Enhancing Civil Engineering Curriculum with Engineering for One Planet (EOP): Insights from an EOP Mini-Grant Project

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Abstract

Recently, the Department of Civil Engineering (CE) at the University of Kentucky established a required undergraduate course (CE 218: Sustainable Engineering) to prepare students to consider their future civil engineering courses within the broader context of sustainability and systems thinking. This course contains modules focused on integrated infrastructure, as well as environmental, economic, and social sustainability. While CE 218 is dedicated to sustainability, we believe training sustainability-minded students will be most successful if topics are integrated throughout the full undergraduate curriculum. Supported by the ASEE Engineering for One Planet (EOP) Mini-Grant Program, we sought the following objectives: (1) revise materials for CE 218 (Sustainable Engineering) to introduce EOP, (2) revise materials for CE 303 (Introduction to Construction Engineering) to integrate EOP outcomes, (3) map EOP outcomes to existing required undergraduate courses, (4) engage CE faculty by introducing the EOP framework and providing opportunities for implementation, and (5) develop a guidance document for faculty interested in integrating EOP in courses. These efforts were assessed for both courses at the University of Kentucky (CE 218 and CE 303) in collaboration with the university's teaching center who provides course feedback by facilitating student focus groups and surveys. Finally, efforts to work toward curriculum-level change and identify opportunities for integrating EOP into other undergraduate courses are discussed.

Background

The Engineering for One Planet (EOP) framework seeks to "transform engineering education to ensure all engineers are equipped with the skills, knowledge, mindsets, and understanding to protect and improve our planet and our lives" [1]. The framework includes a total of 92 sustainability-focused learning outcomes (46 core, 46 advanced) that are organized within 9 topic areas – Systems Thinking, Environmental Literacy, Responsible Business and Economy, Social Responsibility, Environmental Impact Assessment, Materials Selection, Design, Critical Thinking, and Communication and Teamwork (Figure 1). The framework development, led by The Lemelson Foundation, is the product of many years of research that involved stakeholder input across academia, industry, government, and professional and non-profit organizations [1].

Supported by The Lemelson Foundation, the American Society of Engineering Education (ASEE) developed the EOP Mini-Grant Program (EOP MGP) to support faculty who are interested in integrating the EOP framework into engineering curriculum. Through the EOP MGP, faculty in the Department of Civil Engineering at the University of Kentucky piloted integration of EOP into two civil engineering undergraduate required courses, with the long-term vision of expanding the EOP framework throughout the full civil engineering undergraduate curriculum. A key tenet of the EOP MGP is the mentorship program; to this end, our project is informed through our mentor at Rose-Hulman Institute of Technology, who has aligned the EOP framework with learning objectives and content coverage in an established undergraduate sustainability course (CE 250: Sustainable Civil Engineering) and worked toward similar curriculum-level integration of sustainability concepts in subsequent courses. Finally, the EOP

MGP also included a community of practice and culminated in a final symposium to support participants in pursuing and sharing their EOP curricula innovations.

Figure 1. Engineering for One Planet (EOP) framework consisting of 9 topic areas that define a total of 92 sustainability-focused learning outcomes for students; figure reproduced from The Lemelson Foundation [1].

Implementation through Engineering for One Planet Mini Grant Program (EOP MGP)

Recently, the Department of Civil Engineering (CE) at the University of Kentucky established a required undergraduate course – CE 218: Sustainable Engineering – to prepare students to consider their future civil engineering courses within the broader context of sustainability and systems thinking. While CE 218 is dedicated to sustainability, we believe training sustainability-minded students will be most successful if topics are integrated throughout the full undergraduate curriculum. To this end, supported by the EOP mini grant program, we piloted integrating EOP outcomes in CE 303: Introduction to Construction Engineering, with the goal of using CE 303 as a model for additional courses. The specific objectives for the EOP MGP project were to: (1) revise materials for CE 218 (Sustainable Engineering) to introduce EOP, (2) revise materials for CE 303 (Introduction to Construction Engineering) to integrate EOP outcomes, (3) map EOP outcomes to existing required undergraduate courses, (4) engage CE faculty by introducing the EOP framework and providing opportunities for implementation, and (5) develop a guidance document for faculty interested in integrating EOP in courses.

