Integrating the United Nations Sustainable Development Goals and the Envision Rating System to Assess Sustainability in Civil Engineering Capstone Design

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Abstract

Civil Engineering Capstone Design requires undergraduate students to work in teams with professional mentors to develop solutions to relevant real-world problems. Recent changes to both ABET Engineering Accreditation Criteria (EAC) and the Civil Engineering Body of Knowledge (CEBOK3) emphasize the importance of sustainability in design. Realistic design solutions need to consider risk assessment, societal and environmental impacts, relevant codes, standards and regulations, sustainability and resilience. The design teams developed innovative design solutions while gaining an understanding of the impact the solutions have in global, economic, environmental and societal contexts. Students learned to consider the increasing demands for improved transportation systems, resilient and sustainable cities and renewable energy.

This paper focuses on how using the United Nations Sustainable Development Goals (UN SDGs) along with the ASCE Envision Rating System increases civil engineering undergraduate students' awareness of sustainability as they complete their capstone designs. Over the course of two years, civil and multidisciplinary engineering design projects focused on the design of infrastructure; vehicular and pedestrian bridges, buildings; mixed use multistory, civil/site projects; flood control, emergency relief housing and renewable energy, were developed with an awareness of sustainability.

The SDG's were introduced as each design teams began working on their projects. Each student was required to pick at least one goal for incorporation into the proposed design, and every design team was required to use the Envision rating system as a guide to improve the sustainability of their proposed design. The Envision online scoresheets introduce 64 sustainability and resilience credits which the design teams used to assess the sustainability of the proposed designs. The emphasis on sustainability by incorporating both the UN SDG's and Envision expanded the focus of the design to consider the overall plan, construction, maintenance and life cycle of the projects. The incorporation of both criteria helped to guide student decisions, evaluate the environmental impact of the designs and address the benefits the proposed design had on their respective communities. The exposure to both the UNSDGs and the Envision Rating System was supported by the professional mentors. One company even provided funding to support students to complete the Envision training and become Envision Sustainability Professionals.

Design assessments/rubrics were developed for each oral presentation and written submission to evaluate student understanding. These assessments aligned ABET 1 – 7, the UN Sustainable Development Goals and the Envision Rating system. The UN SDG's and the Envision Rating System served as a guide for the student teams to develop sustainable design solutions which considered the economic, environmental and social impacts of the designs.

Consideration of sustainability within the undergraduate Capstone Design is linked to Profession Ethics for all Civil Engineers as noted in the BOK3, "strive to comply with the principles of sustainable development in the performance of their professional duties." Using both the UN SDG's and Envision is a realistic way to bridge the gap between the undergraduate design

experience and the professional expectations students will be obligated to consider in their future careers.

Introduction

Recent changes to ABET criteria and proposed changes to the Civil Engineering Body of Knowledge (BOK) both emphasize the importance of sustainability within civil engineering education [1, 2]. Students are expected to have the knowledge and skills necessary to practice engineering at a professional level and include principles of sustainability within their designs. Requiring students to address sustainability within the capstone design course can help prepare undergraduate students with some of the "knowledge, skills and attitudes necessary for entry into the practice of civil engineering at the professional level." [1] During the 2018-9 academic year, 13 capstone design projects were required to address sustainability within their proposed designs. The United Nations Sustainable Development Goals [3] and the ASCE Envision Rating System were used to assess the sustainability of each design. The rationale behind using both the UN Sustainable Development Goals and the Envision Rating System arose during a workshop at the 2018 ASEE Annual Conference, "Applications of the Envision Rating System in Engineering Courses and Curricula." [4] Workshop participants were asked to look at the 17 UN Sustainable Development Goals, each with 10 objectives, select one goal and match it to the Envision Rating System which is used to evaluate the community, environment and economic life cycle impacts and benefits of infrastructure projects.

