Re-envisioning the Curricular Pathway in Environmental Engineering

Dr. Jennifer Mueller PE, ENV SP, Rose-Hulman Institute of Technology

Dr. Jennifer Mueller is an Associate Professor in the Department of Civil and Environmental Engineering at Rose-Hulman Institute of Technology. She graduated with her BS in Environmental Engineering from Northwestern University and with her MS and PhD in Civil Engineering with an emphasis on Environmental River Mechanics from Colorado State University. Her graduate work focused on exchange of surface water and groundwater, as well as nitrate uptake, in streams with varying degrees of rehabilitation. Dr. Mueller's areas of interest include water quality, sustainable design, watershed hydrology, and river hydraulics. Current projects involve pedagogical studies for incorporating sustainability and ethical decision making in undergraduate engineering education, with an emphasis on touchpoints throughout the four-year curriculum.

Dr. Michelle Marincel Payne, Rose-Hulman Institute of Technology

Dr. Michelle Marincel Payne is an Associate Professor in the Civil and Environmental Engineering at Rose-Hulman Institute of Technology. She earned her Ph.D. in Environmental Engineering from the University of Illinois at Urbana-Champaign, her M.S. in Environmental Engineering from Missouri University of Science and Technology, and her B.S. in Nuclear Engineering from the University of Missouri-Rolla (same school, different name). At Rose-Hulman, Michelle is co-leading a project to infuse an entrepreneurial-mindset in undergraduate students' learning, and a project to improve teaming by teaching psychological safety in engineering education curricula. Michelle also mentors undergraduate researchers to investigate the removal of stormwater pollutants in engineered wetlands. Michelle was a 2018 ExCEEd Fellow, and was recognized as the 2019 ASCE Daniel V. Terrell Awardee.

Dr. Namita Shrestha, Rose-Hulman Institute of Technology

Dr. Namita Shrestha earned her PhD in Civil/Environmental Engineering from South Dakota School of Mines and Technology; Master of Science in Civil/Environmental Engineering from South Dakota School of Mines and Technology. Her research interests include bioelectrochemical systems, microbial electrochemistry, resource recovery from waste/wastewater, waste treatment and nanomaterial for bioelectrochemical application. She is passionate about research-based learning and student-centered pedagogy. She serves as a member of the American Society of Civil Engineers (ASCE), Association of Environmental Engineering and Science Professors (AEESP), Environmental & Water Resources Institute (EWRI) and ASEE.

Re-envisioning the Curricular Pathway in Environmental Engineering

Abstract

Currently, students majoring in civil engineering at Rose-Hulman Institute of Technology (RHIT) do not get exposure to discipline-specific course content in environmental engineering until the final quarter of Year 3. We've noticed that many students we've advised come into their first year with an interest in environmental engineering, but they tend to choose different paths before they even have a course in environmental engineering. We developed a plan that re-envisions the pathway for the environmental engineering curriculum. We evaluated different scenarios of curriculum pathways to provide students with exposure to environmental engineering content earlier in their academic career. Through this process, we explored how to repackage the environmental engineering curriculum, and we assessed impacts on other courses in the civil engineering major program curriculum and the environmental engineering minor program curriculum to determine the feasibility of each option. While evaluating existing course content, we compared current coverage with the American Academy of Environmental Engineers and Scientists (AAEES) Environmental Engineering (EnvE) Body of Knowledge (BOK) [1] and the American Society of Civil Engineers (ASCE) BOK [2]. Through this process, we developed a curricular pathway to introduce students to discipline-specific environmental engineering content early in the academic career that encompasses both the EnvE BOK for the environmental engineering minor degree program and the ASCE BOK for the civil engineering major degree program, as well as meeting ABET accreditation outcomes that could be helpful for other programs that offer Environmental Engineering content within a Civil Engineering degree program as well.

Project Overview

The three environmental engineering (EnvE) faculty in the Civil and Environmental Engineering Department at Rose-Hulman Institute of Technology (RHIT) have devised a plan to re-envision the pathway for the environmental engineering curriculum within our department. Currently, students majoring in civil engineering (CE) do not get exposure to discipline-specific course content in EnvE until the final quarter of Year 3. We've noticed that many students we've advised come into their first year with an interest in EnvE, but they tend to choose different paths before they even have a course in EnvE. We have evaluated different scenarios of curriculum pathways to provide students with exposure to EnvE content earlier in their academic careers. As we explored alternatives for how to repackage the EnvE curriculum, we assessed impacts on other courses in the CE curriculum and the EnvE minor curriculum to determine the feasibility of each option.

