Learning Synergies between Sustainability and Entrepreneurship: A Case Study of Community Development

Dr. Xi Wang, Drexel University

Xi Wang is an Associate Teaching Professor of Construction Management Program at Drexel University. She received her Ph.D. and M.Eng both in Civil Engineering, from the University of Kentucky and Auburn University. She is licensed as a Professional Engineer and LEED Green Associate. She is teaching a range of courses in construction management and will be assisting capstone design projects that directly serve regional construction firms. Her research interests include technology adoption in workforce development in the construction industry, sustainable developments in construction education, and learning motivation for student success in engineering education.

Eliana Roof, Drexel University

Eliana Roof is a student in the Construction Management Program at Drexel University. She plans to graduate in 2029 with a B.S. in Construction Management and a Minor in Writing. She is also a part of Drexel's Pennoni Honors College. Eliana is a LEED Green Associate and has a variety of other field trainings and certifications within the construction industry. Her interests include healthcare construction and humanitarian engineering.

Kathleen M Short

Learning Synergies between Sustainability and Entrepreneurship: A Case Study of Community Development

Abstract

The demand for professionals capable of navigating complex sustainability problems is increasing in the construction industry. Although many construction programs have initiated integrating sustainability in their curriculum, entrepreneurship often receives limited attention, limiting students' ability to apply sustainable principles to practical solutions. The reason is that sustainable development and entrepreneurship are closely connected, with entrepreneurs recognized for developing creative solutions that advance the economy while generating beneficial social and environmental impacts This study investigates the synergies between the sustainable development and entrepreneurial leadership mindsets through a pedagogical strategy that is on the basic of the Kern Entrepreneurial Engineering Network (KEEN) 3Cs framework, including Curiosity, Connections, and Creating Value. The proposed strategy was implemented as a 10-week term project within an undergraduate Construction Sustainability course. Students were tasked to design LEED-certified green communities that are composed of five infrastructure systems: landscape, transportation, water, energy, and solid waste. The project encouraged system thinking, stakeholder engagement, and community-centered decision-making while promoting entrepreneurial mindsets. A hybrid assessment method was adopted, including a sustainable design rubric, peer and self-assessment, course evaluations, and a post-course survey, which correspond to measuring entrepreneurial leadership mindset. The results of design rubric, with mean rubric scores above 6 on a 7-point scale, show strong student performance across environmental, social, and economic pillars of sustainability. Moreover, survey findings reveal meaningful gains in entrepreneurial leadership mindsets, particularly in students' ability to make cross-disciplinary connections and create social and economic values. Qualitative feedback emphasizes increased engagement, improved understanding of sustainability as a multi-dimensional concept, and improved confidence in applying course knowledge to real-life scenarios and challenges. Despite being limited by a small sample size and implementation at a single institution, this project, being a pilot study, indicates that students improved their sustainability skills and entrepreneurial mindset by learning and using the synergies between entrepreneurial leadership and sustainability. The findings provide a practical and replicable teaching method for promoting sustainable and entrepreneurial education within construction management programs.

Introduction

Sustainability provides a comprehensive perspective on the relationship between humanity and the environment, demonstrating that environmental conservation alone is insufficient. Achieving sustainability demands consideration of wider social and economic factors beyond singular self-interest. Education centered on sustainability can motivate future generations to create novel approach that balance ecosystem protection with economic growth. Sustainable development is essential for common welfare, and entrepreneurship is widely recognized as a catalyst for sustainable economic progress. To ensure long-term viability without diminishing the needs of future generations, contemporary businesses are increasingly implementing sustainable practices.

Addressing the social, economic, and environmental dimensions of sustainability, as well as overcoming challenges in a rapidly changing global context, requires entrepreneurial skills and leadership mindsets. Entrepreneurship and sustainable development are thus closely linked, as leaders with entrepreneurial mindsets foster novelty and resilience, aligning economic growth with social and environmental responsibility to create enduring value. This approach requires proactive, adaptable leadership that prioritizes long-term vision, risk-taking, and the creation of shared value for stakeholders and communities. Consequently, the significance of entrepreneurial education in preparing future generations for sustainability-focused initiatives is highlighted by the necessity to cultivate entrepreneurial leadership mindsets for the advancement of sustainable communities.

