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Integrating Professional Credentialing in Sustainability into Civil Engineering Curriculum: A Case Study

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Abstract

The concept of sustainable development rose to prominence with the publication of *Our Common Future* as an output of the United Nations' Brundtland Commission. Recently, increased emphasis on the impacts of climate change and globalization has reinforced the need for the civil engineering profession to address the complex challenges of designing, operating, and maintaining civil works infrastructure that is both sustainable and resilient. This need is reflected both within the Engineering Accreditation Commission's General Criteria and the American Society of Civil Engineers' Civil Engineering Program Criteria required for undergraduate programs in Civil Engineering to be ABET accredited. By the time of graduation, students must have the ability to apply the engineering design process to arrive at solutions that are more than just technically sound. Their solutions must also serve to protect the public health, safety, and welfare of society, as well as address the triple bottom line of sustainability by considering environmental, social, and economic factors. This paper presents a case study on using professional credentialing in sustainability as a mechanism to help educate students on these sorts of considerations within the engineering design process. Students studied for, and earned, the Envision Sustainability Professional credential through the Institute for Sustainable Infrastructure in partial fulfillment of an elective within their undergraduate engineering curriculum. The credentialing process requires completion of an online course that equips students with a framework to consider making systematic changes in planning, design, and delivery of civil works infrastructure. The Envision framework consists of sixty-four sustainability and resilience indicators organized within five categories: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate & Resilience. The framework specifically encourages stakeholder engagement and acceptable risk analysis to help ensure engineers both "do the right project" and "do the project right." This case study presents a crosswalk between the Envision framework to the General Criteria and Program Criteria required for an ABET accredited Bachelor of Science in Civil Engineering program.

Introduction

There are various professional credentials in applying sustainability rating systems to certify projects by quantifying level of achievement across the "triple bottom line" of environmental, social, and economic concerns. Two of the most notable rating systems are the U.S. Green Building Council's (USGBC's) Leadership in Energy & Environmental Design (LEED) and the Institute for Sustainable Infrastructure's (ISI's) Envision. Both rating systems are applicable to civil engineers; however, whereas LEED focuses on "healthy, highly efficient, and cost-saving green buildings," Envision focuses on "sustainable, resilient, and equitable infrastructure" [1] [2]. The Envision rating system can be used across a wide array of infrastructure projects, to include energy generation and distribution; water and wastewater; stormwater management and flood control; transportation systems including airports, roads, bridges, dams, parks, mass transit; and even information/communication systems [3].

This paper presents a case study in the use of Envision as a component of the undergraduate engineering curriculum. Students took a 1-credit course where they independently studied for and earned the Envision Sustainability Professional (ENV SP) credential, wrote a report on how Envision's concepts applied to their undergraduate curriculum, and gave a (digital) poster presentation on their experience earning the credential. Although students also have the opportunity to take a 2-credit course to study for and earn the LEED Green Associate credential, the authors of this paper are focused on the ENV SP.

The sixty-four distinct Envision credits encompass five categories: Quality of Life (QL), Leadership (LD), Resource Allocation (RA), Natural World (NW), and Climate Resilience (CR). Within each category, every credit has multiple levels of achievement that represent a broad spectrum of performance goals ranging from slight improvements beyond conventional practices to restoration and conservation of communities and the environment. This unique ENV SP framework allows engineers to quantify difficult sustainability challenges that surround sustainable development while enhancing progress tracking and the identification of possible trade-offs amidst myriad complex engineering problems. The five credit categories are briefly summarized below.

Quality of Life

Within Envision's framework, the Quality of Life category focuses on the impact of projects and sustainability on a community and how people might be affected by designs [4]. Quality of Life considers numerous factors that contribute to societal well-being, including recreation opportunity, public safety, historical preservation, and community infrastructure functionality. The goal is to not only create and maintain infrastructure that functions properly but also to best satisfy the wants and needs of the public by considering factors such as stakeholder satisfaction, community accessibility, equality, and improvement potential for the future.

Leadership

The Leadership category centers around enacting influential leadership within sustainable community projects, including factors such as collaboration, planning, and economy to influence the sustainable wellbeing of a community in the various stages of lifespan, specifically long-term [4]. Leadership credits foster collaboration, building an inclusive environment, establishing common goals, planning current and future tasks, and meeting objectives in a way that reflects professional responsibilities and making informed judgements.

Resource Allocation

The Resource Allocation category considers the assessment and management of resources within infrastructure projects to maximize efficiency and functionality while also preserving sustainability goals for the project. Resource Allocation addresses various aspects of project management, including materials and resources, energy, water, and the ecosystem. Acquiring materials for a project is insufficient; they must be stored, organized, recycled, and maintained.

Resource Allocation credits evaluate a project's resource optimization, encouraging project managers and teams to minimize excess consumption and recycle to keep the project as "eco-friendly" as possible [4]. Through smart resource utilization, projects can lower their impact on both communities and the environment.