This paper describes how 13 capstone design teams each selected at least one UN Sustainable Development Goal to incorporate into their design. The goals were selected at the beginning of the Fall 2018 semester, and helped the students gain an understanding of the impact engineering solutions have in global, economic, environmental and societal contexts [5]. The sustainability of each proposed design was evaluated using the Envision Rating System. The data presented was taken from the student design reports and frequent assessments by professional advisors, faculty mentors, the capstone design coordinator and the students.

Capstone Design and the United Nations Sustainable Development Goals:

The Civil Engineering Capstone Design course at Stevens Institute of Technology is a two-semester long course that provides the unique experience for senior engineering students to work on real world projects with multi-stakeholder engagement, while developing designs that address current global challenges in infrastructure. Each project has a professional industry sponsor along with professional mentors and a faculty advisor. During the 2018-19 academic year there were 13 projects consisting of two pedestrian bridges, three mixed-use buildings, a highway bridge, a railroad bridge, three site plans, a stormwater collection system, the USEPA Rainworks challenge and a hydroelectric dam. Students self-selected their projects based on their specific engineering interests and worked on teams ranging in size from three to seven students. Nine of the projects were specific to the civil engineering discipline and four were multidiscipline which included students from mechanical, electrical, environmental and computer engineering as well as engineering management students. Table 1 shows the project titles, team makeup and the professional industry mentor.

Table 1: Capstone design project structure for 2018-19 academic year

Project Number	Project Title	Group Size and Makeup	Sponsor
1	Design of a Mixed-Use High Rise	5 Female Civil Engineers	Thornton Tomasetti
2	Reconstruction of a Pedestrian Bridge	2 Male Civil Engineers 2 Female Civil Engineers	Thornton Tomasetti
3	Replacement of a Highway Bridge	1 Male Civil Engineer 4 Female Civil Engineers	WSP USA, Inc
4	Elimination of an Existing Railroad Grade Crossing	4 Male Civil Engineers 1 Female Civil Engineer	Stantec
5	Design of a New Pedestrian Bridge over the Raritan River	5 Male Civil Engineers	Naik Consulting Group and DRG Architects
6	Design of a Five-Story Mixed-Use Building	3 Male Civil Engineers 1 Female Civil Engineer	Structural Workshop, LLC
7	Site Investigation and Design of a Police Warehouse and Response Center	4 Male Civil Engineers	CLS Project Solutions
8	Breezy Point Stormwater Management Improvement Plan	2 Male Civil Engineers 2 Female Civil Engineers 1 Female Environmental Engineer	The Louis Berger Group
9	Stormwater Collection System	3 Male Civil Engineers	Passaic Valley Sewage Commission
10	Flooding Assessment of Rockland County	4 Male Civil Engineers 1 Female Engineering Management	Rockland County Task Force on Water Resources Management
11	US EPA Rainworks Challenge	2 Male Civil Engineers 1 Male Engineering Management 1 Male Computer Engineering	N/A
12	Dundee Dam Hydroelectric Power Plant	1 Male Civil Engineer, 1 Female Civil Engineer, 3 Male Mechanical Engineers, 2 Male Electrical Engineers	Suez
13	Site Design for a Proposed Yacht Club	2 Female Civil Engineers, 2 Male Mechanical Engineers, 1 Female Mechanical Engineer, 1 Female Engineering Management	Christie Engineering

The United Nations Sustainable Development Goals were introduced during the first week of the Fall 2018 semester, Figure 1. Many of the students had never heard of these goals but were all eager to incorporate the sustainable development applications into their proposed design projects.

Each student was asked to conduct research on the UN Goals and then write a brief essay on which goal(s) they wanted to incorporate into their proposed design project. Each group then discussed the goals selected by the individual team members and decided upon the goals that were most applicable to their design project. These results can be found on Table 2. Of the 17 UN Goals the engineering students selected eight as illustrated in Figure 2.