Despite widespread recognition of the value of embedding sustainability into construction education, the discipline continues to lag in both sustainable development and entrepreneurial leadership. Numerous studies have identified persistent gaps in construction education, particularly a lack of practical applications and insufficient depth to fully prepare students with sustainability competencies [1]. Research on student perspectives further emphasizes the need for greater integration of sustainability and a shift toward interdisciplinary curricula to improve students' competencies and understanding of how their actions affect community sustainability [2]. Given the increasing demand for LEED-certified construction projects and the growing market for sustainable practices [1], a comprehensive pedagogical strategy is required to strengthen sustainability education within construction management programs.

Entrepreneurial education has received limited attention in construction classrooms compared to engineering fields [1]. This may be due to perceptions among construction entrepreneurs that establishing a construction business is less advantageous than in other sectors. The project-based and dynamic nature of the construction industry contributes to an unpredictable entrepreneurial environment, possibly obstructing the development of sustainable construction businesses [3]. Furthermore, construction entrepreneurs commonly lack recognition for their entrepreneurial efforts relative to peers in other industries, possibly due to the prevailing emphasis in the U.S. education system on the "college for all" paradigm. Consequently, young adults may not perceive construction as a viable entrepreneurial career path [4].

To address these gaps in construction education, this study introduces a pedagogical strategy designed to enhance construction students' sustainability competencies by integrating entrepreneurial leadership perspectives. The proposed approach is based on the concepts of sustainability and entrepreneurial leadership. It takes into account the key attributes of a sustainability vision, demonstrated through initiatives that promote environmental, social, and economic benefits within the community. Sustainable initiatives are considered innovations that stand out as a fundamental aspect of entrepreneurial vision, which encourage curiosity, facilitate connections, and generate value for others [5]. The pedagogical strategy is implemented as a term project within a sustainability course in Construction Management program. Its effectiveness is assessed by means of a case study and evaluations methods in various formats.

Literature Review

Sustainability

The growing adoption of sustainable practices in the construction industry has prompted increased scholarly attention to how sustainability is addressed within undergraduate education. Prior studies emphasize the need for construction-related programs to expand their curricula to cover sustainable practices in response to evolving industry demands [6]. In particular, the Leadership in Energy and Environmental Design (LEED) framework developed by the U.S. Green Building Council has been widely discussed as a benchmark for incorporating sustainability within construction education, as it promotes interdisciplinary design integration, professional training, and market transformation through sustainable materials and construction methods [7]. Within this educational context, the concept of sustainability competencies has developed into a central theme in literature.

Sustainability competence is generally viewed as the capacity to understand socio-ecological systems, embrace sustainability values, and take informed action that promotes long-term environmental and societal well-being [8]. Researchers define sustainability competencies as encompassing cognitive abilities, practical skills, motivational, and social aspects required to address sustainability issues across private, institutional, and societal contexts [9]. This multidimensional perspective is consistent with the OECD's definition of competencies as a cohesive combination of knowledge, skills, attitudes, and values crucial to sustainable development and social cohesion [10]. Recent studies have also aimed to identify and categorize core sustainability competencies. A growing consensus highlights five key domains of competency: systems thinking, futures thinking, values thinking, strategic thinking, and interpersonal skills [6]. In addition, studies have examined pedagogical strategies for fostering these competencies, such as experiential learning, cross-disciplinary collaboration, and problem-based approaches [11] [12]. The current literature emphasizes the critical role of aligning construction education curricula with competency-based frameworks to prepare graduates for sustainability-driven professional practice.