Sustainable Engineering (CE 218) is a required undergraduate course designed for sophomores majoring in civil engineering at the University of Kentucky. This required course was taught for the first time in Fall 2023 (additionally taught Fall 2024, Spring 2025) and introduces students to sustainability concepts and its connection to civil engineering infrastructure. Course topics are divided into modules for integrated infrastructure systems (including systems thinking), environmental sustainability (including footprints and life cycle assessment), economic sustainability (including time value of money and life cycle costing), social sustainability (including design thinking and social impacts), and synthesis (including sustainability rating systems and navigating sustainability trade-offs). The course utilizes a combination of lectures, activities, guest speakers, and a student-led sustainability challenge exploration.

In Fall 2024 for the first time, supported by the EOP MGP, this course introduced students to the EOP framework and highlighted relevant EOP learning outcomes (Table 1) at the beginning of each course module. In many cases, existing course topics already strongly aligned with the EOP framework (e.g., Sustainable Development Goals, life cycle thinking, social impacts) and therefore course activities remained the same and references to specific EOP learning outcomes were added. In these instances, the EOP framework was used to articulate the learning outcomes and serve as a visual reference of how course topics were connected throughout the semester. In some cases, the EOP framework led to additional course activities to further emphasize key EOP learning outcomes. For example, a class focused specifically on systems thinking – including defining a system, interpreting causal loop diagrams, and interconnectedness of environmental, economic, and social considerations – was added to further address EOP core learning outcomes for Systems Thinking.

Introduction to Construction Engineering (CE 303) is a required undergraduate course designed for juniors majoring in civil engineering at the University of Kentucky. It is one of many courses in the junior year that introduces the breadth of topics (e.g., water resources, environmental, geotechnical, structural) within the civil engineering discipline. Course topics include the construction industry, planning and scheduling, critical path method, the design process, plans and specifications, estimating, earned value, and engineering economics. In Fall 2024, supported by the EOP MGP, this course explicitly connected course content to EOP outcomes related to Systems Thinking, Responsible Business and Economy, Social Responsibility, Critical Thinking, and Communication and Teamwork (Table 1). In general, this was accomplished by explicitly incorporating systems thinking and social impacts into course modules. When this concept was introduced, it was highlighted and connected with the EOP Framework and then interactive learning was used to better illustrate the concept. For example, in-class exercises allowed the students to explore the impact that construction projects had on the surrounding communities and other indirect stakeholders. Exam questions were modified to allow the students to discuss the unintended consequences of construction projects on both direct and indirect stakeholders to allow the students to demonstrate basic understanding of systems thinking.

Throughout this EOP MGP project, the integration of EOP into CE 218 and CE 303 at the University of Kentucky has been enhanced through mentoring provided by co-author Dr. Mueller at Rose-Hulman Institute of Technology. There, Dr. Mueller teaches CE 250: Sustainable Civil Engineering, which is a required sophomore-level course for all civil engineering majors. This course is similar to CE 218 at the University of Kentucky and has been taught there for over 10 years. The course utilizes a combination of lectures, assignments, case studies, and a group research project to explore sustainability as it relates to civil engineering. Specific course topics include discussion of the water, nitrogen, and carbon cycles, sustainable design, systems thinking, life cycle assessment, social impacts, sustainable design frameworks and rating systems, and community development. The EOP framework was developed after this course was originally established; therefore, the course learning objectives and content coverage have since been aligned with the framework and EOP continues to be a tool for guiding course improvements (Table 1).

Table 1. EOP core learning outcomes mapped to CE 218 (Sustainable Engineering) and CE 303 (Introduction to Construction Engineering) at the University of Kentucky as well as CE 250 (Sustainable Civil Engineering) at Rose-Hulman Institute of Technology. Core learning outcomes are numbered according to the EOP framework [1].