- Goal 5: Gender Equality
- Goal 6: Clean Water and Sanitation
- Goal 7: Affordable and Clean Energy
- Goal 9: Industry, Innovation and Infrastructure
- Goal 11: Sustainable Cities and Communities
- Goal 12: Responsible Consumption and Production
- Goal 14: Life Below Water
- Goal 15: Life on Land

Figure 1. United Nations Sustainable Development Goals
https://fezana.org/wp-content/uploads/unsdg.jpg

Figure 2: Student selection of UN Sustainable Development Goals

Of the eight UN Sustainable Development goals selected by this group there was not an obvious difference between males and females. Research has shown that females prefer careers which focus on communal values, benefiting others [6]. The career paths of this group have already begun as they are all engineering majors in their senior year. The author wanted to see if adding the UN Sustainable Development Goals would increase the motivation for the proposed designs to have an added communal component. As can be seen in figure 3 there was no specific preference to any particular goal based on gender. Contrary to the research which states that females prefer disciplines with communal goals of collaboration and the ability to help others [7] the males in the class selected a wider range of goals than the females.

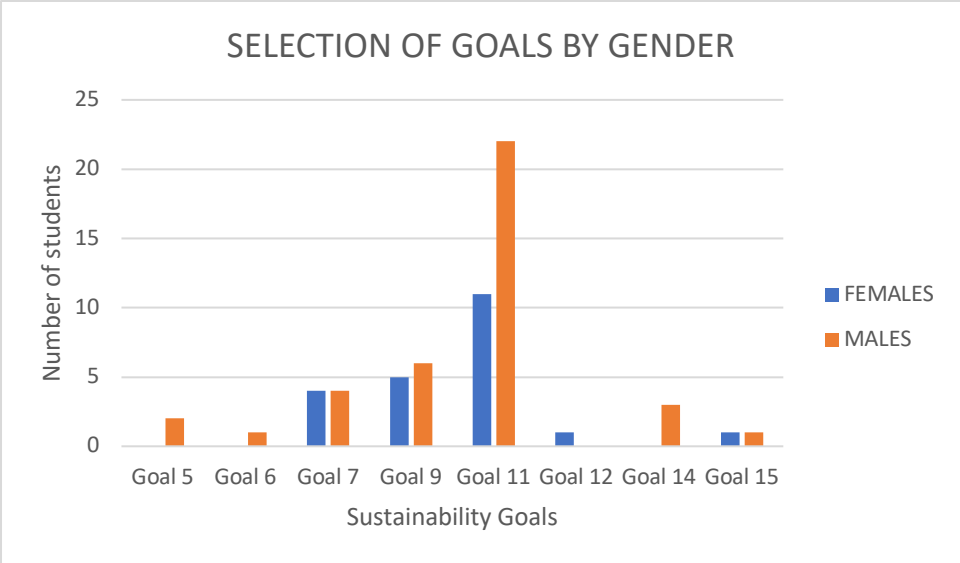

Figure 3: Student selection of UN Sustainable Development Goals by Gender

Table 2: Selection of UN Sustainable Development Goals

Project Title	UN Sustainable Development Goal
Design of a Mixed-Use High Rise	Goal 11
Reconstruction of a Pedestrian Bridge	Goals 9 and 11
Replacement of a Highway Bridge	Goals 9 and 11
Elimination of an Existing Railroad Grade Crossing	Goals 9, 11 and 15
Design of a New Pedestrian Bridge	Goals 9, 11 and 14
Design of a Five-Story Mixed-Use Building	Goal 11
Site investigation and Design of 730 3rd Avenue	Goal 11
Breezy Point Stormwater Management Improvement Plan	Goal 11
Stormwater Collection System	Goals 6 and 11
Flooding Assessment of Rockland County	Goal 11
US EPA Rainworks Challenge	Goals 9, 11 and 14
Dundee Dam Hydroelectric Power Plant	Goal 7 and 11
Site Design for a Proposed Yacht Club	Goals 6, 7, 9 and 12

Designing with a Sustainable Development Goal

The senior design projects encompassed a wide range of civil engineering designs; structural, transportation, site plans, stormwater management and clean-energy. The UN Sustainable Development Goals were used to increase the student's awareness of global issues and helped them to incorporate sustainable elements into their proposed designs [8]. The student teams were encouraged by their professional mentors and faculty advisors to *think outside of the box* and look beyond traditional design solutions while still meeting the needs of their clients and stakeholders. The sustainable design elements the teams developed are as follows:

All six structural projects (three bridges and three buildings) selected Goal 11 – Sustainable Cities and Communities. One team also incorporated Goal 9 – Industry, Innovation and Infrastructure. These teams were encouraged to push the limits of their designs and develop solutions which provided more than what is traditionally required by design codes.

