Teaching Students How to Address Resiliency and Equity in Infrastructure Design through the Envision Rating System

Dr. Jennifer Mueller PE, 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. John Aidoo, Rose-Hulman Institute of Technology

Dr. Aidoo is currently a Professor of Civil Engineering Department at Rose-Hulman Institute Technology. Prior to this appointment, he worked as the Bridge Design Engineer at South Carolina Department of Transportation.

Dr. Matthew D. Lovell P.E., Rose-Hulman Institute of Technology

Matthew Lovell is an Associate Professor in the Civil Engineering Department at Rose-Hulman Institute of Technology, and he currently serves as the Interim Senior Director of Institutional Research, Planning, and Assessment office. He is also serving as t

Dr. Kyle Kershaw P.E., Rose-Hulman Institute of Technology

Dr. Kyle Kershaw is an Associate Professor in the Department of Civil Engineering at Rose-Hulman Institute of Technology. Kyle's primary teaching duties include courses in geotechnical engineering and construction materials. His research interests inclu

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.

Teaching Students How to Address Resiliency and Equity in Infrastructure Design through the Envision Rating System

Abstract

The Institute for Sustainable Infrastructure's Envision Rating System does more than measure resiliency, social equity, and environmental justice of civil infrastructure projects; it also provides a framework for guiding design decisions throughout the entire design process. We are utilizing Envision as a framework to teach civil engineering undergraduate students how to consider quality of life, allocation of resources, and resiliency in their designs. By applying Envision as a tool to provide concrete guidance during the design process, students begin to regard these considerations as inherent in making technical design decisions.

To equip our students with the knowledge to proactively utilize this framework as a design tool, we use a micro-insertion technique to incorporate varying aspects and levels of depth into the Envision framework throughout Years 2, 3, and 4 in our civil engineering undergraduate curriculum. First in Year 2, we provide a broad overview of Envision and apply the system to a real civil engineering project, wherein students discuss relevant credits that are applicable to the project. Then, students delve into one credit category as it relates to a large-scale water infrastructure project in their fluid mechanics course. In Year 3, students deepen their understanding within each Envision category in subsequent design courses that each cover a different credit category through soil mechanics and structural design in concrete and steel. Up to this point, the focus is to understand the intent and metric of the relevant credits that are exemplified in each course. In this way, students understand the purpose of a credit and how they can achieve a measurable increase in meeting the purpose of the credit through design. Finally in Year 4, students review the entire framework to identify and justify credits that apply to their senior capstone design projects. Students first review the framework and note relevant credits that serve as project goals. Upon understanding the intent and metric of the credit, or project goal, students utilize the levels of performance achievement to document and justify how well they have met each identified project goal or credit.

Examples of student work show that Envision can be used as a tool to gain knowledge of how designs can be informed by the rating system beyond using it as a tool to retroactively evaluate a project. Through our approach, we are utilizing the credits and metrics of the framework to instill a mindset of design thinking that encourages students to consider all relevant Envision credit considerations in their designs.

Introduction

The Institute for Sustainable Infrastructure's Envision Rating System (Envision) provides a framework for civil infrastructure that is sustainable, equitable, and resilient through all stages of planning, design, and implementation [1]. This holistic framework can be applied to all civil

infrastructure projects, including transportation, waste management, landscape architecture, water management, information transmission, and energy production and transfer [2]. Envision registered projects can earn recognition at various levels of achievement through a verification process. Collections of sustainability performance indicators are grouped as credits to earn under five categories – Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience (Figure 1) [2]. By educating civil and environmental engineering students how they could apply Envision when designing civil infrastructure and assessing the sustainability of infrastructure, we are encouraging students to make design decisions that move beyond traditional considerations.

Implementation

Covering three academic years and eight required courses, students majoring in civil engineering at Rose-Hulman Institute of Technology utilize Envision through a variety of applications. First, students are introduced to Envision and apply one category of Envision to an infrastructure project in two second-year courses. Then in third-year technical design courses, they delve deeper into different categories of the rating system . Finally, they apply Envision to their senior capstone projects to assess sustainability and resiliency in the final design. Throughout the process of this approach with multiple touchpoints across the curriculum, students have the opportunity to see the rating system through a wide lens, zoom in to more fully understand particular credits and how to assess them, and then apply the entire system to a real civil engineering design project.