Natural World

The Natural World category considers the impact of infrastructure projects on the surrounding environment and ecological systems. This category considers main factors of project impacts on habitats, soil, air, water, and the general climate [4]. Credits are primarily focused on the environment and how project decisions should minimize negative impacts on ecosystems.

Climate and Resilience

The Climate & Resilience category demonstrates the importance of long-term planning and climate change considerations. Project designers must be able to predict and consider how changing weather, storms, and temperature patterns might impact infrastructure. Major projects seek to score well within this category by mitigating climate change and environmental impact, adapting to past and future climate changes, planning for resilience, and incorporating the community in an effort to reduce vulnerability and infrastructure's impact on the climate [4].

Background

The phrase "triple bottom line" was coined in 1994 by John Elkington, founder of the British consultancy SustainAbility, who argued that corporations should consider people, planet, and profit when calculating the full cost of doing business [5]. Since then, the concepts of people, planet, and profit (or social, environmental, and economic) have become integral to civil engineering education and the civil engineering profession.

With regard to civil engineering education, programs seeking ABET accreditation must meet General Criteria set forth under the Engineering Accreditation Commission (EAC) as well as Civil Engineering Program Criteria set forth by the American Society of Civil Engineers (ASCE). Table 1 and Table 2 below detail the EAC General Criterion 3: Student Outcomes and ASCE's Civil Engineering Program Criteria, both of which are effective for the 2024-2025 accreditation cycle. Underlined text indicates key words for referencing each outcome or criterion. ABET Student Outcomes, which describe what graduates can do by the time of graduation, specifically include the components of the triple bottom line in #2 and #4. ASCE's Civil Engineering Program Criteria specifically include application of the principles of sustainability in #1.a.iii.

Table 1: ABET EAC General Criterion 3: Student Outcomes [6]

1.	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
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
3.	an ability to communicate effectively with a range of audiences
4.	an ability to 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
5.	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6.	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7.	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Table 2: ASCE's Civil Engineering Program Criteria [6]

1.	Curriculum The curriculum must include:
1.a.	Application of:
1.a.i.	mathematics through differential equations, probability and statistics, calculus-based physics, chemistry, and either computer science, data science, or an additional area of basic science
1.a.ii.	engineering mechanics, materials science, and numerical methods relevant to civil engineering
1.a.iii.	principles of sustainability, risk, resilience, diversity, equity, and inclusion to civil engineering problems
1.a.iv.	the engineering design process in at least two civil engineering contexts
1.a.v.	an engineering code of ethics to ethical dilemmas
1.b.	Solution of complex engineering problems in at least four specialty areas appropriate to civil engineering
1.c.	Conduct of experiments in at least two civil engineering contexts and reporting of results
1.d.	Explanation of:
1.d.i.	concepts and principles in project management and engineering economics
1.d.ii.	professional attitudes and responsibilities of a civil engineer, including licensure and safety
2.	Faculty The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience.

The term “complex engineering problems” appears in ABET Student Outcome #1 and ASCE’s Civil Engineering Program Criteria #1.b. ABET defines complex engineering problems as including “one or more of the following characteristics: involving wide-ranging or conflicting technical issues, having no obvious solution, addressing problems not encompassed by current standards and codes, involving diverse groups of stakeholders, including many component parts or sub-problems, involving multiple disciplines, or having significant consequences in a range of contexts” [6]. The pursuit of sustainability can play a significant role in making engineering problems complex. A characteristic of the triple bottom line is that its pursuit is “not a straightforward endeavor” and that there is much “complexity and inherent tensions involved in managing the three dimensions of sustainability” [7].

ASCE also publishes its Civil Engineering Body of Knowledge (CEBOK), which focuses on preparing future civil engineers to join the profession and details desired levels of achievement within the cognitive (thinking) and affective (social/emotional/feeling) domains of learning [8]. The term sustainability appears 117 times within the 173 pages of the CEBOK, 3rd Ed. ASCE calls for undergraduate civil engineering students to demonstrate an ability to identify and explain “concepts and principles of sustainability” and apply such “to the solution of complex engineering problems” within the cognitive domain [8]. Within the affective domain, students are to “acknowledge the importance of sustainability in civil engineering” and “comply with the concepts and principles of sustainability in civil engineering” [8].

With regard to the civil engineering profession, ISI is inextricably-linked with ASCE. ISI is an education and research nonprofit organization established in 2010 by ASCE, the American Public Works Association, and the American Council of Engineering Companies, and it developed the Envision rating system in partnership with the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design [9]. Throughout ISI and ASCE documents, one will find significant overlap in sustainability concepts. For example, within the preamble to the ASCE Code of Ethics, it states that engineers are to govern their professional careers on [four] fundamental principles, the first of which is to “create safe, resilient, and sustainable infrastructure” [10]. “ASCE defines sustainability as a set of environmental, social, and economic conditions (aka “The Triple Bottom Line”) in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or the availability of environmental, social, and economic resources” [11]. ASCE’s Policy Statement 418 - The Role of the Civil Engineer in Sustainable Development states that “civil engineers shall be committed to following the ASCE Principles of Sustainable Development: Principle 1 – Do the right project… [and] Principle 2 – Do the project right” whereas ISI’s Envision Credit LD2.2: Plan for Sustainable Communities states that “Envision is not only about doing the project right, it is about doing the right project” [4] [11]. Table 3 shows the correlation between ASCE’s Committee on Sustainability’s new publication, *ASCE/COS 73-23: Standard Practice for Sustainable Infrastructure* and the five Envision credit categories. It is evident that ISI’s Envision rating system is well-integrated with ASCE and the civil engineering profession.