The design of a Mixed-Use High-Rise Building in New York City incorporated Goal 11 by considering the impact the large building will have within the dense urban environment of midtown Manhattan. The team considered urban management practices which reduced the impact on the environment. These practices included water reuse within the building, water saving fixtures, windows which reduce heat loss and a green roof.

The design of a Five-Story Mixed-Use Building focused on Goal 11 by providing separate safe and secure areas for both retail and residential tenants, including separate parking areas. They added inclusive bathrooms and also selected resilient and sustainable materials for their proposed design.

The design of a Police Warehouse and Response Center considered Goal 11 by ensuring that the design of the first floor specified an elevation above the new (post Sandy) FEMA flood elevation in order to withstand a storm similar to Hurricane Sandy. The proposed design also incorporates required ADA compliant features and includes a unique internal ramp for vehicles to pass through the building to assure quick response and community resource allocation.

The proposed Highway Bridge over a river in New Jersey incorporated Goals 9 and 11. Their innovative design specifies long spans to limit the number of piers within the waterway. The design also examined the use of sustainable materials including high performance concrete and self-consolidating concrete. In addition to designing for ADA compliance, Goal 11 was addressed by adding wide shoulders along each side of the bridge to accommodate pedestrians, bicycles and emergency access. Sustainability was also considered within the proposed geometry of the bridge in order to avoid environmentally sensitive areas.

The two Pedestrian Bridges incorporated Goal 11 by ensuring that the bridges were ADA compliant. They each also added additional sustainable measures including solar lighting along the bridge approaches and main span. Rain gardens have been proposed to collect runoff from the bridges and both were designed with supports located so that they would not impact the region below, one a river, the other three railroad tracks.

The proposed railway bridge, Elimination of an Existing Railroad Grade Crossing, addressed both Goals 9 and 11 by increasing the resiliency of the existing commuter rail. The proposed design of the rail bridge over a roadway culvert ensures that the commuter rail elevation meets the new (post Sandy) FEMA flood elevation. The design updates and expands the critical infrastructure within a specific region. This design increases the railway reliability by eliminating the need for stopping at grade crossings, reducing commuting times and positioning the tracks above the roadway flood elevation.

The three site plan design projects focused on Goals 6, 7, 9, 12 and 15. These projects consisted of a Site Design for a Proposed Yacht Club, the Flooding Assessment for Rockland County, and the Breezy Point Stormwater Management Improvement Plan for a community along the Long Island shoreline. The site design for the proposed yacht club addressed Goals 6, 7, 9, 12 and 15 by reusing rainwater, implementing compostable toilets within the bathrooms, a living machine for all sanitary waste, proposing net-zero energy structures by using innovative design elements to meet the criteria for passive buildings, implementing sustainable and green materials for construction and improving the land surface and usage of the existing pier. The combination of all these features is a unique engineering ecosystem that exceeded the requirements of the sponsor, client and stakeholders.

The Flooding Assessment for Rockland County incorporated Goals 11 and 15. The design this team proposed focused on alleviating frequent flooding and making the region sustainable by improving land surfaces with the addition of green infrastructure in an effort to decrease runoff and increase infiltration. The Breezy Point Stormwater Management Improvement Plan addressed Goal 11 by creating a more sustainable urban area, preventing the economic and social impacts of frequent flooding and designing flood control systems which maintain a positive connection between the environment and the urban setting. Their proposed design incorporates

green infrastructure, permeable pavement, bioretention swales and a large pervious area consisting of athletic fields with subsurface retention.