Students are introduced to Envision in a required sustainable civil engineering course during Year 2. Through an in-class activity, they explore the rating system as a whole to understand the various categories and credits within each category. They learn the purpose of the rating system and that each listed credit was formulated based on a specific intent. In this way, students recognize the meaning behind the framework to shift the focus away from tallying points. After becoming familiar with the content of the framework, students select credits that are relevant to an actual civil infrastructure project presented in class. Based on consideration of relevant Envision credits, they work in peer groups to discuss and recommend a proposed design based on three alternatives presented [3]. In a subsequent fluid mechanics course project in Year 2, students delve deeper into the Quality of Life category by identifying stakeholders involved in a large water infrastructure project. Using the questions in the Envision Pre-Assessment Checklist [1] and a concept map approach, students research each stakeholder's needs, concerns, and expectations to create a plan for how an engineer might engage with them. The Envision Pre-Assessment Checklist [1] includes a series of questions for each credit to help the students determine if the credit is relevant to their project and how well they can achieve the intent of the credit. With their stakeholder research in mind, students analyze their project at the intent and metric levels for at least one Quality of Life credit to assess the social impacts of the project and to justify a recommendation to improve the project's sustainability [3].

Figure 1: Categories and credits in the Envision Rating System [2]

During Year 3, Envision is incorporated into three required technical civil engineering design courses in soil mechanics, concrete design, and steel design. Following a similar model of applying Envision in the fluid mechanics course in Year 2, each course focused on one particular category. Through a lab assignment in soil mechanics, students performed a slope stability analysis for a newly constructed residence hall on campus. Focusing on the Natural World category, students addressed questions from the Envision Pre-Assessment Checklist [1] for the following three credits:

- NW2.2 Manage Stormwater
- NW3.2 Enhance Wetland and Surface Water Functions
- NW3.5 Protect Soil Health

Based on discussion within their lab group, students report how well the completed project, as designed, met the criteria for these credits and how their assessment might change if a slope stability problem occurred in the future.

Within the concrete design course, students assess material properties of low-carbon concrete vs. traditional concrete and how this may impact which material they recommend for their design. Students also practice assessing safety factors and risk involved in determining appropriate sizes of concrete beams to handle the design loads. These class activities are aligned with the Climate and Resilience category, particularly the following credits:

- CR1.1 Reduce Net Embodied Carbon
- CR2.3 Evaluate Risk and Resiliency

Students are first tasked with designing a reinforced concrete beam, given the design parameters in a problem statement. Then, using an embodied carbon spreadsheet, students estimated the embodied carbon in their preliminary design. By modifying material properties in their design, they try to lower the embodied carbon in their design and comment on how varying different parameters impacted the total carbon footprint of the design.

For the steel design course, an introductory class session discusses the steel manufacturing process and the life cycle and high recyclability of steel while maintaining original material properties of virgin material. After watching a video on the design and construction of Lee Hall III on the campus of Clemson University, students complete a reflection exercise. Through this case study, students reflect on how steel contributes to the efficient use and recyclability of structural materials, as well as how prefabrication can help reduce construction waste and construction time. In this course, students examine further into the Resource Allocation category, particularly the following credits:

- RA1.2 Use Recycled Materials
- RA1.4 Reduce Construction Waste

Finally, students apply Envision to their senior capstone design projects. During the concept development phase in the first course of the senior design sequence, students review the list of Envision credits. Viewing these credits as project goals with an intention associated with each

one, student teams first select subcategories that they perceive as being most important to their client and then subcategories that are most important to the team, themselves. They discuss differences and commonalties among each list of priorities. Considering the identified priorities as guiding principles, the team identifies 5-10 total credits among the prioritized subcategories. They consider these as their overarching project goals and describe how each is relevant and important to their project.

During the technical design phase in the second course of the senior design sequence, students revisit the credits selected in the previous quarter. Taking a closer look into individual credits, we review the intents of each credit and associated metrics to measure how well the project achieves each credit, as well as the various levels of achievement that can be met for each credit. In this approach, students focus on the *how* and *why* of meeting anticipated levels of achievement instead of assigning point values.

Students then apply the Envision Pre-Assessment Checklist [1] to their capstone design project. In this way, students are making technical design decisions that are informed by the Envision checklist. Utilizing the selected credits, student teams document the assessment of sustainability in their final design based on Envision [3].

Assessment Results and Discussion

At the end of winter quarter of Year 2, 3, and 4, students are asked to participate in a brief, retrospective gains survey. Students responded that they agreed or disagreed, to varying levels on a 5-point Likert scale, to the following statements:

1. I am familiar with the Envision rating system for sustainable infrastructure.
2. I can explain the purpose of Envision as a rating system for sustainable infrastructure.
3. I can utilize Envision to measure sustainability in civil engineering design.
4. Work in this course has increased my awareness of the Envision rating system.
5. Work in this course has increased my ability to apply the Envision rating system to the design of civil engineering infrastructure.