	Systems Thinking	*218*	*303*	*250*
1	Explain interconnectedness (e.g., intersecting, related and/or connected systems; human actions and global environmental and social impacts and consequences; synergies and rebound effects) and how all human-made designs and activities rely upon and are embedded within ecological and social systems	✓	✓	✓
2	Identify dynamic impacts between and among different parts of the system (i.e., social, environmental, and economic considerations)	✓		✓
3	Apply relevant concepts from required disciplines to the study of real-world problems and their solutions with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness	✓		
4	Create solutions that consider the scale of the activity relative to the planetary system boundaries (i.e., carrying capacities)			✓
	Environmental Literacy	***218***	***303***	***250***
1	Recognize opportunities (i.e., social, economic, and environmental benefits, etc.) to solve environmental challenges			✓
2	Explain whole life-cycle and closed-loop systems thinking as related to the impact of their work (e.g., understanding of life-cycle burdens of design alternatives)	✓		✓
3	Discuss key global ecosystem services (i.e., water, carbon, energy, and nitrogen cycles, as well as nutrient cycling, soil formation, pollination, waste decomposition, etc.) and how they are interconnected	✓		✓
4	Explain the nature and role of energy in the world, our daily lives, and in engineering practices (e.g. is energy literate)			✓
5	Examine data about environmental issues (e.g., climate change, energy and water use, scarcity and pollution, air quality, waste management, toxicity, etc.) including consideration for past/current/future and local/regional/global impacts	✓		✓
	Responsible Business and Economy	***218***	***303***	***250***
1	Recognize opportunities and demand for more inclusive and sustainable business models, such as models that leverage product durability (e.g., renting, upgradeability, repairability, modularity, resale, etc.), protect consumers and their privacy, reflect the interests and needs of diverse users and consumers, and reflect ethical considerations		✓	

2	Examine risks and opportunities related to changing social, economic, political, and ecological systems on their work (e.g., extended costs, value, trade-offs, partnerships, regulations, policies, etc.)	✓	✓	
3	Demonstrate awareness that different revenue and business models can positively or negatively influence environmental and social systems as a result (e.g., shared ownership models, service models, leasing with take-back instead of asset sales for planned obsolescence, employee-owned, public-private partnerships, business-NGO collaboration models, etc.)		✓	
4	Demonstrate awareness of alternative forms of capital beyond financial resources (including natural, human, social, and physical) and awareness of emerging economic systems intended to promote environmental and social responsibility in economic thinking (e.g., Doughnut Economics, circular economy, etc.)			✓
5	Weigh the near- and long-term costs and value of their work to the environment and society through the sustainable use of resources and engagement with stakeholders		✓	
Social Responsibility		***218***	***303***	***250***
1	Identify the United Nations Sustainable Development Goals (SDGs)	✓		✓
2	Recognize and be empathetic to ethical implications relative to the social impact of their work	✓	✓	✓
3	Describe how engineering activities directly and indirectly cause positive and negative social/cultural impacts throughout the design life-cycle, both to workers producing the products (i.e., labor practices, livelihood, health, etc.) and to communities, society, and non-human life (i.e., resources acquisition, waste production and management, traditional/cultural methodologies, etc.)	✓	✓	✓
4	Recognize that some communities (e.g. communities of color, rural communities, etc.) have historically been negatively impacted and/or intentionally marginalized, and continue to be disproportionately negatively impacted by engineering activities		✓	
Environmental Impact Assessment		***218***	***303***	***250***
1	Explain high-level environmental impact assessments (e.g., basic Life-Cycle Assessments (LCAs) and life-cycle hazards; i.e., how they work, what information they require, how to incorporate their findings into their work)	✓		✓
2	Recognize current eco-labelling systems and certificates (i.e., EPEAT, Energy Star) for sustainable production and consumption	✓		
3	Interpret broader energy, climate, water, wastewater, air pollution, and land-use implications of their work by conducting basic environmental impact assessments (e.g., Life-Cycle Assessments, carbon footprints, etc.)			✓
4	Question complex or contradictory information to make decisions among trade-offs (i.e., What is the cost of the decision? Who and what will be most impacted by the decision? Are marginalized communities part of the decision?)	✓		
Materials Selection		***218***	***303***	***250***
1	Identify potential impacts of materials (e.g., embodied energy, emissions, toxicity, etc.) through the supply chain — from raw material extraction through manufacturing, use, reuse/recycling, and end of life — with a focus on minimizing negative impacts to the planet and all people (i.e., especially those who have been intentionally marginalized)	✓		✓