Table 3: Comparison and alignment of topics between ASCE/COS 73-23 and the Envision™ framework [4] [12]

Chapters in ASCE/COS 73-23		Envision™ Framework Categories
1. General		
2. Sustainability Leadership	→	Leadership
3. Quality of Life	→	Quality of Life
4. Resource Allocation	→	Resource Allocation
5. Natural World	→	Natural World
6. Greenhouse Gas Emissions 7. Resilience	→	Climate and Resilience
8. Life-Cycle Cost Analysis (LCCA)		(LCCA is covered in Leadership, Credit LC3.3: Conduct a Life-Cycle Economic Evaluation)

Literature Review

The use of Envision within civil engineering curriculum is not new; however, most literature focuses on using the rating system and case studies of actual projects to facilitate student learning.

Educators have leveraged Envision within the engineering design capstone course [13] [14]. One group of educators identified a need for increased knowledge of sustainability, so they developed a module with learning objectives that included definitions of basic concepts of sustainability, sustainable development, the triple bottom line, cradle-to-cradle, life-cycle assessment and whole-system thinking, accompanied by application of the Envision rating system to an infrastructure project [13]. The authors concluded that, although their PowerPoint presentation and assessment assisted in students achieving lower levels of development, deeper learning and higher levels of achievement would require a dedicated sustainability engineering course [13]. Another author described how the Envision™ rating system was used by 13 capstone design teams to evaluate their proposed designs [14] This study found that "gaining familiarity with the Envision Rating System allowed students to think about sustainability in a dynamic manner in an effort to improve their proposed designs" and that "several students have even taken the initiative to become accredited Envision Sustainability Professionals" [14]. The author concluded that results "clearly indicate that the Envision Rating System helped students to increase the sustainable design components considered within the capstone design projects" [14].

Another example of Envision in undergraduate civil engineering curriculum used the rating system as a part of in-class active learning activities within a first-year introduction to engineering course [15]. After a short lecture on sustainable engineering, the instructor provided students with the Envision rating system and asked groups of students to align five credits to each of the elements of the triple bottom line. The instructor's observations were that students easily mapped environmental related credits but struggled with economic related credits [15]. Nevertheless, the exercise helped introduce students to basic sustainability concepts.

Other educators have leveraged sustainability rating tools like Envision to specifically help teach front-end planning for sustainable infrastructure projects [16]. Results of these efforts suggest that using the rating system tool helped students to "believe that it is important to integrate sustainability criteria during the design, construction, and operation of an infrastructure project" [16].

Still others have used case studies of Envision certified infrastructure projects to investigate rating system credits in the context of how they applied to actual projects. In one example, students were asked to assess and evaluate stakeholders' requirements and design priorities and to assess the triple bottom line. In this instance, the instructors concluded that leveraging the Envision rating system helped students to gain understanding of the "cognitive biases and barriers [that] commonly inhibit sustainable outcomes in decision making" [17]. In another example, educators focused on leveraging Envision as a mechanism to support ABET EAC Student Outcome #7 [18]. In a junior-level construction/engineering economics course, students participated in a service-learning project where they worked with community partners and a real-world project to choose a discrete credit in each of the five Envision credit categories and write memos on its application to the project [18]. In a different study, instructors presented student teams with the Envision Pre-Assessment Checklist spreadsheet, the Envision Rating System Guidance Manual, and copies of case studies that used the rating system [19]. The instructors concluded that, in their opinion, the Envision Rating System is "much better as a teaching tool and applicable to a broader range of civil and environmental engineering projects" than LEED [19].

Scant literature exists on earning the ENV SP credential itself as a part of civil engineering curriculum. A recent study of sustainable infrastructure curriculum found a gap in the availability of the topic within higher education and proposed guidelines for incorporating Envision within Architecture, Engineering, and Construction education [20] [21]. In the authors' research into construction management (not civil engineering) programs, they found that only two programs taught infrastructure sustainability and just three that offered credentialing processes within the bachelor's degree [21]. The authors claimed that having students earn the ENV SP credential "can help them to learn about existing social issues related in infrastructures and contribute to building more equitable and sustainable infrastructure systems in their careers" [20]. Finally, it appears that having students earn credentials in sustainability may be useful in general. One researcher investigating the positive trend in earning professional credentials in sustainability concluded that such recognition "presents a window of unique opportunity for individuals to distinguish themselves and advance as new standard for performance takes hold" [22].