Entrepreneurial Leadership Mindsets

Entrepreneurship is a creative process wherein entrepreneurs discover and leverage business opportunities by utilizing resources and generating value [13]. The significance of entrepreneurship has been emphasized due to its favorable impact on economic progress. To encourage entrepreneurial endeavors among the upcoming workforce, it is essential to invest in students to cultivate this mindset [14]. Consequently, to support students' readiness and enthusiasm for launching their own businesses, educational institutions and programs across various fields, especially engineering, have recently incorporated entrepreneurial leadership as a prominent topic in their curricula [15]. The main goal is to nurture students' entrepreneurial aspirations to start their own businesses and concentrate on cultivating entrepreneurial mindsets and skills, such as recognizing market opportunities, collaboration, communication, and leadership [16]. Specifically, according to the Kern Entrepreneurial Engineering Network [5], an entrepreneurial leadership mindset is fundamental to professionals to work together to address societal challenges and enhance the built environment for humanity. This mindset covers a spectrum of attitudes and behaviors essential to problem-solving, fostering innovation, and creating value. The three components of an entrepreneurial mindset that prepare students for success are known as the 3Cs: Curiosity, Connections, and Value creation. Curiosity entails a student's enthusiasm to explore, which is a vital skill in our fast-changing world. In other words, it demonstrates constant curiosity about the changing world and explores a contrarian view of accepted solutions. Connections signify the students' commitment to seeking knowledge and merging it with the insights generated by their curiosity. It is also about integrating information from many sources to gain insight, assess, and manage risk. Connections are essential for turning discoveries into cutting-edge solutions. Generating value means providing benefits to others and motivating students to take initiative in the value-creation process independently. It indicates an ability to identify unforeseen opportunities to create extraordinary value and persist through and learn from failure.

The Synergy between Entrepreneurial and Sustainability Education

Sustainable development and entrepreneurship are closely connected, with entrepreneurs recognized for developing creative solutions that advance the economy while generating beneficial social and environmental impacts [17]. Entrepreneurs who emphasize sustainable practices build an environment where social responsibility is woven into the company's core values from the beginning, combining conventional economic objectives with an innovative viewpoint that takes into account the ecological and social consequences of the business [18]. For example, ventures that prioritize sustainability often have missions to tackle specific social or environmental issues, such as shifting to renewable energy, enhancing civic participation, or aiding victims of gender-based violence. Some founders may integrate sustainability into their business practices by guarantee accountable supply chains and actively interacting with their communities [19].

For the aforementioned reasons, many studies emphasize the values of integrating sustainability into entrepreneurial education. Entrepreneurial education fosters creativity, adaptability, and a profound comprehension of socioeconomic relationships. It assesses the considerable effects of an entrepreneurial leadership mindset on social structures, environmental protection, and economic stability, reaching beyond traditional business knowledge [20]. Kotla and Bosman [21] call for a holistic approach to teaching sustainability-focused entrepreneurship through a collaborative effort that brings together teachers and learners from various countries and fields of study, enabling students to solve complex sustainability-related challenges that impact society. Fanea-Ivanovici and Baber [22] explore how educators may support students intending to become future entrepreneurs by promoting sustainability objectives to encourage sustainability initiatives. Furthermore, Suguna et al. [23] provide a roadmap for stakeholders dedicated to sustainable community development by informing the creation of strategic initiatives, curriculum revisions, and policies that incorporate entrepreneurial education.

Gaps in Construction Management Education

While there is an increasing body of literature exploring the unique impacts of entrepreneurial mindsets in sustainable education, a thorough grasp of the connections between the two is still lacking, specifically in construction education. Construction management, however, has historically lagged in both sustainability education and incorporating entrepreneurial thinking [24] [25]. Specifically, technology is evolving rapidly, as are the expectations surrounding sustainable construction practices. If the industry fails to equip the current and future workforce with the skills required to meet these emerging standards, we could find ourselves lagging behind. Research indicates that construction students often lack opportunities to engage with projects that mirror real-world complexity [26]. Furthermore, concentration on technical knowledge, such as scheduling and cost estimation, often limits the development of higher-order skills, including adaptability, creativity, and leadership [27], which are essential to sustainable development. Some universities and programs have incorporated sustainability courses into their construction curriculum, making them mandatory for students. However, there is a challenge within sustainable design education: the need to acknowledge the necessity for change and implement it within the business [28].

Therefore, to address these gaps and better prepare students for the industry's changing requirements, this study explores the synergies between sustainability and entrepreneurship and integrates these concepts in the construction and community development contexts. Specifically, this study has three primary objectives. First, it seeks to provide insights into how entrepreneurial education can promote sustainable community development across diverse environmental and socioeconomic contexts by identifying key elements and examining their interrelationships. Second, the proposed strategy builds upon established theoretical models, integrating concepts from the existing literature supported by empirical analysis to offer educators practical insights. Finally, this study adds to the ongoing discussion on integrating sustainable entrepreneurial education into construction courses by presenting effective pedagogical practices. By introducing innovative teaching approaches that foster students' sustainability competencies, the study addresses a major shortfall in the current literature.