		218	303	250
3	Critique the environmental and social impacts of designs created by others			✓
4	Compare materials properties (e.g., chemical, physical, and structural properties) and performance aligned with end-use application			✓
Critical Thinking		***218***	***303***	***250***
1	Define problems comprehensively with consideration of consequences, unintended and intended	✓	✓	
4	Recognize that every person has a role in sustainability, and has the right and need to be informed about the environmental/social/economic impacts of the products they purchase, consume, and discard	✓		
6	Critique complex ethical and values-based choices, employing empathy when evaluating conflicts of interest, trade-offs, and uncertain knowledge and contradictions within problem constraints		✓	
Communication and Teamwork		***218***	***303***	***250***
1	Communicate through audience-specific written, graphic/visual, oral, and interpersonal communication skills	✓		✓
3	Demonstrate ability to work within and function well on teams and across disciplines	✓		
5	Prioritize projects, schedules, and time, and manage people equitably and inclusively		✓	

Assessment of EOP integration with midsemester course feedback

The integration of EOP learning outcomes in CE 218 and CE 303 were assessed through collaboration with the Center for the Enhancement of Learning and Teaching (CELT) at the University of Kentucky. CELT administers midsemester course feedback for interested instructors at a helpful time in the semester when the feedback can still be implemented to improve the student learning experience. In CE 218, CELT conducted midsemester course feedback through a focus group discussion (without the instructor present) combined with an anonymous survey that students took online at the conclusion of the discussion. In CE 303, CELT conducted midsemester course feedback through an anonymous survey that students took online at a time of their choosing. In both cases, CELT collected the student feedback anonymously and then aggregated the results and summarized them to the instructors. The Institutional Review Board (IRB) at the University of Kentucky determined that the assessment portion of this project was considered a quality improvement assessment activity and did not require IRB review.

CELT's midsemester course feedback is designed to address multiple course components including both structure and content delivery. For example, students are asked questions such as "what has helped you learn and succeed in this course?" and "what would help you be more successful in this course?". Additionally, instructors have the option of working with CELT to incorporate specific questions that are of interest; it is within this section that students were asked questions regarding the EOP framework.

In CE 218 (Sustainable Engineering), students were asked to rate their agreement with the following statements (options of “agree”, “no preference”, and “disagree”):

1. “I am familiar with the Engineering for One Planet (EOP) framework.”
2. “I have seen the Engineering for One Planet (EOP) framework in another class I have taken or am taking now.”
3. “Through this class, I am improving my ability to apply systems thinking and consider the interconnectedness of civil engineering infrastructure.”

In CE 303 (Introduction to Construction Engineering), students were asked to rate their agreement with the following statements (options of “strongly agree”, “agree”, “unsure”, “disagree”, and “strongly disagree”):

4. “I am familiar with the Engineering for One Planet (EOP) framework.”
5. “I can apply systems thinking to evaluate construction projects.”

The first questions (#1 for CE 218 and #4 for CE 303) were used to assess student familiarity with the EOP framework which was presented to students in both courses. Additionally, students were asked about their ability to apply systems thinking (#3 for CE 218 and #5 for CE 303) with the intention of gauging how well students were achieving EOP learning outcomes related to systems thinking – regardless of whether they recognized the EOP framework. Finally, in CE 218, students were asked if they had seen the EOP framework in any other classes (#2 for CE 218) to assess integration of EOP outcomes throughout the undergraduate civil engineering curriculum.

Assessment results from midsemester course feedback provided insights related to EOP familiarity, applying systems thinking, and integration of EOP across the curriculum (Figure 2). In both courses, most students agreed that they were familiar with the EOP framework (26 of 39 students in CE 218 and 13 of 16 in CE 303). Furthermore, a large majority of students agreed that they were improving their abilities to apply systems thinking in both courses; this was evident with 36 of 39 students in agreement in CE 218 and 15 of 16 students in agreement in CE 303, with no students indicating they disagreed in either course. Put together, these results suggest that students are achieving the EOP learning outcomes related to systems thinking, even if they did not recall being introduced to the EOP framework in class.