Case Study and Methodology

This case study considers four undergraduate engineering students who earned the ENV SP in partial fulfillment for successful completion of CE189: Independent Study in Civil Engineering (1.0 Credit Hours). Of the four students, two were seniors majoring in civil engineering, one was a junior majoring in civil engineering, and one was a senior majoring in mechanical engineering. Per the course catalogue offering:

> "The cadet pursues study of a research or design topic in civil engineering on an individual or small group basis, independent of a formal classroom setting. The scope of the course is tailored to the needs of the project and interests of the cadet in consultation with a faculty advisor. Activities vary by project but include defining the problem, studying the fundamentals involved, organizing an approach, performing research, achieving a solution, submitting a written report, and giving a formal briefing." [23]

The structure of CE189 is meant to be flexible in order to accommodate countless opportunities for independent study. In this instance, the students formed a small group and defined the problem as earning a professional credential while still an undergraduate student, an achievement rather uncommon for their peers. They studied the fundamentals involved through mentorship discussions with their advisor and reading about the history of ISI, the development of the Envision rating system, and requirements for earning the ENV SP credential. They learned that, to become an ENV SP, they would need to take seven online training modules and achieve 75% or better on a 75-question, multiple-choice, open book, online exam [24]. They organized an approach by backwards planning to meet course requirements, including their report, presentation, and successfully passing the credentialing exam. They performed research by taking the training online and reading from the *Envision Sustainable Infrastructure Framework Guidance Manual, Version 3*. They achieved a solution by successfully completing the training and passing the exam, then they submitted a written report and gave a formal briefing. Additionally, at the beginning of the course, the students were required to establish a written contract with their advisor that defined success for the course, and they had to maintain a time log of "billable hours" throughout the semester to document their time investment.

For the written report portion of the course, the authors decided to leverage a "Relationship Matrix" tool, which is a component of a process called the Quality Function Deployment (QFD), in order to conduct a crosswalk between the Envision credits and categories to the ABET Student Outcomes and the ASCE's Civil Engineering Program Criteria. The QFD methodology originated in Japan in the 1970s to better design quality into manufactured products and is taught as a part of the engineering design process in the mechanical engineering program at the United States Military Academy [25] [26]. The Relationship Matrix is a tool to quantify perceived relationships between the "WHATs" and "HOWs" of design at four levels: "no relationship, weak/possible relationship, medium/moderate relationship, and strong relationship" using a scale of 0, 1, 3, and 9, respectively [25]. This non-linear scale is utilized in order to assign the highest weights to those elements with the strongest relationships as calculations proceed. For example, the relationship between Envision Credit LD1.1 Provide Effective Leadership & Commitment and the ABET Student Outcome #6 ("Experiment & Data") is weak as there is just indirect correlation between effective leadership and collection of data; conversely, LD 1.1 has a strong relationship with ABET Student Outcome #4 ("Ethical & Professional") as effective leadership guides the ethics and behavior of a team. In this case study, the authors leveraged the relationship matrix tool from the QFD methodology in an attempt to quantify their subjective assessments of the relationships between each Envision credit to each ABET Student Outcome as well as between each Envision credit to each ASCE Program Criterion. Because the Envision Credit Categories correspond to five of the seven online training modules required to take the exam, the relationship levels also serve to quantify how much those training modules contributed to the ABET Student Outcomes and ASCE's Civil Engineering Program Criteria. The micro view of the relationship between each ENV SP credit and each ABET Student Outcome is used to help remove possible biases that a macro view relating just the credit category title to student outcomes could impart.

Results

The relationship matrices and graphical interpretation of results are shown in Figure 1 through Figure 4. Each ABET Student Outcome and ASCE Program Criterion have the same number of data entries, so their importance ranks and score ranks are the same at the bottom of each matrix. However, when comparing Envision Credit Categories, each category has a different number of credits; QL has 14 credits, LD 12, RA 14, NW 14, and CR 10 for a total of 64 credits across the five credit categories. Due to this uneven distribution, the importance ranks need not match the score ranks for credit categories.

From Figure 1 and Figure 3, it is evident the authors found Student Outcomes #2 ("Design") and #4 ("Ethical & Professional") to be the most supported by an understanding of the concepts presented within Envision. Likewise, it appears that the Envision Credit Category of Leadership has the most in common with the ABET Student Outcomes. From Figure 2 and Figure 4, it is evident the authors found ASCE's Civil Engineering Program Criteria 1.a.iii. ("Principles of Sustainability"), 1.d.ii. ("Professional Attitudes & Responsibilities"), and 1.a.v. ("Code of Ethics") most supported by an understanding of the concepts presented within Envision. Likewise, it appears that the Envision Credit Categories of Leadership and Quality of Life have the most in common with the ASCE's Civil Engineering Program Criteria.