Pedagogical Strategies

This study suggests a pedagogical strategy integrating the KEEN 3Cs into construction education, as shown in Figure 1. Curiosity is achieved by motivating students to explore new ideas, challenge assumptions about traditional construction, and research innovative solutions. Creating Value is about designing projects that are people-centered while also considering sustainability and cost efficiency, thereby generating value beyond the immediate function. Connections involve helping students understand how their decisions influence various stakeholders and connect theoretical knowledge with practical constraints, such as environmental risk mitigation. Furthermore, this strategy considers the characteristic attributes of a sustainability vision, which can be reflected in efforts that encourage beneficial environmental, social, and economic impacts on the community.

Methodology

This study integrated the proposed strategy into a 10-week experiential learning project within an in-person Construction Sustainability course. Specifically, the instructor used a project-based approach, with participants from building design and construction backgrounds working in small groups (five to six students) under the supervision of an instructor. The topic of the project was centered on a green community, where the requirements and expectations for sustainable considerations were presented to the students. The students used the integrative design thinking process to create a sustainable community. The course term project involved 30 students, representing varied academic and professional backgrounds in the Architecture, Engineering, and Construction disciplines.

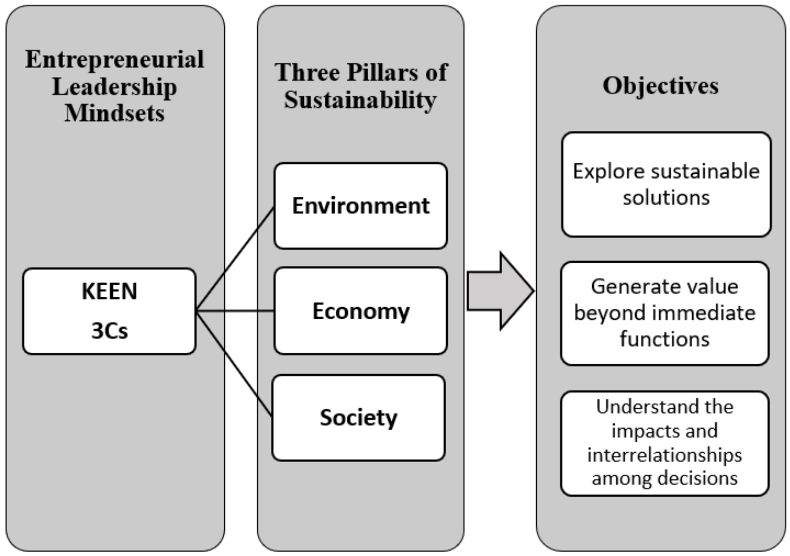

Figure 1. Pedagogical Strategy that Combines KEEN 3Cs and Sustainability Elements

Course Project Descriptions

Students were tasked to design a LEED-certified sustainable community with a focus on the performance of five basic infrastructure systems: landscape, transportation, water, energy, and solid waste. Landscape infrastructure refers to the network of open areas within and around a community that deliver a variety of services tailored to the local context. Landscapes contribute to the distinct character of a place, provide recreation opportunities, support biodiversity and natural functions, supply water, food, and material resources, alleviate and offset the adverse effects of other infrastructure systems, and enhance the community's resilience to both natural and man-made threats [26]. Second, transportation infrastructure comprises the systems and processes that facilitate the movement of people and goods. It is significantly connected to the economic well-being of communities. Infrastructure for sustainable transportation should strive to prevent, reduce, and offset adverse effects on both communities and the environment as it inevitably expands to support increasing demand. Planning initiatives ought to prioritize establishing land use patterns, density, and compactness to enhance effective transit solutions [29]. Third, water infrastructure is responsible for the treatment, collection, and distribution of drinking water, rainwater, and wastewater. It does more than draw water from nature but also returns it with low environmental impact [30]. Therefore, in addition to enhancing the functionality of networks and facilities, sustainable water infrastructure planning should involve natural process management to reduce the amount of built infrastructure needed. Implementing natural drainage and rainwater harvesting techniques is a further crucial aspect of stormwater management [31].

