so on. We recommend hiring an adjunct instructor with a technical writing background and an English degree to teach the writing portions of the course and aid the the capstone director. The capstone director will also have to participate in some English department training activities.

4.2 HONRS 499R / CE 499R: Honors or Senior Thesis

> **Proposed Change**
>
> Allow students completing senior theses (honors theses or mentored research projects with substantive deliverables) to count their work as a culminating design experience.

ABET requires a "culminating major engineering design experience" incorporating "engineering standards and multiple constraints" and based on "earlier coursework." We have satisfied this requirement with Capstone in the past, but alternative projects such as honors theses and mentored research may also qualify. Past students who completed both Capstone and an alternative experience expressed that their alternative experience was more meaningful.

At BYU, where undergraduate research is so highly valued, we ought to offer it as a pathway to fulfilling this requirement. A senior thesis option can run parallel to Capstone 2. Logistically, we would establish a 3-credit CE 499R Senior Project course for such students (there is already a HONRS 499R). Early in the Capstone 1 course, a senior thesis student would petition the undergraduate coordinator. demonstrating that they have a mentor and an appropriate project that can be publication-ready by the end of the second semester. Upon approval, this student would be excused from a capstone project group. Throughout the second semester, the student would develop the project and prepare the final deliverables. The student's work will be evaluated by a three-member committee consisting of the undergraduate coordinator (or honors coordinator for honors students), the mentor, and one other faculty member to ensure that it is appropriate as a culminating design experience.

5 Student Stories

This section presents a set of stories that reflect the variety of experiences possible for students in our program. They are at least partially derived from student exit interviews. Additionally, we present how the new GE proposal will impact the curriculum.

5.1 Sarah (Environmental Hydrology)

Sarah came to BYU not knowing what her major would be, but she knew she wanted to help the environment. She passed AP Calculus in high school and played the cello in her high school orchestra. She's not sure about grad school, but could be persuaded. Her program of study is shown in Figure 5.1.

Freshman Year When arriving at BYU Sarah was mostly focused on GE's while looking for a major. One day on the BYU website she sees a profile of Jim Nelson's research, and decides she wants to learn how to do environmental hydrology. She has already taken the PWS Environmental Biology class as well as Chem 105, so she enrolls in CCE 101 for Winter semester. In March she receives a call to serve a Chinese speaking mission in Canada, and is gone for 18 months.

Sophomore Year When Sarah returns from her mission, she wants to continue studying Chinese, so she makes room in her schedule for Chinese 301 and 302 by putting off the Math classes for a semester.

Junior Year Sarah elects to skip structural analysis and transportation engineering so that she can attain a deeper focus on environmental hydrology. She still has breadth classes in soil mechanics and engineering materials, which will prepare her for design electives next year. She decides to take English Civ instead of the Music series she started as a Freshman so it will double-count for her Letters GE requirement, while adding an Arts GE elective in Asian art.

Senior Year While taking the design classes in GIS software and hydraulics, Sarah is recruited for a senior research project and associated study abroad. She builds hydrologic hazards mapping software for communities in Nepal as a culminating design experience.