ISI Envision Rating System			ABET Student Outcomes											
Credit Category	Envision Credit		1. Solve	2. Design	3. Communicate	4. Ethical & Professional	5. Team	6. Experiment & Data	7. New Knowledge	Credit Raw Score	Credit Category Relative Importance	Credit Category Importance Rank	Credit Category Average Relationship Score	Credit Category Score Rank
Quality of Life	QL1.1	Improve Community Quality of Life	3	9	3	9	3	1	3	31	0.207	3	4.36	4
	QL1.2	Enhance Public Health & Safety	3	9	1	9	3	1	3	29				
	QL1.3	Improve Construction Safety	3	9	1	9	9	1	1	33				
	QL1.4	Minimize Noise & Vibration	3	9	1	9	1	3	1	27				
	QL1.5	Minimize Light Pollution	3	9	1	9	1	3	1	27				
	QL1.6	Minimize Construction Impacts	3	9	1	9	1	1	1	25				
	QL2.1	Improve Community Mobility & Access	3	9	1	9	3	1	3	29				
	QL2.2	Encourage Sustainable Transportation	3	9	3	9	3	3	1	31				
	QL2.3	Improve Access & Wayfinding	3	9	3	9	9	3	3	39				
	QL3.1	Advance Equity & Social Justice	3	9	3	9	9	3	3	39				
	QL3.2	Preserve Historic & Cultural Resources	3	9	3	9	3	1	1	29				
	QL3.3	Enhance Views & Local Character	3	9	3	9	3	1	1	29				
	QL3.4	Enhance Public Space & Amenities	3	9	3	9	3	1	1	29				
	QL0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--				
Leadership	LD1.1	Provide Effective Leadership & Commitment	3	3	9	9	3	1	1	29	0.210	1	5.23	2
	LD1.2	Foster Collaboration & Teamwork	3	3	9	3	9	1	1	29				
	LD1.3	Provide for Stakeholder Involvement	9	9	9	9	9	3	9	57				
	LD1.4	Pursue Byproduct Synergies	3	3	1	3	1	3	9	23				
	LD2.1	Establish a Sustainability Management Plan	3	9	9	9	9	1	3	43				
	LD2.2	Plan for Sustainable Communities	9	9	3	9	3	3	3	39				
	LD2.3	Plan for Long-Term Monitoring & Maintenance	3	9	9	3	3	3	3	33				
	LD2.4	Plan for End of Life	9	9	9	9	9	3	3	51				
	LD3.1	Stimulate Economic Prosperity & Development	3	9	3	9	3	3	3	33				
	LD3.2	Develop Local Skills & Capabilities	3	9	3	3	3	3	3	27				
	LD3.3	Conduct a Life-Cycle Economic Evaluation	9	9	3	9	3	3	3	39				
	LD0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--				
Resource Allocation	RA1.1	Support Sustainable Procurement Practices	3	9	3	9	3	9	9	45	0.208	2	4.38	3
	RA1.2	Use Recycled Materials	3	9	1	3	1	3	3	23				
	RA1.3	Reduce Operational Waste	3	9	1	3	1	3	1	21				
	RA1.4	Reduce Construction Waste	3	9	1	3	1	3	1	21				
	RA1.5	Balance Earthwork On Site	3	9	1	3	1	3	1	21				
	RA2.1	Reduce Operational Energy Consumption	9	9	3	9	3	3	3	39				
	RA2.2	Reduce Construction Energy Consumption	9	9	3	9	3	1	1	35				
	RA2.3	Use Renewable Energy	9	9	3	9	3	3	3	39				
	RA2.4	Commission & Monitor Energy Systems	1	3	1	1	1	9	9	25				
	RA3.1	Preserve Water Resources	9	9	3	9	3	3	3	39				
	RA3.2	Reduce Operational Water Consumption	9	9	3	9	3	3	3	39				
	RA3.3	Reduce Construction Water Consumption	9	9	3	9	3	1	1	35				
	RA3.4	Monitor Water Systems	1	3	1	1	1	9	1	17				
	RA0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--				
Natural World	NW1.1	Preserve Sites of High Ecological Value	3	9	3	9	3	1	3	31	0.179	5	3.77	5
	NW1.2	Provide Wetland & Surface Water Buffers	9	9	1	9	1	1	1	31				
	NW1.3	Preserve Prime Farmland	1	9	1	9	1	1	1	23				
	NW1.4	Preserve Undeveloped Land	3	9	1	9	1	1	1	25				
	NW2.1	Reclaim Brownfields	1	9	1	9	1	1	1	23				
	NW2.2	Manage Stormwater	1	9	1	9	3	3	1	27				
	NW2.3	Reduce Pesticide & Fertilizer Impacts	1	9	1	9	1	1	1	23				
	NW2.4	Protect Surface & Groundwater Quality	3	9	1	9	1	1	1	25				
	NW3.1	Enhance Functional Habitats	1	9	1	9	1	1	3	25				
	NW3.2	Enhance Wetland & Surface Water Functions	1	9	1	9	1	1	3	25				
	NW3.3	Maintain Floodplain Functions	9	9	3	9	1	3	1	35				
	NW3.4	Control Invasive Species	3	9	1	9	1	1	1	25				
	NW3.5	Protect Soil Health	3	9	1	9	1	1	1	25				
	NW0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--				
Climate and Resilience	CR1.1	Reduce Net Embodied Carbon	9	9	1	9	1	3	3	35	0.196	4	5.95	1
	CR1.2	Reduce Greenhouse Gas Emissions	9	9	1	9	1	3	3	35				
	CR1.3	Reduce Air Pollutant Emissions	9	9	1	9	1	3	3	35				
	CR2.1	Avoid Unsuitable Development	3	9	3	9	3	3	9	39				
	CR2.2	Assess Climate Change Vulnerability	9	9	1	9	1	3	9	41				
	CR2.3	Evaluate Risk and Resilience	9	9	1	9	1	9	9	47				
	CR2.4	Establish Resilience Goals and Strategies	3	9	3	9	9	3	9	45				
	CR2.5	Maximize Resilience	9	9	1	9	1	9	9	47				
	CR2.6	Improve Infrastructure Integration	9	9	3	9	9	3	9	51				
	CR0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--				
Student Outcome Relative Importance:			0.143	0.261	0.080	0.244	0.092	0.083	0.097					
Student Outcome Importance Rank:			3	1	7	2	5	6	4					
Student Outcome Average Relationship Score:			4.7	8.5	2.6	7.9	3.0	2.7	3.1					
Student Outcome Score Rank:			3	1	7	2	5	6	4					