Moreover, energy infrastructure is responsible for managing and transforming available natural resources into energy carriers such as electricity, heat, and fuel, which are then supplied to people. Energy security is essential for assuring a high quality of life, fostering economic growth, and consequently, preserving social stability. However, energy production currently accounts for the majority of global greenhouse gas emissions. This has placed energy at the center of project targeting at achieving sustainability and resilience [32]. Consequently, sustainable energy infrastructure must guarantee consistent and equitable access to energy carriers for all individuals and businesses, while encouraging responsible usage and efficient practices. It should utilize natural resources within the limits of the environment's regenerative capacity, offering renewable, low-emission alternatives [33]. Finally, solid waste infrastructure encompasses the processes and facilities necessary for the collection, processing, and ultimate disposal of waste. Nevertheless, methods that depend heavily on landfilling for final disposal can lead to significant social and environmental consequences. Thus, planning should prioritize reducing waste at the source while also creating strategies that treat solid waste as a valuable resource [34].

Students were required to include all essential features of each basic infrastructure system and demonstrate how they function in synergy. The synergy could be shown in three formats: 1) establishing a shared platform for collaboration that everyone can engage with; 2) the integration that occurs between infrastructure and natural systems, which demands an extensive understanding of the impacted natural systems to either preserve or restore them or to compensate for any interference; 3) infrastructure processes themselves. Decisions must highlight and promote the connections and interactions among different infrastructure systems, with the aim of achieving efficiency, resilience, and minimizing environmental impact [35]. All of those connections are referred to as synergies. They could be used as opportunities for each infrastructure system to assist or be assisted by others in resolving operational challenges, optimizing facility placement, managing by-products, and more. The synergies map how each system relates to the others, providing students with a better understanding of the repercussions planning strategies can have across the community's operations [36]. These notions of integrated, systemic, and high-level planning form the core content of this term project, supporting a unified and cross-disciplinary process for improving existing community developments or developing new ones. The structure of their final outputs is shown in Table 1.

Table 1. Structure of Design Content

Landscape Infrastructure	1) Landscape Demand 2) Landscape Program 3) Landscape Pattern 4) Landscape Maintenance
Transportation Service & Infrastructure	1) Public Transit Services 2) Transportation Networks 3) Transportation Management 4) Accessibility to Essential Facilities

Water Infrastructure	1) Water Consumption 2) Water Supply 3) Water Treatment 4) Water Networks
Energy Infrastructure	1) Energy Consumption 2) Energy Supply 3) Energy Generation 4) Energy Distribution
Solid Waste Infrastructure	1) Solid Waste Generation 2) Solid Waste Diversion Model 3) Solid Waste Treatment and Disposal 4) Solid Waste Collection and Transfer

Student Sample of Work: Re-development

Each group plans and leads a charrette at the beginning of the term. Every student was asked to play a specific role in a multi-disciplinary team, such as an architect, civil engineer, etc. A Charrette lays the basis for the success of integrative design, building consensus, formalizing project expectations, optimizing the design workflow, and setting the team up for success by supporting and setting specific goals. It allows project actors to share their perspectives when their inputs can still be easily incorporated into the design. Table 2 shows a sample charrette agenda developed by students. One team developed sustainable strategies that primarily fall into five categories, as instructed: Sustainable site development, water management, energy management, transportation and accessibility, and community education. Beginning with sustainable site development, they chose a brownfield site for remediation that had previously been an oil refinery. This was not only to follow the LEED recommendations, but also to repurpose underutilized land and minimize the environmental impact of development in previously undisturbed natural areas.

Table 2. A Sample of Charrette Agenda Developed by Students

Sustainable Design Topics	**Discussion Question**
LEED goals:	Which LEED level (target points) would your team like to achieve for the building?
Site, Stormwater, and Water Strategies:	Where will the project be located?
	How will the building design leverage climatic factors and passive systems?
	What is the building’s water budget?
	How and where can stormwater be managed on-site?
	Which low-flow fixtures will be used in the plumbing system?
Energy Strategies:	What is the energy target?