The Stormwater Collection System team worked closely with a local utility to design a stormwater collection system which reduces the frequency of combined sewer overflow (CSO) events. This team focused on Goal 6 by reducing the volume of runoff entering the combined sewer with a unique storm water collection system not typically found in the US but common in Thailand. The design they developed also addresses Goal 11 by making the city more sustainable and able to handle excess rainfall without taxing the waste water treatment plant or discharging raw sewage into receiving waters.

The Dundee Dam Hydroelectric Power Plant incorporated Goals 7 and 11 into their design by providing clean affordable energy to the local area around the dam and proposed power plant.

The USEPA Rainworks Challenge incorporated Goals 9, 11 and 14 by proposing design upgrades to existing campus infrastructure. Their design proposes adding green infrastructure within existing impervious areas, increasing infiltration, reducing storm water runoff and combined sewer overflows. The addition of sensors into their rain garden and bioretention swales will help promote education and collaboration between different academic disciplines and the local community.

Assessing the use of UN Goals

Assessing the incorporation of the UN Goals into the capstone design was accomplished throughout each semester with the use of rubrics for both oral presentations and written submissions a sample of which is shown in Figure 4. At the beginning of the fall semester each team met for a kick-off meeting with their professional mentors. At this meeting, the project deliverables were developed, and the design schedule established. The UN Sustainable Development goals were discussed in detail and each team was tasked with researching how to best implement their selected goal(s) into the design. The senior design coordinator attended these meetings and explained the correlation between the UN Sustainable Development Goals, the ASCE BOK and the ABET Criteria. The primary goal from an academic perspective was to increase the student's awareness of global issues and how to use their engineering knowledge to improve the quality of life for all and hopefully provide positive change to people impacted by their designs [9]. The combination of using both the UN Sustainable Development Goals along with the Envision Rating System to increase the sustainability of a real-world design project added a unique dimension to this capstone design course. The student teams worked closely with their industry sponsors to develop designs which provided benefits to the stakeholders, community and environment while also adhering to all design standards.

Element	Excellent	Very Good	Good	Needs Improve-ment
Score	*4*	*3*	*2*	*1*
Introduction of the project scope and client's needs (Outcome 1)				
Identify engineering principles which are being applied (Outcome 1)				
Describes the design requirements and identification of all codes and standards (Outcome 2)				
Technical design – detailed development of design alternatives (Outcome 2)				
Evaluation of design alternatives – supported with sound engineering (Outcome 2)				
Technical content – includes drawings, equations and design methodology (Outcome 2)				
UN Sustainable Development Goal(s) are being considered and supported within the design (Outcome 2)				
Envision Rating System – design considers public health, safety, environmental and economic factors (Outcome 4)				
The design includes an innovative solution if possible (Outcome 8)				
Project schedule (Outcome 5)				
Organization, quality and clarity of presentation (Outcome 3)				
Ability to communicate effectively as a team (Outcome 5)				
Total Points (out of 48)				

Figure 4. Sample oral presentation assessment rubric with ABET Outcomes.

The average results of the assessments for the oral presentations throughout the fall semester for the question "UN sustainable development goals are being considered and supported within the design" were a 3.58/4 and for the written reports a 4.5/5. Students were also assessed at the end of the fall semester and asked if the "technical aspects of their design successfully incorporated UN Sustainable Development Goals." The results were a 3.73/4. These results clearly indicate that consideration of the UN Sustainable Development Goals was achieved within the capstone design course to assess sustainability within their designs.