In addition to proposing changes to the curricular pathway, we evaluated content in the current EnvE courses to enable us to develop new, relevant courses and lab modules to support these efforts. To facilitate this process, we conducted a survey among members of our department's

board of advisors and alumni who are practicing engineers to prioritize relevant EnvE topics from the American Academy of Environmental Engineers and Scientists (AAEES) Environmental Engineering Body of Knowledge (BOK) [1] that they apply most in practice.

Curricular Pathway Scenarios

To give students earlier exposure to EnvE design, we identified alternative approaches to rearranging EnvE course offerings, as well as the possibility of creating an introduction to CE course in the freshman year. Collectively, these changes could allow students to be exposed to all topics of civil engineering to be able to make better informed decisions as they seek out first internships and begin to build their identities as civil engineers.

EnvE Course and Lab Alignment

An overall change we recommend is to combine the current 4-credit CE460 Introduction to EnvE and the current 2-credit CE461 EnvE Lab into a technical design lab-based course for 4-credits offered as a new version of CE460* Introduction to EnvE. This approach of combining a lecture and lab as a packaged 4-credit hour course would be consistent with other technical design lab-based courses offered in the department such as soil mechanics, hydraulics, and CE materials. This change frees up two credits to be allocated elsewhere in the curriculum.

Earlier Exposure to EnvE in the Curriculum

In addition to combining the lab and lecture to create the CE460* Introduction to EnvE, we could rearrange the timing of when students take it to gain EnvE exposure earlier in the curriculum. Specifically, the new CE460* Introduction to EnvE course would move to the Fall Quarter of Year 3 (instead of Spring Quarter of Year 3). To make this work, the timing of other courses would need to be modified: in exchange, CE336 Soil Mechanics would be moved to Spring Quarter of Year 3 (Figure 1).

Reallocation of Two Credits

In the creation of the combined lab and lecture CE460* Introduction to EnvE course, two credits are freed up to be allocated elsewhere in the curriculum. We identified three alternatives for reallocating these two credits, some of which support strengthening the EnvE curriculum, and some that support our overall program. In a first alternative, they could be used to develop a new Introduction to CE course that would provide students with early exposure to all CE subdisciplines. In this course, students would be introduced to introductory concepts, targeted design elements, and applications encompassing all CE subdisciplines (environmental, water resources, structural, geotechnical, transportation, and construction). One way to accomplish our desire to include an introduction to CE course would be to expand our current EM103 Introduction to Design course from a 2-credit course to a 4-credit course to include the additional content (Figure 1).

Another option for allocating the two credits could be to turn CE431 Steel Design and CE432 Concrete Design I into 4-credit courses (Figure 1). These are both currently offered as 3-credit courses, a relic of past curricular changes, but they were originally intended to be offered as 4-credit courses.

A third option for allocating the two credits could be to add two credits to the current 2-credit CE250 Sustainable Civil Engineering course. In this alternative, some of the environmental science and public health aspects from the original CE460 Introduction to EnvE course could be moved into a 4-credit CE250 Sustainable CE course (Figure 1). Topics such as air pollution, risk and toxicity, and hazardous waste, relate to life cycle impact categories already covered in CE250 Sustainable CE. A potential advantage of this alternative is that students might view a 4-credit course as having more rigor than the current 2-credit course.

Adding a new EnvE Course

The addition of a new EnvE course would introduce two pathways in our program: structural and environmental engineering. In this alternative, after students complete CE432 Concrete Design 1 in the Winter Quarter of Year 3, they could follow a structural engineering path by taking the CE431 Steel Design in Spring Quarter of Year 3 or following an EnvE path by taking the newly developed EnvE Applications course in Spring Quarter of Year 3 (Figure 1). The EnvE Applications course would utilize course content that was removed during the consolidation of the separate EnvE technical design course with the EnvE lab course when creating the new 4-credit CE460* Introduction to EnvE technical design lab-based course. This new EnvE Applications course would also include additional coursework to be developed. The additional curriculum development would be guided by the EnvE BOK [1] and results of the survey we conducted to collect data on professional experiences in EnvE among practitioners.