Figure 1: Relationship Matrix between ABET Student Outcomes and Envision Credits

ISI Envision Rating System			ASCE Program Criteria													
Credit Category		Envision Credit	1.a.i. Mathematics & Basic Science	1.a.ii. Mechanics, Materials, & Numerical Methods	1.a.iii. Principles of Sustainability	1.a.iv. Engineering Design Process	1.a.v. Code of Ethics	1.b. Complex Engineering Problems	1.c. Experiments & Results	1.d.i. Project Management & Economics	1.d.ii. Professional Attitudes & Responsibilities	Credit Raw Score	Credit Category Relative Importance	Credit Category Importance Rank	Credit Category Average Relationship Score	Credit Category Score Rank
Quality of Life	QL1.1	Improve Community Quality of Life	0	0	9	9	9	9	0	3	9	48	0.259	1	3.64	2
	QL1.2	Enhance Public Health & Safety	0	0	9	9	9	3	0	3	9	42				
	QL1.3	Improve Construction Safety	0	0	9	9	9	9	0	9	9	54				
	QL1.4	Minimize Noise & Vibration	0	0	9	3	3	3	0	1	3	22				
	QL1.5	Minimize Light Pollution	0	0	9	3	3	3	0	1	3	22				
	QL1.6	Minimize Construction Impacts	0	0	9	3	3	3	0	9	3	30				
	QL2.1	Improve Community Mobility & Access	1	3	9	3	3	9	0	3	3	34				
	QL2.2	Encourage Sustainable Transportation	0	0	9	3	3	3	0	1	3	22				
	QL2.3	Improve Access & Wayfinding	0	0	9	3	9	3	0	3	9	36				
	QL3.1	Advance Equity & Social Justice	0	0	9	3	9	3	0	3	9	36				
	QL3.2	Preserve Historic & Cultural Resources	0	0	9	3	9	3	0	3	9	36				
	QL3.3	Enhance Views & Local Character	0	0	9	3	3	3	0	1	3	22				
	QL3.4	Enhance Public Space & Amenities	0	0	9	3	3	3	0	1	3	22				
	QL0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--	--	--				
Leadership	LD1.1	Provide Effective Leadership & Commitment	0	0	9	3	9	3	0	9	9	42	0.231	2	3.83	1
	LD1.2	Foster Collaboration & Teamwork	0	0	9	3	9	3	0	9	9	42				
	LD1.3	Provide for Stakeholder Involvement	0	0	9	9	9	3	0	9	9	48				
	LD1.4	Pursue Byproduct Synergies	0	0	9	3	1	3	0	3	1	20				
	LD2.1	Establish a Sustainability Management Plan	0	0	9	3	3	3	0	9	3	30				
	LD2.2	Plan for Sustainable Communities	0	0	9	3	9	3	0	9	9	42				
	LD2.3	Plan for Long-Term Monitoring & Maintenance	0	0	9	3	9	3	0	3	3	30				
	LD2.4	Plan for End of Life	0	0	9	3	9	3	0	3	3	30				
	LD3.1	Stimulate Economic Prosperity & Development	0	0	9	3	3	3	0	9	3	30				
	LD3.2	Develop Local Skills & Capabilities	0	0	9	1	3	3	0	3	3	22				
	LD3.3	Conduct a Life-Cycle Economic Evaluation	1	0	9	3	9	9	0	9	3	43				
	LD0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--	--	--				
Resource Allocation	RA1.1	Support Sustainable Procurement Practices	0	0	9	1	3	1	0	9	3	26	0.182	3	2.56	4
	RA1.2	Use Recycled Materials	0	0	9	3	1	1	0	1	1	16				
	RA1.3	Reduce Operational Waste	1	0	9	1	1	1	0	1	1	15				
	RA1.4	Reduce Construction Waste	1	0	9	1	1	1	0	9	1	23				
	RA1.5	Balance Earthwork On Site	3	0	9	1	1	3	0	3	1	21				
	RA2.1	Reduce Operational Energy Consumption	3	0	9	1	1	3	0	3	1	21				
	RA2.2	Reduce Construction Energy Consumption	3	0	9	1	1	3	0	9	1	27				
	RA2.3	Use Renewable Energy	3	0	9	3	3	3	0	3	3	27				
	RA2.4	Commission & Monitor Energy Systems	3	0	9	1	1	1	9	3	1	28				
	RA3.1	Preserve Water Resources	3	0	9	1	1	1	0	1	3	19				
	RA3.2	Reduce Operational Water Consumption	3	0	9	1	1	3	0	3	1	21				
	RA3.3	Reduce Construction Water Consumption	3	0	9	1	1	3	0	9	1	27				
	RA3.4	Monitor Water Systems	3	0	9	1	1	1	9	3	1	28				
	RA0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--	--	--				
Natural World	NW1.1	Preserve Sites of High Ecological Value	0	0	9	1	3	1	0	3	9	26	0.164	4	2.31	5
	NW1.2	Provide Wetland & Surface Water Buffers	3	1	9	1	3	1	0	1	3	22				
	NW1.3	Preserve Prime Farmland	0	0	9	1	3	1	0	1	3	18				
	NW1.4	Preserve Undeveloped Land	0	0	9	1	3	1	0	1	3	18				
	NW2.1	Reclaim Brownfields	0	0	9	1	3	1	0	1	1	16				
	NW2.2	Manage Stormwater	0	3	9	1	3	1	0	3	1	21				
	NW2.3	Reduce Pesticide & Fertilizer Impacts	0	0	9	1	3	1	0	1	1	16				
	NW2.4	Protect Surface & Groundwater Quality	1	0	9	1	3	1	0	3	9	27				
	NW3.1	Enhance Functional Habitats	0	0	9	1	3	1	0	1	3	18				
	NW3.2	Enhance Wetland & Surface Water Functions	0	0	9	1	3	1	0	1	1	16				
	NW3.3	Maintain Floodplain Functions	3	3	9	1	3	1	0	3	9	32				
	NW3.4	Control Invasive Species	0	0	9	1	3	1	0	1	1	16				
	NW3.5	Protect Soil Health	0	0	9	1	3	1	0	1	9	24				
	NW0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--	--	--				
Climate and Resilience	CR1.1	Reduce Net Embodied Carbon	3	1	9	1	3	1	0	1	3	22	0.164	4	3.33	3
	CR1.2	Reduce Greenhouse Gas Emissions	3	1	9	1	3	1	0	1	3	22				
	CR1.3	Reduce Air Pollutant Emissions	3	1	9	1	3	1	0	1	3	22				
	CR2.1	Avoid Unsuitable Development	1	0	9	3	9	1	0	3	9	35				
	CR2.2	Assess Climate Change Vulnerability	9	3	9	1	3	1	0	3	9	38				
	CR2.3	Evaluate Risk and Resilience	9	3	9	3	9	1	0	3	9	46				
	CR2.4	Establish Resilience Goals and Strategies	3	0	9	3	3	1	0	3	3	25				
	CR2.5	Maximize Resilience	9	3	9	3	3	1	0	3	3	34				
	CR2.6	Improve Infrastructure Integration	3	1	9	3	3	1	0	3	3	26				
	CR0.0	Innovate or Exceed Credit Requirements	--	--	--	--	--	--	--	--	--	--				
		Student Outcome Relative Importance:	0.049	0.014	0.323	0.087	0.148	0.087	0.011	0.131	0.150					
		Student Outcome Importance Rank:	7	8	1	5	3	5	9	4	2					
		Student Outcome Average Relationship Score:	1.4	0.4	9.0	2.4	4.1	2.4	0.3	3.6	4.2					
		Student Outcome Score Rank:	7	8	1	5	3	5	9	4	2					