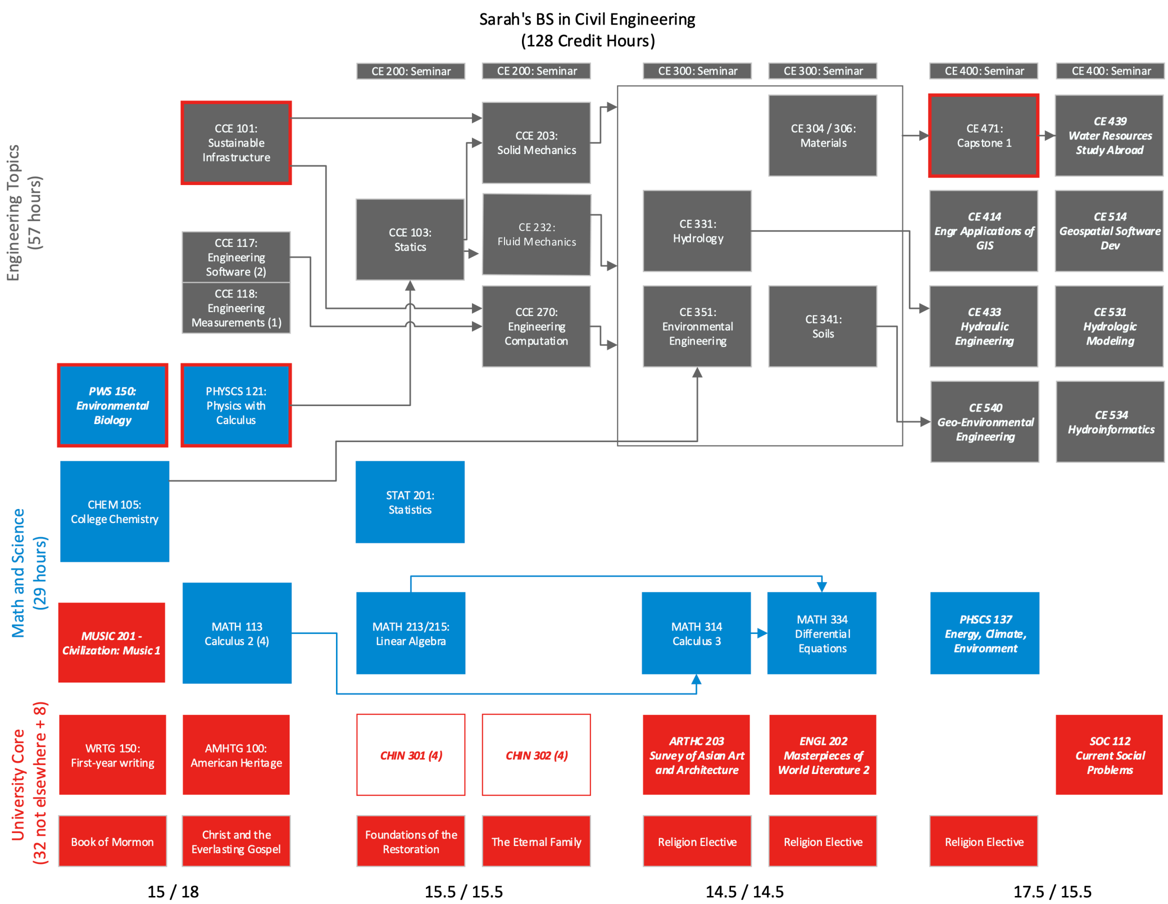

Figure 5.1: Sarah's proposed program flowchart.

5.2 John (UDOT Engineer)

John chose to major in Civil Engineering because his uncle is a civil engineer with the state highway department. He is not planning on an MS degree; his goal is to get into practical classes as quickly as possible so that he can get an internship with UDOT leading to their rotational engineering program. His program of study is shown in Figure 5.2.

Freshman Year John learned from his uncle that engineers use CAD and surveying tools, so he signs up for those as his 117/118 pair.

Sophomore Year In order to save a credit hour and get through the math sequence as quickly as possible, John opts for the 2-class Math for Engineers option. He also notices that because he doesn't plan to take CE 351: Environmental, he can put off CHEM 105 and instead take his fluids and computations class a semester earlier. This gives him a head start on Materials and Soils, preparing him for an internship with a geotechnical engineering firm with UDOT contracts.

Junior Year John has a girlfriend who served her mission in Paris, and they decide to take the French and Italian cinema class together to fill his arts GE elective. For his life science and social science GE electives, John decides that Environmental Biology might fill in some things he missed by not taking CE 351, and the disasters class in the geography department could provide useful background for a highway engineer who is worried about resiliency. And because he is a little bit ahead in the program, John gets started on his design electives, opting to take CE 461 in his junior year. He also decides to take CE 331 Hydrology as a tech elective, even though he already has fulfilled the breadth requirement for the program.

Senior Year Hearing more about all the things a UDOT rotational engineer works on, John fills out his four remaining CE electives with an eclectic mix of traffic engineering, hydraulic engineering, and reinforced bridge design. And after putting off his GE Civ classes, John realizes that he kind of liked his literature teacher back in high school and decides to do a series in English and Comparative Literature, which double-counts as his GE Letters requirement. His team's capstone project involves a drainage plan for a new pedestrian trail in Springville, and he's glad he took the extra class in Hydrology the year before.