This final alternative would support all CE subdisciplines more equally and provide more options to students by reducing the current singular emphasis on the structural pathway. This plan offers a solution with minimal changes to the curriculum while offering more options for our students and still meeting ABET and departmental needs. Experiencing EnvE design coursework in an expanded EnvE curriculum would allow students to gain EnvE knowledge earlier in the curriculum and in a deeper way.

Impact Assessment of Curricular Pathways

In determining the feasibility of these options, we assessed impacts on existing classes and the timing of course offerings. We evaluated the impacts of these changes on student course load per term and faculty availability to teach additional courses each term. We found that by merging CE460 Introduction to EnvE lecture and CE461 Introduction to EnvE lab courses results in a reduction of student credits from 17 to 15 in Spring Quarter of Year 3. Swapping the timing of CE460* Introduction of EnvE and CE336 Soil Mechanics led to no change in student course load, as this is an even exchange of credits per quarter. However, this swap in timing does lead

to changes in teaching loads, so instructors of the two courses would need to change which courses they teach in the quarters impacted by this rearrangement (fall and spring quarters).

Reallocation of the two credits to EM103 Introduction to Design in Spring Quarter of Year 1, or one credit to CE432 Concrete Design 1 in Winter Quarter of Year 3 and one credit to CE431 Steel Design 1 in Spring Quarter of Year 3 would increase student course load each term, but the increase would be within the 18 credits allowed per term before it is considered an overload. As a new Introduction to CE course, or expanded EM103 Introduction to Design course, would be co-taught by most instructors in the department because of the need to include expertise in all subdiscipline areas, this course would slightly add to each faculty member's teaching load for the fall quarter. The third option of reallocating the two credits to form a 4-credit CE250 Sustainable CE course would lead to an overload of course credits for students in Winter Quarter of Year 3. The current instructor of this course could absorb the extra credits, or another course typically taught that quarter could be taught by another instructor.

Adding an EnvE applications course in Spring Quarter of Year 3 would not alter course loads for students, as they would choose between CE431 Steel Design 1 or the new EnvE Applications course. The new EnvE Applications course could be taught by the former instructor of CE461 EnvE Laboratory, as that course will no longer be taught.