	How can occupancy patterns and uses be incorporated into building design?
	What are the HVAC needs?
	Is daylight the primary source of illumination? How will it be controlled?
	What is the inventory of plug load equipment for this building, and how can we optimize plug load energy use?
Indoor Environmental Quality:	What recycled, reused, or salvaged materials might be used in construction?
	How can nature be incorporated into the building?
Operations and Maintenance:	What operational considerations need to be made?
	How will energy use and generation be tracked and verified?
	Will the building connect with and contribute to the community? How?

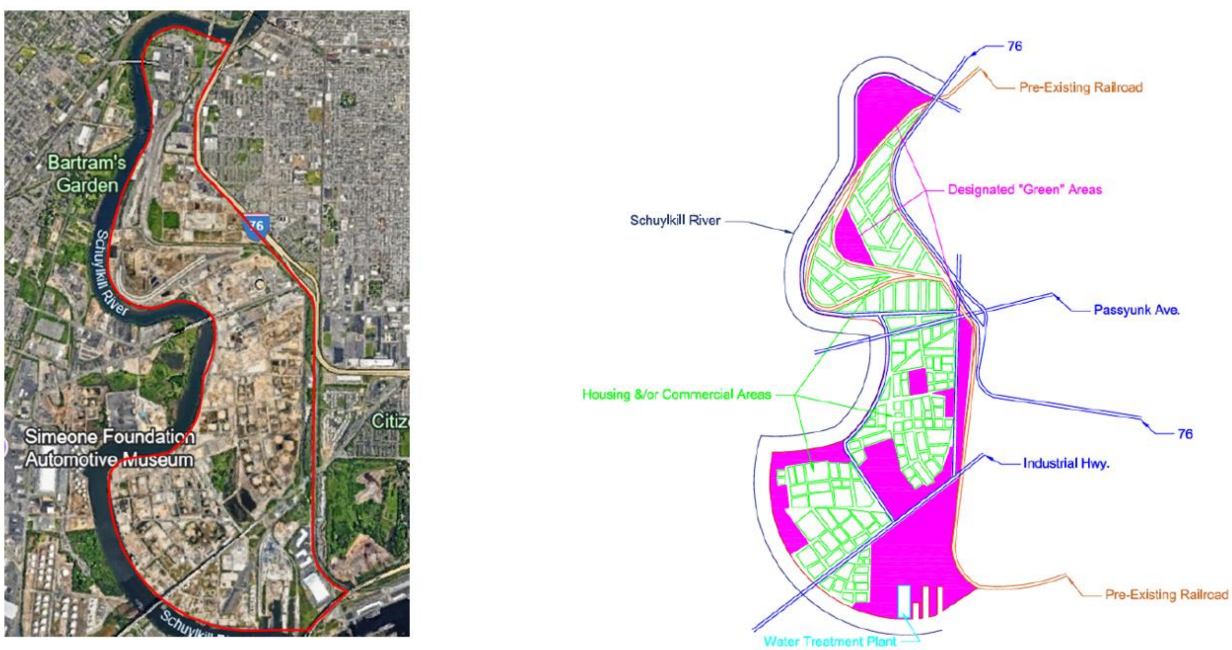

Figure 2. Selected Site and Re-development Plan

Because of the location of this brownfield site, near the mouth of a natural waterbody, they realized that they needed to be extraordinarily mindful of the water management systems. Water consumption was reduced via the integration of rainwater-harvesting systems for irrigation and by designing landscaping with low water demand. Furthermore, recycled water systems were proposed for non-potable use, further reducing water demand. The plan also included a treatment facility to ensure the community's water supply met health and environmental standards while conserving energy. Along with sustainable water management systems, they also placed heavy emphasis on the energy management systems they chose. With a focus on decreasing dependance on fossil fuels and promoting renewable energy, solar panels were selected as the primary energy generation method, making use of the site's sunlight. Energy that is not used would be fed back into the grid, advancing overall efficiency. Furthermore, the community maintained its carbon-neutral goals by designing and building energy-efficient buildings.