Figure 2: Relationship Matrix between ASCE's Civil Engineering Program Criteria and Envision Credits

Note: there is a numerical tie between ASCE's Civil Engineering Program Criteria 1.a.iv. and 1.b., as well as between Envision Credit Categories Natural World and Climate and Resilience in terms of relative importance.

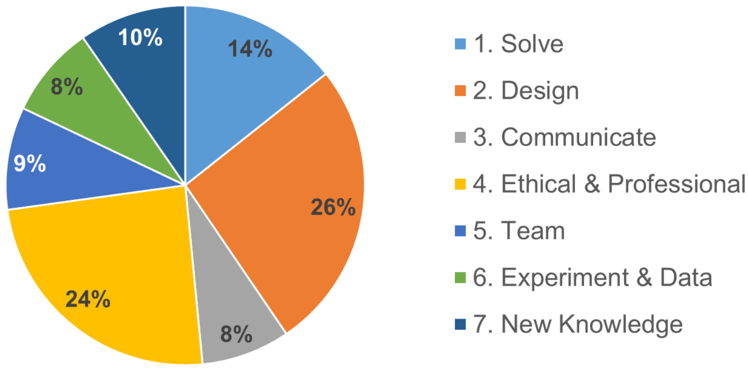

Figure 3: Relative Strength of Correlation between ABET Student Outcomes and Envision