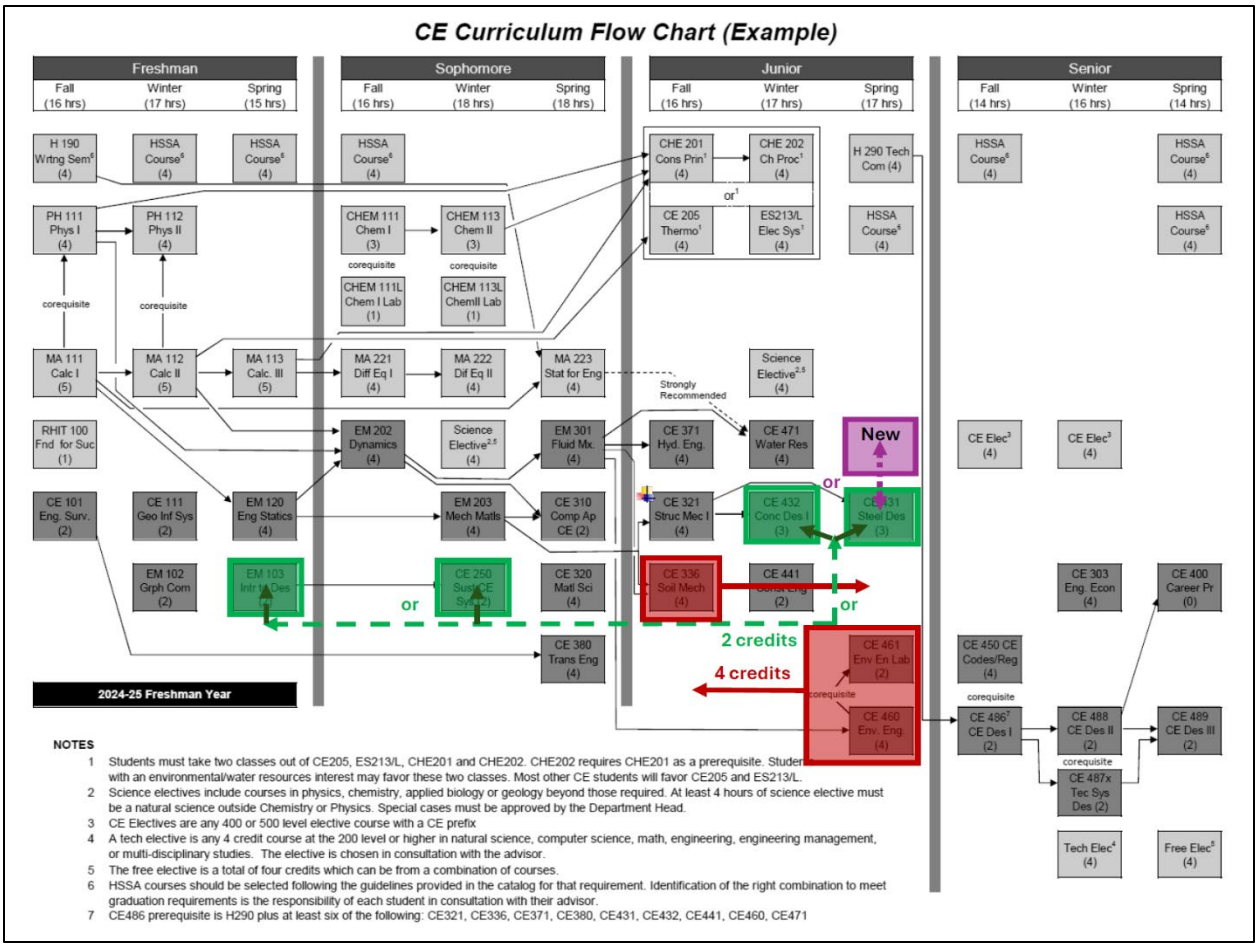

Figure 1: CE curriculum flow chart notated to indicate possible rearrangement of courses (red indicates option for earlier exposure to EnvE in the curriculum; green indicates options for reallocation of two credits;purple indicates option of a new EnvE course)

Data Collection Method

To support decision making of course rearrangement and the content desired in the new EnvE Applications course, this study was designed to explore the experiences of practitioners. Specifically, this study was designed to address the following research questions:

1. Which key topic areas in EnvE should be prioritized to best prepare students for professional practice?
2. What depth of coverage is most effective in EnvE topic areas to best prepare students for professional practice?

To be able to prioritize EnvE content in our civil engineering curriculum, we prepared a survey to understand practitioners' experiences based on the EnvE BOK [1]. To establish potential biases in experience based on actual design experience in areas of civil engineering, practitioners first ranked their experience from the most experience in actual engineering design work to the least experience for the following (1=most experience in actual engineering design work, 6=least

experience in actual engineering design work) subdisciplines of civil engineering: structural, geotechnical, construction, environmental, water resources, and transportation. To establish a sense of experience level, we asked participants about their status as a professional engineer.

To understand practitioners' experiences and help us determine constituency and level of EnvE content and placement in the curriculum, the survey asked participants to rate topics based on how often they performed engineering work in each EnvE topic area on a scale of 1-4 (1=much of my work experience is related to this topic, 2=some, 3=little, 4=none).

To determine the necessity of given learning areas to further consider reimagining our curriculum, the survey asked practitioners to respond on a scale of 1-3 based on how necessary they perceive each area to conducting design work in the EnvE field. In the survey, there was no limit to how many of each number (1, 2, or 3) they used in answering this question. Each topic could have a number: 1 = extremely essential, 2 = somewhat important, 3 = not necessary.

To solicit practitioner feedback, we leveraged our Board of Advisors, alumni, and other practitioners in our networks. Specifically, we sought feedback from our Board of Advisors at an in-person meeting followed by an email request from our full membership of the Board of Advisors and alumni. Altogether, we solicited 81 independent responses.