Use of the Envision Rating System to further support sustainability

The Envision Rating System was developed in partnership between the ASCE, American Public Works Association (APWA), American Council of Engineering Companies (ACEC) and the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design [10]. Envision is a holistic sustainability rating system to help professionals plan and execute sustainable infrastructure projects [11]. In order to increase student awareness of the impact their proposed designs will have on the surrounding community and environment the Envision rating system was introduced within the capstone design course and required for each design project [12]. Envision focuses on infrastructure projects and encourages the designer to consider a large range of sustainable design elements. The Envision rating system was not

designed to be used on buildings so the two building design projects were encouraged to think beyond the walls of each building. These two teams were encouraged to develop designs which considered the impact the structure will have on the adjacent community, develop designs which enhance the environment in which the building is located, address stakeholder concerns and consider the lifecycle of the building. The sponsors for these two projects allowed the design teams to propose sustainable design elements which aligned with the Envision Rating System. These included:

- Incorporation of public space within the building. The proposed spaces would be inclusive to all and safe for both the public users as well as the tenants of the proposed structure.
- Reducing the carbon footprint of the building during construction and throughout the lifecycle of the building.
- Reducing independence on the power grid by adding solar panels, increasing energy efficiency of the building's "skin" and HVAC systems.
- Minimizing the use of raw materials within the buildings.
- Minimizing the impermeable footprint of the building and increasing green space around the structure.
- Adding living roofs to each structure.

Many of the students and sponsors were not familiar with the Envision Rating System but all were open to using it to address the sustainability of the proposed designs. The student teams and sponsors used the Envision Checklist to measure the sustainability of the proposed designs. Envision has 64 sustainability indicators called credits divided into five categories which are further broken down into different criteria each with an available number of points:

- Quality of Life – Purpose, Community and Wellbeing
- Leadership – Collaboration, Management and Planning
- Resource Allocation – Materials, Energy and Water
- Natural World – Siting, Land & Water and Biodiversity
- Climate and Resilience – Emission and Resilience

Each of these categories is further divided into specific criteria which allow the designer to assess the environmental, social and economic impacts of the design. Credits are associated with each of the 5 categories, the specific criteria within each category and a basic yes or no response to an assessment question. The credits are weighted within each category based on the impact, ease of implementation and sustainability tradeoffs. The result is a clear and simple method to evaluate the sustainability for any type of infrastructure. The number of credits determines the Envision Award Level the design achieves: verified (20% of total points), silver, (30% of total points), gold (40% of total points) or platinum (50% of total points).

Most of the senior engineering students and many of the professional mentors were not familiar with the Envision Rating System. In an effort to familiarize the students with the Envision Rating System, the Envision Scorecard was reviewed with the class at the beginning of the semester and each team was asked to consider which criteria they felt could be incorporated into their designs [13]. The teams then met with their faculty advisors and professional mentors to further evaluate the feasibility of the Envision Criteria. As the semester progressed, each team was required to provide an update of their Envision Credits and discuss the rationale behind their

design decisions. The Envision Rating System was also directly assessed using rubrics for all oral presentations, Figure 4 and written report submissions, Figure 5.

At the conclusion of the Fall 2018 semester, all of the structural focused design projects were better able to assess the sustainability of their designs by using the Envision Rating System. The design projects which focused on site plans and stormwater management found it a challenge to implement the Envision Rating System into their first semester design proposals. Many of these teams worked to develop several design alternatives during the fall semester and thus assigning criteria to different alternatives was useful for evaluating and comparing alternatives but not ideal for assessing the sustainability of an alternative which will be further developed during the spring semester [14].

The tabulated results of the Envision Rating System for the 13 design projects is presented in Table 3. These values represent the credits for the designs as of the end of the Fall 2018 semester. The Envision Rating System will be continually referenced, and the credits reconsidered throughout the Spring 2019 semester. At the conclusion of the Spring 2019 semester each design team will have to determine the Award Level: verified, silver, gold or platinum their design will achieve as per the Envision Rating System.

Please assign numbers 0-5 for each of the listed statements pertaining to the report and presentation according to the key.