5.3 Emma (University Honors, M.Arch Preparation)

Emma is a high-achieving student who wants to improve the design and ecological impact of built spaces. She hopes for placement in a top Master of Architecture program, and believes that completing a structural engineering-focused BS in CE would be good preparation. Emma also hopes that completing University Honors will help distinguish her application. Her program is shown in Figure 5.3

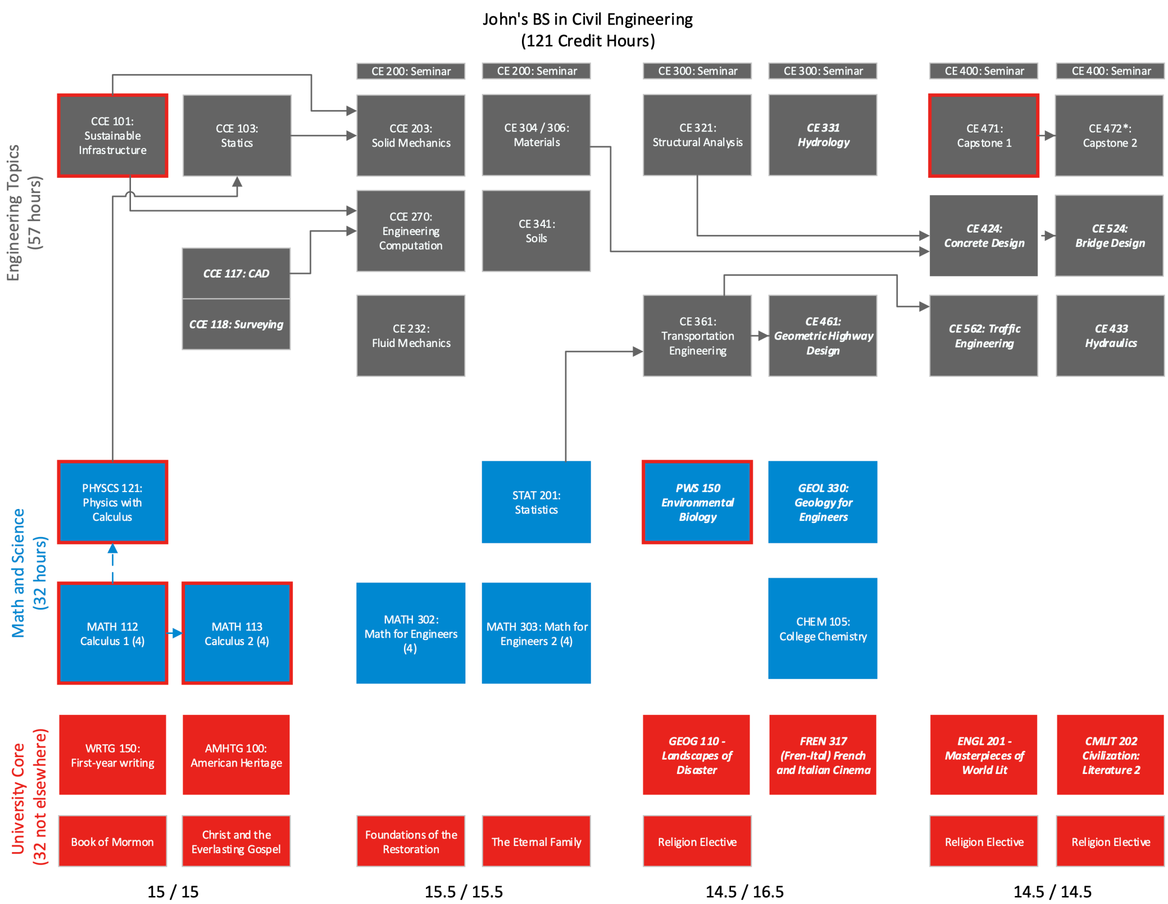

Figure 5.2: John's proposed program flowchart.

Freshman Year For the engineering software class, Emma pairs BIM and a class in data collection with drones because it sounds cool. She also takes the first-year Honors classes.

Sophomore Year Emma selects Art History civilization classes because she hopes to learn about how humans have built spaces for themselves throughout history. The trips to the JFSB provide a welcome relief from Chemistry and Solid Mechanics, where she can stretch a different part of her brain.