The survey did not request demographic information from the survey participants, but given the national span of our alumni base, we obtained responses from across the US with a concentration of responses from practitioners in the Midwest.

Survey Results

Feedback from engineering practitioners provided insight when prioritizing EnvE topic content in curriculum. Of the practitioner survey respondents, approximately 86% reported having their professional engineering license. To provide a better perspective of the level of direct work experience in EnvE, we asked the practitioners to rank their experience in the subdiscipline areas of civil engineering as noted in Table 1. The list of EnvE topics in Table 2 and EnvE learning areas in Table 3 were obtained from the EnvE BOK [1]. Tables 1-3 show the questions and the mean rating score for each response.

Table 1: Mean ratings for personal subdiscipline experience in civil engineering, ranked from most experience (1) to least experience (6) of responders (n=85)

CE Discipline Area	**Mean**	**SD**
Construction Engineering	3.05	1.45
Water Resources Engineering	3.24	1.94
Transportation Engineering	3.58	1.86
Environmental Engineering	3.61	1.83
Geotechnical Engineering	4.33	1.64
Structural Engineering	4.39	1.96

Table 2: Mean ratings for work-related EnvE topics, ranked from most relevant (1) to work experience to least relevant (4) to work experiences of responders (n=85)

EnvE BOK Topic [1]	**Mean**	**SD**
Stormwater management	2.16	1.03
Water quality management	2.45	1.10
Water/wastewater transport systems	2.47	1.02
Sustainability	2.72	0.89
Drinking water supply and treatment	2.93	1.10
Water pollution control technology	2.95	1.12
Wastewater treatment	2.98	1.15
Green infrastructure	2.99	0.91
Site assessment for contamination	3.07	1.02
Contaminated site remediation	3.15	0.92
Environmental health	3.22	0.82
Design for energy	3.30	0.90
Hazardous waste management	3.35	0.88
Ecological risk assessment	3.35	0.81
Ecosystem services	3.37	0.89
Solid waste management	3.44	0.97
Occupational health	3.53	0.75
Asbestos abatement	3.56	0.75
Air quality management	3.64	0.67
Risk and toxicity	3.65	0.70
Industrial hygiene	3.73	0.62
Air pollution control technology	3.74	0.62
Mold remediation	3.80	0.67
Insect and rodent control	3.81	0.57
Radiation protection	3.82	0.56
Food sanitation	3.87	0.51

Table 3: Mean ratings for learning areas necessary to conduct design work in EnvE, ranked from most essential (1) to least essential (3) based on experience of responders (n=85)

EnvE BOK Learning Area [1]	**Mean**	**SD**
Effective communication	1.13	0.40
Professional and ethical responsibilities	1.29	0.55

Basic environmental math and science knowledge	1.34	0.59
Problem formulation and conceptual analysis	1.38	0.62
Use of modern engineering tools	1.39	0.64
Multi-disciplinary teamwork to solve environmental problems	1.39	0.62
Lifelong learning	1.44	0.59
Project management	1.44	0.57
Creative design	1.52	0.59
Leadership	1.56	0.63
In-depth competence	1.59	0.64
Risk, reliability, and uncertainty	1.72	0.63
Sustainability	1.73	0.66
Design and conduct experiments	1.86	0.62
Societal impact and environmental policy	1.88	0.68
Sampling and analysis of pollutants	1.96	0.70
Business and public administration	1.96	0.68
Multi-media breadth and interactions (fate and transport of substances)	2.24	0.63
Globalization and other contemporary issues	2.32	0.62

Discussion and Conclusion

Based on survey results, content areas that we feel must be maintained and reinforced in the EnvE curriculum include topics rated as more than “little” of practitioners work experience being related to that topic:

- stormwater management,
- water quality management,
- water and wastewater transport systems,
- sustainability,
- drinking water supply and treatment
- water pollution control technology,
- wastewater treatment,
- green infrastructure,
- site assessment for contamination.

Less depth will be allocated to topics that were rated in the range of some to no relevant work experience (SD span around mean covers ratings ranging from 2-4), with some of these topics being moved to CE250 Sustainable CE:

- contaminated site remediation,

- environmental health,
- design for energy,
- hazardous waste management,
- ecological risk assessment,
- ecosystem services,
- solid waste management,
- occupational health,
- asbestos abatement,
- air quality management,
- risk and toxicity.