0	Statement not addressed at all
1	Statement addressed improperly, major revision needed
2	Uncomfortable with the way statement area addressed
3	Statement addressed properly, but lacks sufficient detail
4	Minor reservations about how statement addressed
5	Completely satisfied

	Description	Written Report	Comments
1	The design team has phrased the problem statement clearly and understands the problem.	/5	
2	The design alternatives were developed using appropriate engineering methods and tools.	/5	
3	The designs presented are accurate and supporting calculations are provided.	/5	
4	The report includes appropriate drawings, sketches and details which support the proposed designs.	/5	
5	All design codes and standards have been addressed properly.	/5	
6	UN Sustainable Development Goals are identified and supported within the design.	/5	
7	Appropriate environmental considerations have been addressed using the Envision Rating System.	/5	
8	A rough cost estimate has been developed.	/5	
9	Project plan/schedule for the semester was realized.	/5	
10	The report is well organized and well written.	/5	

Figure 5: Sample written report rubric

Table 3: Results of the Envision Checklist for each design project

	Quality of Life	Leadership	Resource Allocation	Natural World	Climate and Resources	Total Points	Recognition Level
Total Points Available	26	19	41	46	11	143	
Design of a Mixed-Use High Rise	16	15	15	7	7	60	Gold
Reconstruction of a Pedestrian Bridge	21	17	16	30	5	101	Platinum
Replacement of a Highway Bridge	23	17	19	32	5	96	Platinum
Elimination of an Existing Railroad Grade Crossing	18	16	29	44	10	117	Platinum
Design of a New Pedestrian Bridge	23	17	13	26	4	83	Platinum
Design of a Five-Story Mixed-Use Building	17	18	29	23	10	97	Silver
Site investigation and Design of 730 3rd Avenue	18	17	24	24	4	87	Platinum
Breezy Point Stormwater Management Improvement Plan	15	17	13	16	4	65	Gold
Stormwater Collection System	17	18	12	39	8	94	Platinum
Flooding Assessment of Rockland County	17	11	29	23	7	87	Platinum
US EPA Rainworks Challenge	12	17	7	17	3	56	Silver
Dundee Dam Hydroelectric Power Plant	9	12	5	2	5	33	Verified
Site Design for a Proposed Yacht Club	16	17	32	30	9	104	Platinum

There is no direct link between the Envision Rating System and the UN Sustainable Development Goals. The combination of both encouraged the students to think beyond the limits of their design projects and develop designs which addressed global issues while considering the larger impact of their proposed designs. Many of the proposed designs were modified in an effort to address both criteria. The sponsors were all active participants in the implementation of both criteria and helped the teams develop designs which were practical, met the client's needs but added sustainable elements which may not be part of the professionally developed design. Examples of some of the added design elements are provided in table 4.

The design additions which addressed sustainability using both criteria allowed the students to develop innovative solutions to some traditional infrastructure problems. This additional consideration aligned very well with the Institute's 8th ABET outcome which focuses on innovation and entrepreneurship. Typically, Civil Engineering projects have difficulty meeting this outcome as the designs represent a service and not a device. The inclusion of sustainable elements into the proposed designs encouraged the student teams to develop innovative solutions which addressed global issues while considering the local impacts of their designs. The professional mentors encouraged the design enhancements while also discussing the realistic limitations some of the proposals presented to the project stakeholders and clients.

Table 4. Proposed sustainable design elements to address both criteria.