Junior Year To prepare herself for the structural design classes she is interested in, Emma takes Materials and Structural Analysis. She is also interested in the urban transportation planning course, so she takes Environmental Engineering and Transportation to fill out her CE Core, as well as the Energy, Climate, and the Environment class offered in the Physics department. Because she is in the Honors Program, Emma picks three Unexpected Connections classes that also fill her Life Science, Social Science, and Arts General Education requirements. She especially liked the class "Blessed are the Poor: Understanding Poverty through History and Theology" taught by faculty in Sociology and Religion.

Senior Year Now prepared with substantive breadth in CE and other courses of her choosing, Emma digs into her senior year with a difficult set of technical electives and begins working with Dr. Judd on her honors thesis, looking at self-correcting floor mechanisms in steel frame buildings. She wishes she could go back in time and take the class in structural sensors for her CCE 118 option, but it's not too much of a lift to figure out how to attach and calibrate the sensors and associated equipment during her summer research assistantship. She uses this effort as her culminating design experience, and the ability to focus on this complex design problem helps to generate a publication-quality research article.

5.4 New University GE

The proposed curriculum will map well onto the proposed University GE. All of the STEM requirements will be absorbed into the existing course requirements. CCE 101 will be designated as an Explorations: Science and Technology course, which is probably a better fit for its content than either the Global and Cultural Awareness or the Social Science in the current University Core. In the flowchart in Figure 5.4, we show CCE 101 paired with a first-year writing class; in the new GE, first-year writing will be taught in a seminar with an explorations class. The new foreign language requirement will increase the proposed credit hours from 122 to 125 (121 to 124 with the two course Math sequence); we could elect to remove a technical elective if and when the new GE begins.