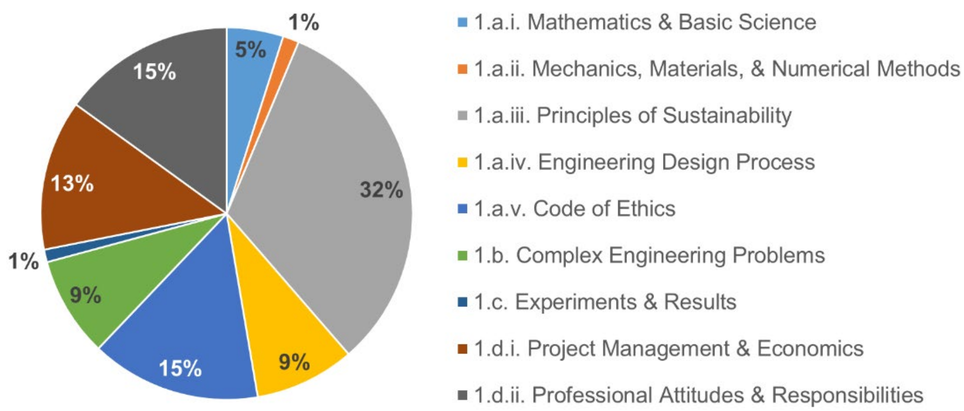

Figure 4: Relative Strength of Correlation between ASCE's Civil Engineering Program Criteria and Envision

Discussion

All four students enrolled in CE189 successfully completed their online training modules through ISI, passed their certification examination, and completed the written report and presentation requirements. In total, students averaged spending 37 hours over the semester on the course, whereas the target for a 1-credit course is 40 hours.

Anecdotal evidence reveals students that complete an independent study and are successful in earning a professional credential feel a sense of pride and accomplishment. The students demonstrated an ability to acquire and apply new knowledge on their own, which supports ABET Student Outcome #7. Further, although not the same level as achieving professional licensure, earning professional credentials contributes toward student appreciation of professional attitudes and responsibilities, which supports ASCE's Civil Engineering Program Criteria 1.d.ii. During presentations, students frequently commented that demonstrating the discipline to study for and earn a professional credential gave them confidence in their ability to plan a study routine and demonstrate the same discipline in studying to successfully pass the Fundamentals of Engineering Exam.

Recommendations from students in course-end-feedback included applying the rating system to a real-world project. For future offerings of this elective course, the faculty advisor will seek out opportunities for the students to apply the rating system to infrastructure projects underway on campus grounds. Rather than writing a formal report on their learning, the students may visit and engage with stakeholders to discuss the project, complete the Envision Pre-Assessment Checklist [27], and communicate the results through a presentation with questions and answers.

The experience of studying for and earning a professional credential in sustainability can be leveraged in other ways across civil engineering curriculum. As previously stated, students at USMA also have the opportunity to study for and earn the LEED Green Associate credential. Because such an endeavor typically takes approximately 80 hours, this independent study is now offered as a 2-credit independent study course. For academic programs that do not offer independent study courses, earning a credential like Envision could still be incorporated as a major component of an existing course on infrastructure. Since completing the training modules and taking the online exam would likely comprise less than one-third of a typical 3-credit course, earning the credential could compliment a broader set of course-wide learning objectives.

Beyond the learning value and confidence that studying for and earing a professional credential while still an undergraduate student brings, an additional benefit is professional capability. At USMA, those who graduate and become Engineer Officers within the U.S. Army are able to apply the ENV SP credential toward earning Skill Identifiers (SIs). SIs signify specific skills that require further professional development and qualification through completion of functional courses, self-development, and operational experience, and they are used to classify officers with specific expertise for better selection of duty positions. Obtaining different SIs allows for higher flexibility of broadening and developmental positions in which one may serve. Earning the ENV SP credential supports being awarded the W1: Facilities Planner and W7: Energy and Environmental Officer SIs.

Conclusion

Implementation of the ENV SP professional credential into the civil engineering curriculum at USMA has enabled cadets to learn more deeply about the societal, environmental, and leadership contexts that accompany sustainable development. The independent study course provided students the opportunity to be responsible for their own learning, which promotes the development of lifelong learning skills and self-discipline to study for and pass an exam, all while having a small group and faculty advisor to lean on when needed. By involving students earlier in their undergraduate careers, their future civil engineering courses will be seen through the lens of sustainability and the lessons learned while earning the ENV SP. The ENV SP students also have the opportunity to inspire their peers to pursue the credential themselves once they see how their newfound knowledge has enhanced their skills and abilities within the civil engineering curriculum.

Integrating ENV SP into civil engineering curriculum is a method that can be implemented at other universities to help address the entire spectrum of ABET Student Outcomes and ASCE's Civil Engineering Program Criteria. Earning the credential allows students to see just how much sustainability is tied to the policies, code of ethics, and other principles of their profession, and they become better prepared to both do the right project and do the project right.

Disclaimer

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