Topics that were rated in the range of little to no relevant work experience (SD span around mean covers ratings ranging from 3-4) will not be required components of the curriculum. These topics include:

- industrial hygiene
- air pollution control technology
- mold remediation
- insect and rodent control
- radiation protection,
- food sanitation.

The learning areas shown in Table 3 have been assessed in student learning outcomes annually as part of our department's continuous improvement plan for program accreditation. Our department is currently undergoing discussions on modifications to the student learning outcomes for future years, and this information can be used to inform areas of focus if the department decides to make changes to the current student learning outcomes being assessed.

Upon reviewing the impacts from the timing of course offerings and considering the balance of faculty load each term, we recommend combining CE460 Introduction to EnvE and CE461 EnvE Lab into a technical design lab-based course for 4-credits and offered as the CE460* Introduction to EnvE to be taught in the Fall Quarter of Year 3. To move this combined course to the fall term, we recommend moving the CE336 Soil Mechanics course to the Spring Quarter of Year 3 (Figure 2). This change in timing would lead to changes in courses taught for the two instructors who typically teach the CE460* Introduction to EnvE and CE336 Soil Mechanics courses in both the Fall and Spring Quarters, but there would be no change in student course loads in either quarter. The merging of the EnvE lecture and lab course into one unified course allows for reorganization of content and removal of redundant content that may be covered in both courses.

We recommend the two leftover credits from combining the separate EnvE lecture and lab courses be used to turn CE250 Sustainable CE into a 4-credit course. As this leads to an overload of course credits for students in Winter Quarter of Year 2, we recommend that a science elective be moved to Fall Quarter of Year 4 (Figure 2). This change results in students carrying

16 course credits in Winter Quarter of Year 2 and 18 course credits in Fall Quarter of Year 4, which are acceptable credit loads per term.