Brownfield remediation was not the only driving factor behind their site selection; choosing a location with pre-existing roads and railways that could be easily integrated into the city's transportation infrastructure is highly beneficial. They proposed expanding bus routes, installing electric shuttle systems, and revitalizing existing train tracks to reduce greenhouse gas emissions. A walking and biking trail system was designed to encourage active transportation, while transit stops were deliberately placed to ensure accessibility. As a result of these efforts, car dependence was reduced, and sustainable transit became more attractive and viable. Finally, they understand that all the effort put into designing, building, and maintaining this community would be wasted if those who reside there are not educated about sustainable practices and integrated into the community's longevity. They proposed programs and workshops to educate residents on sustainable practices, including waste reduction, recycling, and energy conservation. Residents were encouraged to participate in maintaining green spaces by integrating community gardens. Along with this, they plan to host community-centered events in the many green spaces throughout our planned community to cultivate a sense of interconnectivity and relationships amongst residents. In doing so, they create something people genuinely care about, and residents would be sad to see go should their plans fall through. By empowering residents with knowledge and resources, they ensured that sustainability strategies would remain effective and evolve with the community's needs.

Student Sample of Work: New development

One team proposed a new sustainable neighborhood designed to achieve LEED v4 Neighborhood Development Silver certification, integrating environmental guardianship, social well-being, and economic viability into a unified community model. The project demonstrated how considered planning, green infrastructure, and community-centered design can work together to develop a resilient and livable neighborhood. The development consists of 16 energy-efficient homes accommodating approximately 60–70 residents within a low-density, 2-square-mile site, as shown in Figure 3. At the heart of the community is a multipurpose community center that functions as the social, cultural, and operational hub of the neighborhood. The center includes shared amenities such as fitness facilities, educational and children's spaces, a library, community dining, event areas, mail and waste services, and charging stations for Neighborhood Electric Vehicles. These amenities are intended to promote social interaction, reduce individual resource consumption, and support local economic activity.