Finally, in CE 218, most students disagreed that they had seen the EOP framework in another class they had taken or were currently taking (14 agree, 8 neutral, 17 disagree). These results were expected as this was the first semester that the EOP framework was introduced in any course within the curriculum; therefore, only students who were co-enrolled in CE 218 and CE 303 had the potential to have seen the EOP framework in another course. It is our hope that the agreement for this statement will grow in future years as EOP may later be integrated in other courses in the curriculum. Therefore, these data can serve as a baseline assessment and can be asked in collaboration with CELT in future years in CE 218, CE 303, and other courses integrating EOP outcomes.

The assessment of this pilot effort has limitations that could be addressed by future assessment efforts. First, the study used midsemester surveys and focus group discussions due to the collaboration with CELT, who offers this as an existing service at the midsemester point; end of semester assessment would provide additional insights. Second, the assessment focused broadly on familiarity with EOP and self-reported improvement of systems thinking learning outcomes. With appropriate IRB review, future efforts could benefit from a more rigorous assessment of student achievement of EOP learning outcomes by directly assessing student work, for example.

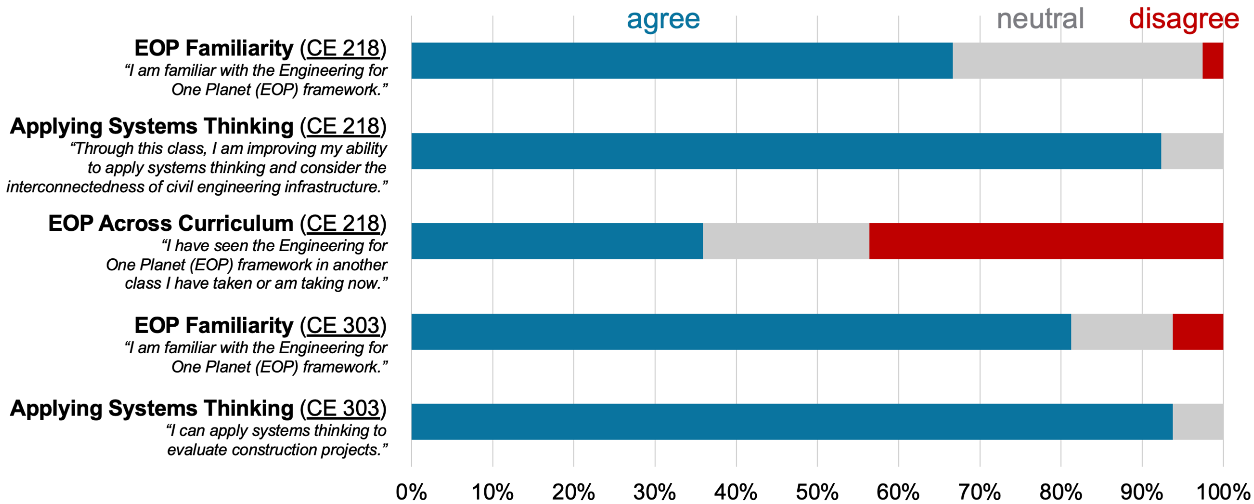


Figure 2. Assessment of EOP integration using midsemester course feedback collected by the Center for the Enhancement of Learning and Teaching (CELT) at the University of Kentucky. Colors indicate agreement with the specific statements (blue = agree, gray = neutral, red = disagree). The category "agree" includes answers of "agree" in CE 218 and "strongly agree" and "agree" for CE 303. The category "neutral" includes answers of "no preference" for CE 218 and "unsure" for CE 303. The category "disagree" includes answers of "disagree" for CE 218 and "strongly disagree" and "disagree" for CE 303.