Project Number	Project Title	Sustainable Element
1	Design of a Mixed-Use High Rise	Common space for the community, material selection to minimize the use of raw materials, a living roof.
2	Reconstruction of a Pedestrian Bridge	Solar lights, CarbonCure concrete and rain gardens at the base of the structure.
3	Replacement of a Highway Bridge	Use of sustainable materials, multipurpose lane for walkers and bicycles, innovative stormwater collection system.
4	Elimination of an Existing Railroad Grade Crossing	Reducing traffic, multipurpose lane for walkers and bicycles.
5	Design of a New Pedestrian Bridge over the Raritan River	Rain gardens within the span, solar lights, addition of benches for community use.
6	Design of a Five-Story Mixed-Use Building	The structure is inclusive, safe, resilient and sustainable.
7	Site Investigation and Design of a Police Warehouse and Response Center	Internal ramp to accommodate vehicles and provide through access. The addition of a second floor for use as an official command/emergency center.
8	Breezy Point Stormwater Management Improvement Plan	Recreational facilities (soccer, baseball, softball etc.) within areas prone to flooding. Subsurface retention, numerous green infrastructure technologies.
9	Stormwater Collection System	Reduction of pollutants into receiving waters by reducing CSO events. Sustainable system design requiring minimum excavation.
10	Flooding Assessment of Rockland County	Reducing the impact of flooding and restore land areas by implementing green infrastructure.
11	US EPA Rainworks Challenge	Reduction of pollutants in surface water runoff, decrease CSO events.
12	Dundee Dam Hydroelectric Power Plant	Use of renewable (alternative) energy, increase quality of life, noise and vibration reduction.
13	Site Design for a Proposed Yacht Club	Zero net energy facility, compostable toilets, rainwater harvesting systems.

Assessing the implementation of the Envision Rating System

Assessing the use of the Envision Rating System into the capstone design was accomplished throughout each semester with the use of rubrics for both oral presentations and written submissions, Figures 4 and 5. The Envision Checklist was referenced throughout the semester as the design progressed. Many of the criteria included within the checklist were not applicable to the designs, especially those pertaining to construction and maintenance. The design teams and the sponsors were not required to achieve any specific award level but used the checklist to maximize sustainable design components which could be incorporated into the proposed design. 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. The use of Envision along with the consideration of the UN Sustainable Development Goals increased

student's awareness of global sustainability issues within engineering designs. Several students have even taken the initiative to become accredited Envision Sustainability Professionals.

The average results of the assessments for the oral presentations throughout the fall semester for the question "The Envision Rating System design considers public health, safety, environmental and economic factors" were a 3.66/4 and for the written reports a 4.5/5. Students were also assessed at the end of the fall semester and asked if the "The design alternatives developed consider the overall needs of the client, the desired use and the Envision Rating System." The results were a 3.61/4. These clearly indicate that the Envision Rating System helped students to increase the sustainable design components considered within the capstone design projects.

Conclusion

The ASCE BOK includes the requirement that civil engineers must "include principles of sustainability in design" [1] while ABET requires engineering graduates to have "an ability to apply engineering design to produce solutions that meet specific needs with consideration of public health, safety and welfare as well as global, cultural, social, environmental and economic factors [2]." Applying these criteria into the Civil Engineering Capstone Design which exposes the senior engineering students to real-world design challenges reflects experiences students will face as professionals, benefiting those who plan to pursue engineering careers after graduation.

Exposing students to both the UN Sustainable Development Goals and the Envision Rating System aligns with both the ASCE BOK and ABET criteria requiring engineers to understand the importance of sustainability within their designs. The Capstone Design projects examined within this study are all infrastructure projects which did not address all of the UN Sustainable Development Goals, but they did address eight out of the seventeen. With the addition of the Envision Rating System students learned to think beyond their specific site. They used these two criteria to consider the social, economic and environmental impacts of their designs [15]. The design teams were also encouraged to collaborate with the stakeholders as much as possible when developing their designs. In the absence of actual interactions with the stakeholders, the professional mentors provided the teams with data sets consisting of stakeholder concerns.

The interactions between the undergraduate students and the professional mentors afforded both groups the opportunity to explore sustainable design components which would meet two very different criteria. These interactions provided unique opportunities for the students to develop design solutions which can "benefit both the community and the student." [16].

Encouraging students to experience design activities focusing on sustainability better prepares them for the global challenges they will face during the course of their careers. "Students who participate in real world design are better able to translate their experiences into marketable outcomes [17]." In additional to gaining familiarity with both the UN Sustainable Development Goals and the Envision Rating System the experience of working closely with professional mentors required the students to communicate effectively and become socially aware of the global impact of their designs. These skills are essential to all engineering graduates whether they pursue careers in professional design or research.

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