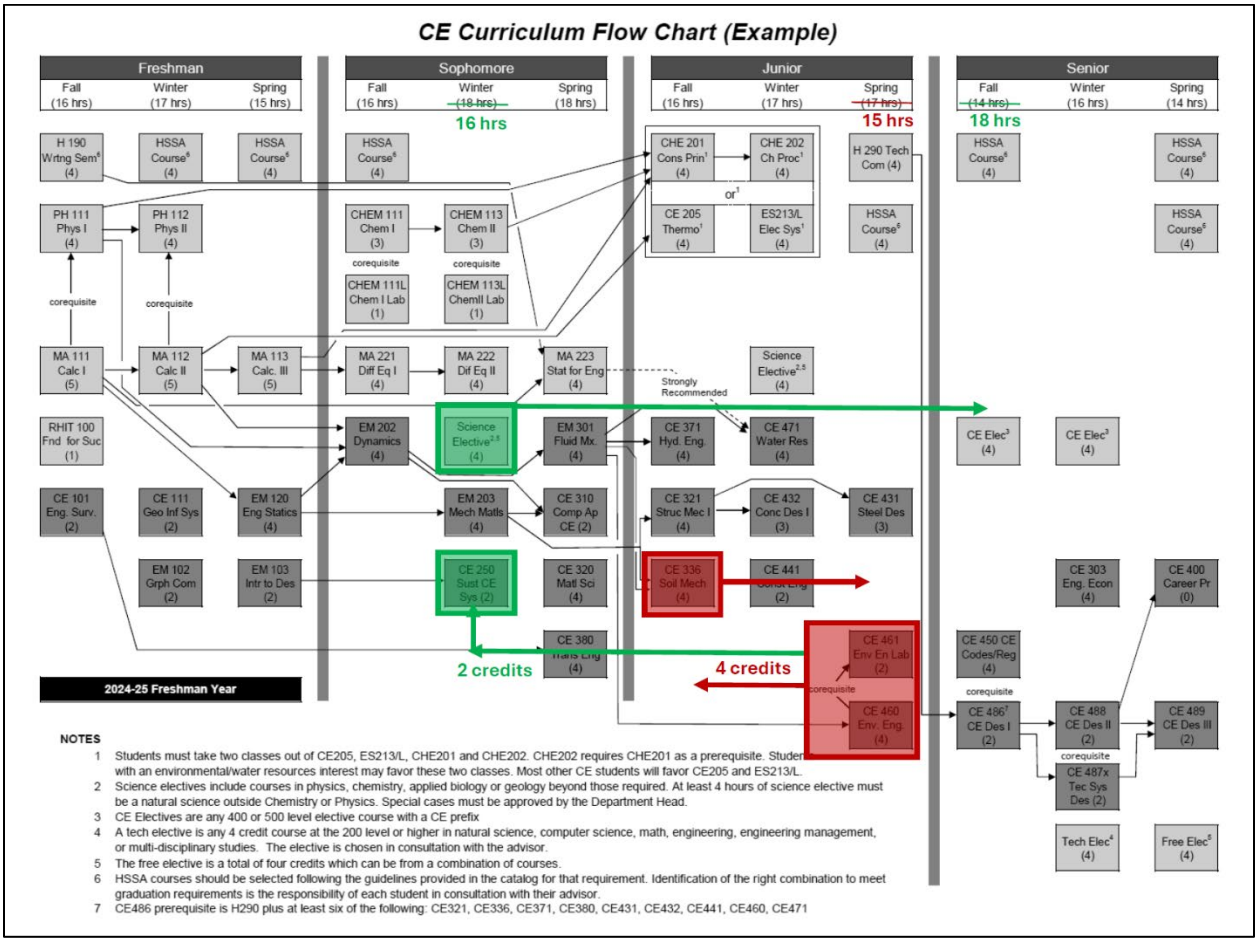

Figure 2: CE curriculum flow chart notated to indicate recommended changes (red indicates option for earlier exposure to EnvE in the curriculum; green indicates options for reallocation of two credits)

To determine content changes in the redesigned CE460* Introduction to EnvE course and the addition of two credits in CE250 Sustainable CE course, we used the survey responses to inform the most relevant content areas and the degree of depth desired. By moving some of the environmental science and public health content from CE460 Introduction to EnvE into CE250 Sustainable CE, we will now have the capacity for a deeper level of learning on the topics that rated the highest among practitioners surveyed, as listed above. With the two additional credits in CE250 Sustainable CE, the lesser-rated EnvE topics currently covered in the CE460 Introduction to EnvE lecture course and relevant to environmental science and human health can be covered in CE250 Sustainable CE, further allowing for greater depth of more relevant EnvE design topics in the new CE460* Introduction to EnvE course.

Using this EnvE BOK [1] informed approach, survey results have guided the prioritization of EnvE content coverage and the level of depth in course curriculum to ensure students are

prepared with the most relevant information to successfully practice as EnvE professionals. Expanding CE250 Sustainable CE from a 2-credit course into a 4-credit course, the relevant topic content from the EnvE BOK [1] can be taught. Therefore, we do not recommend the addition of another EnvE course entitled EnvE Applications. Our recommended rearrangement and reallocation of course credits allow for more in-depth EnvE design coverage and for earlier exposure to that coverage than what exists in the current curriculum. Furthermore, the earlier exposure allows for the development of hands-on opportunities for students to gain early exposure to applications and relevant skills that could be motivating and beneficial for early internships. For example, activities could include providing EnvE-focused undergraduate research opportunities or collaboration with the American Society of Civil Engineers (ASCE) student chapter and the Hoosier River Watch program, a citizen science program to track water quality of Indiana waterways to monitor the water quality of Lost Creek on campus.

We acknowledge the study limitation related to the fact that we obtained responses from the practitioners whom we asked, primarily our alumni. However, this concern is mediated by the fact that we sought feedback from the practitioners who are most likely to employ our graduates.

References

[1] American Academy of Environmental Engineering, Inc. 2009. Environmental Engineering Body of Knowledge. Prepared by the Environmental Engineering Body of Knowledge Task Force. 82p.

[2] American Society of Civil Engineering. 2008. Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future. Second Edition.

[3] Marincel Payne, M., J. Mueller, and M. Robinson. 2015. Developing a Course-based Master of Environmental Engineering Degree. In Proceedings of the 122nd American Society of Engineering Education Annual Conference & Exposition, June 14-17.