Path forward for integrating of EOP across full curriculum

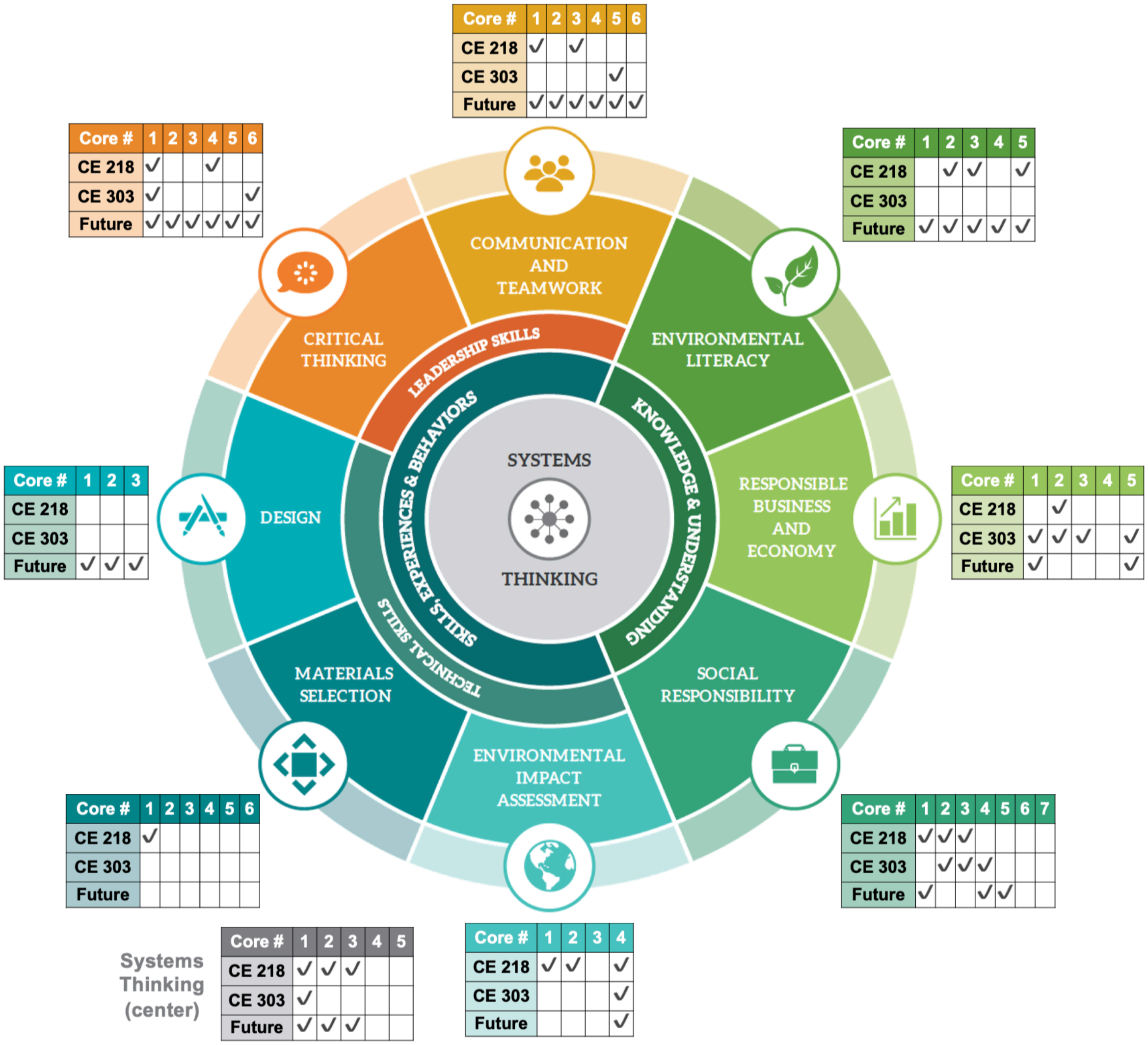
Long-term, we aim to collaborate with instructors to continue to grow EOP integration throughout the undergraduate civil engineering curriculum at the University of Kentucky. As was true for CE 218 and CE 303, we expect many existing civil engineering courses already address EOP learning outcomes due to synergies between the EOP framework and student outcomes defined for ABET accreditation [1]. Therefore, we endeavor to use the EOP framework as a common foundation to document these ongoing efforts and identify additional growth opportunities.

Through this EOP MGP project, EOP has been integrated into two courses at the University of Kentucky (CE 218 and CE 303) and possible learning outcomes have been preliminarily mapped to four additional required undergraduate courses in the civil engineering curriculum, specifically: Transportation Engineering (CE 331), Introduction to Environmental Engineering (CE 351), Civil Engineering Systems Design (CE 429), and Water Resources Engineering (CE 461G). Collectively, these learning outcomes connect to all 9 topic areas within the EOP framework (Figure 3); however, some topics are covered more thoroughly than others, and there are opportunities for more balanced coverage in the future if EOP could be integrated across the entire curriculum. For example, the required undergraduate course of Civil Engineering

Materials (CE 381) has potential to address multiple EOP outcomes within the Materials Selection topic area.