Tables 1-3 show students' perspectives, retrospectively, on their familiarity with and ability to utilize Envision, where 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree.

Table 1: Mean values and standard deviations (SDs) of student responses at the end of the sustainable civil engineering course in Year 2 (n=39)

Statement	Mean response	SD of responses
I am familiar with the Envision rating system for sustainable infrastructure.	2.05	0.83
I can explain the purpose of Envision as a rating system for sustainable infrastructure.	2.18	0.97
I can utilize Envision to measure sustainability in civil engineering design.	2.33	0.70
Work in this course has increased my awareness of the Envision rating system.	2.03	1.09
Work in this course has increased my ability to apply the Envision rating system to the design of civil engineering infrastructure.	2.05	0.97

Table 2: Mean values and standard deviations (SDs) of student responses at the end of the concrete design course in Year 3 (n=27)

Statement	Mean response	SD of responses
I am familiar with the Envision rating system for sustainable infrastructure.	1.93	1.00
I can explain the purpose of Envision as a rating system for sustainable infrastructure.	2.41	1.05
I can utilize Envision to measure sustainability in civil engineering design.	2.22	0.93
Work in this course has increased my awareness of the Envision rating system.	2.70	0.99
Work in this course has increased my ability to apply the Envision rating system to the design of civil engineering infrastructure.	2.33	1.00

Table 3: Mean values and standard deviations (SDs) of student responses at the end of the winter term of senior capstone design in Year 4 (n=19)

Statement	Mean response	SD of responses
I am familiar with the Envision rating system for sustainable infrastructure.	1.89	0.74
I can explain the purpose of Envision as a rating system for sustainable infrastructure.	2.37	1.01
I can utilize Envision to measure sustainability in civil engineering design.	2.47	1.02
Work in this course has increased my awareness of the Envision rating system.	2.42	1.07
Work in this course has increased my ability to apply the Envision rating system to the design of civil engineering infrastructure.	2.47	1.17

Although there are no substantial differences among mean responses for each individual question or across the touchpoints in Year 2, 3, and 4 courses, students generally note that they agree with the statements. Since Year 2 is the first time they learn about Envision, it might make sense that the class instruction impacted their learning more than it did in senior design. During Year 2, students are given just a brief introduction, so they may not realize what they do not know. Conversely, in Year 4 when students delve deeper into documentation requirements for each credit, they acknowledge the extent of considerations that need to be made in reaching the desired level of achievement for each credit and realize their ability to utilize Envision as an assessment tool may not be as high as a student who sees it for the first time as a simple list.

During AY2022-23 and AY2023-24, the Envision assignment in senior capstone design was utilized for departmental continuous improvement and assessment of student outcomes. For the student outcome to “analyze the sustainable performance of civil engineering projects from a systems perspective,” this assignment scored 83% passing rate in AY 2022-23 and 100% passing rate in AY 2023-24. Since that time, the civil engineering department has modified our department’s student learning outcomes to adopt ABET 1-7 [4]. Artifacts collected from the Envision assignment in senior capstone design are being used to assess how well students meet ABET 2: “an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors” [4]. This assessment is scheduled to be completed during summer 2026 for AY 2025-26, so results are not yet available to report.

Additionally, each application of Envision through Years 2, 3, and 4 aligns with ABET Civil Engineering program criteria through the “application of principles of sustainability, risk, and resilience to civil engineering problem” [4].

Conclusion

Our approach of setting an introductory foundation of Envision, investigating deeper into several categories through practical examples in discipline-specific courses, and applying the rating system to senior capstone design project provides students with multiple touchpoints to understand and evaluate sustainability of projects. Students are reminded of the motivation and purpose of Envision. As countries around the globe utilize more resources and generate more waste as they become more developed nations, the need for environmental protection, social equity and public health, and economic recovery amid a changing global climate is imperative in engineering design and creating resilient infrastructure.

References

[1] Institute for Sustainable Infrastructure. 2026. "Envision Resources." https://sustainableinfrastructure.org/resources/ (accessed January 10, 2026).

[2] Institute for Sustainable Infrastructure. 2018. "Envision: Sustainable Infrastructure Framework Guidance Manual." Third Edition.

[3] Mueller, J., Marincel Payne, M., and Shrestha, N. 2025. "Incorporating the Envision Rating System as a Teaching Tool for Sustainability in Civil Engineering Infrastructure." In Proceedings of the 2025 American Society of Engineering Education Annual Conference and Exposition. June 22-25, 2025. Montreal, Canada.

[4] ABET. 2026. "Criteria for Accrediting Engineering Programs, 2025 – 2026." ABET Engineering Accreditation Commission. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2025-2026/ (accessed April 26, 2026).