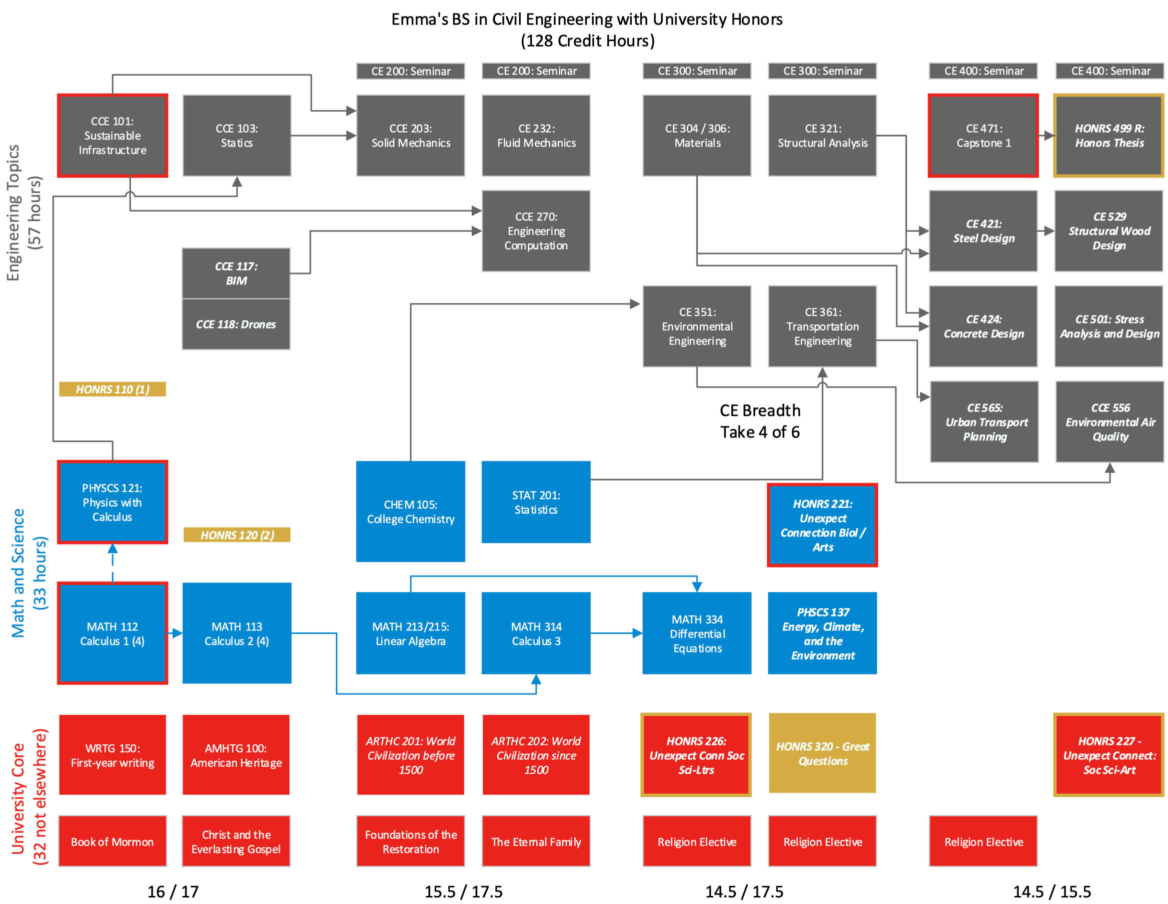

Figure 5.3: Emma's proposed program flowchart.

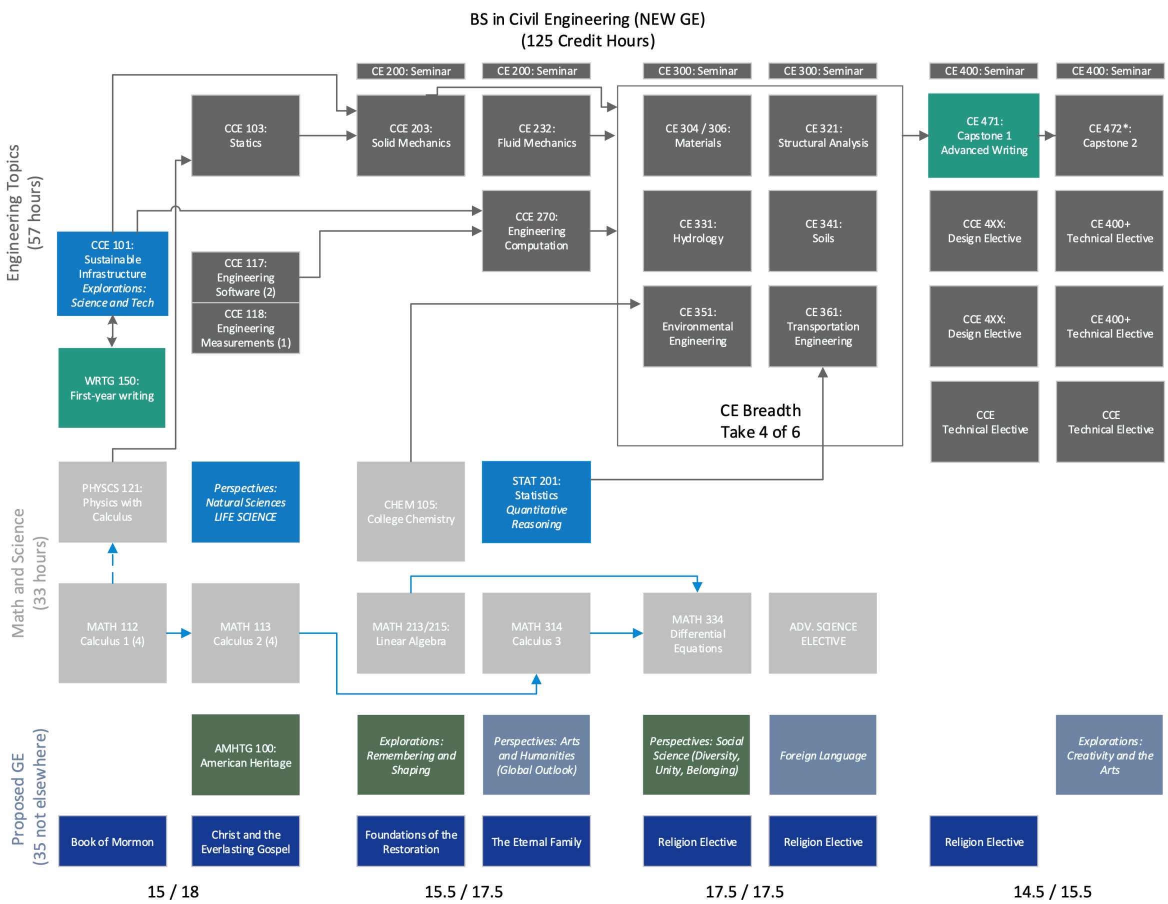

Figure 5.4: Proposed program flowchart under the new University GE.