Current and future work include continued engagement with instructors of required undergraduate courses within the civil engineering curriculum. Through this EOP MGP project, the project team introduced additional faculty to the EOP framework and opportunities for implementation during a department faculty meeting presentation. Additionally, the team created a PowerPoint slide deck as guidance for other faculty members interested in integrating EOP in their courses. In addition to including background information about EOP, the slide deck was developed for instructors to be able to easily copy slides into their existing course slides, thus lowering the barrier for new faculty engagement. These slides include an overview of the EOP framework as well as a slide for each of the specific EOP learning outcomes; therefore, instructors can copy and paste the slide(s) for the relevant outcome(s) within their course.

Long-term, the project team endeavors to expand EOP throughout the civil engineering curriculum. This path forward includes the following activities: (1) working closely with individual instructors to refine the mapping of EOP outcomes to the full curriculum and support faculty who are interested in explicitly discussing EOP in their courses; (2) continuing integration of EOP into CE 218 (Sustainable Engineering) and CE 303 (Introduction to Construction Engineering); (3) continuing assessment of EOP integration through midsemester course feedback, using the Fall 2024 semester as a baseline; and (4) identifying opportunities for parts of the EOP framework that are not currently well integrated into the existing curriculum. It is anticipated the EOP Framework will eventually be used to support ABET assessments. Ultimately, the initial steps taken through this EOP MGP project and this proposed path forward provide a foundation for interdisciplinary conversations regarding sustainability and practical support for integrating sustainability concepts into existing courses – all in service of a larger vision to train sustainability-minded civil engineers.



Core #	1	2	3	4	5	6
CE 218	✓		✓			
CE 303					✓	
Future	✓	✓	✓	✓	✓	✓

Core #	1	2	3	4	5	6
CE 218	✓			✓		
CE 303	✓					✓
Future	✓	✓	✓	✓	✓	✓

Core #	1	2	3	4	5
CE 218		✓	✓		✓
CE 303					
Future	✓	✓	✓	✓	✓

Core #	1	2	3
CE 218			
CE 303			
Future	✓	✓	✓

Core #	1	2	3	4	5
CE 218		✓			
CE 303	✓	✓	✓		✓
Future	✓				✓

Core #	1	2	3	4	5	6
CE 218	✓					
CE 303						
Future						

Core #	1	2	3	4	5	6	7
CE 218	✓	✓	✓				
CE 303		✓	✓	✓			
Future	✓			✓	✓		

Core #	1	2	3	4	5
CE 218	✓	✓	✓		
CE 303	✓				
Future	✓	✓	✓		

Core #	1	2	3	4
CE 218	✓	✓		✓
CE 303				✓
Future				✓

Figure 3. EOP core learning outcomes that were integrated in CE 218 (Sustainable Engineering) and CE 303 (Introduction to Construction Engineering) through this EOP MGP project as well as preliminary mapping of EOP outcomes to four other required undergraduate courses in the civil engineering curriculum at the University of Kentucky – specifically Transportation Engineering (CE 331), Introduction to Environmental Engineering (CE 351), Civil Engineering Systems Design (CE 429), and Water Resources Engineering (CE 461G) (collectively labeled "Future").

Acknowledgments

The authors would like to thank ASEE and The Lemelson Foundation for supporting this mini grant project. The authors would also like to thank Isaac Oluk for support as the teaching assistant in CE 218 as well as Madeline Miller at the Center for Enhancement of Learning and Teaching (CELT) at the University of Kentucky for conducting course feedback. The Institutional Review Board (IRB) at the University of Kentucky determined that the assessment portion of this project was considered a quality improvement assessment activity and did not require IRB review.

Reference

[1] "The Engineering for One Planet Framework: Essential Sustainability-focused Learning Outcomes for Engineering Education (2022)," The Lemelson Foundation, Portland, OR, USA.