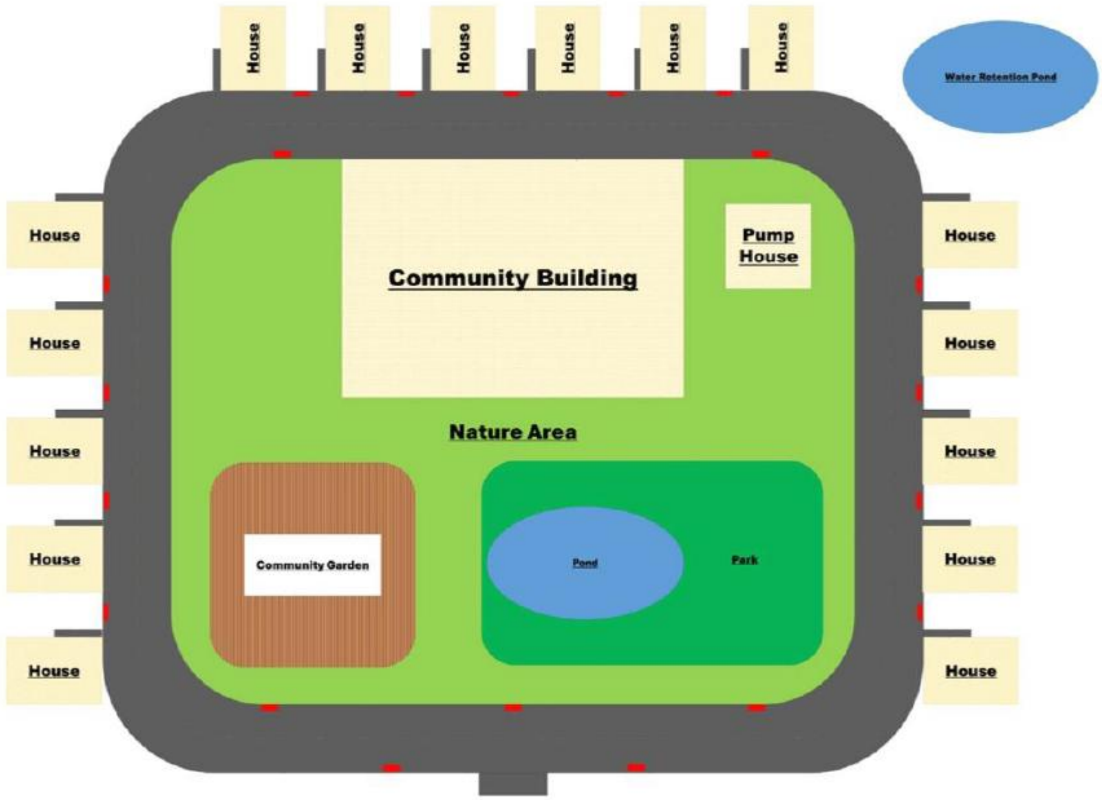

Figure 3. Layout of the Community

The neighborhood layout follows a road loop system that enhances walkability, improves traffic flow, and simplifies utility access and maintenance, as shown in Figure 4. This design also supports efficient stormwater management through a network of bioswales, a retention pond, and permeable landscapes, which collect and filter runoff for reuse in irrigation. Native plants, rain gardens, and green corridors form the backbone of the landscape strategy, reducing water demand, supporting biodiversity, and mitigating urban heat island effects. Sustainability is embedded at the residential scale through all-electric, high-performance homes equipped with solar panels, heat pump systems, Water Sense fixtures, and low-VOC materials. Rainwater harvesting, native landscaping, and EV-ready garages further reduce environmental impact while lowering long-term utility costs for residents. Durable construction materials and efficient systems enhance affordability and long-term value.

Apart from environmental performance, the design emphasizes community engagement and education. Community gardens (See Figure 4), composting programs, interpretive signage, and collaborations with nearby schools promote environmental literacy and collective stewardship. Construction practices prioritize erosion control, reduced disturbance, and local hiring to minimize environmental and social impacts. Overall, this community serves as a comprehensive model for sustainable neighborhood development, demonstrating how integrated design strategies can support resource efficiency, social cohesion, and economic resilience while meeting LEED Silver standards and enhancing residents' quality of life.

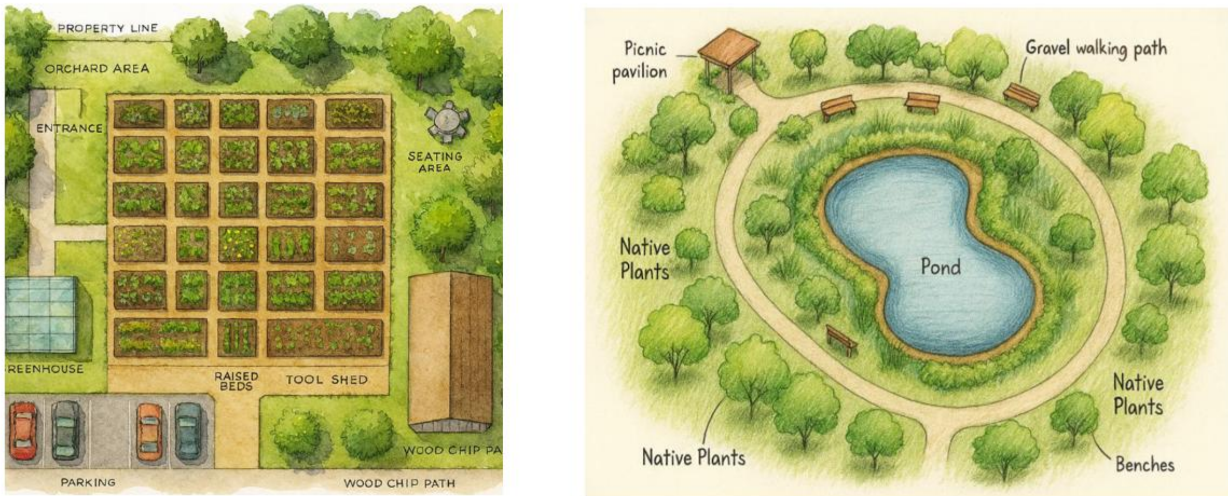

Figure 4. A Loop Road System and Community Gardens

Assessment and Results

Sustainability Competencies: Self- and Peer-Assessment

An effective approach to evaluating student capabilities in sustainable design is crucial. Research has shown that both surveys and rubrics effectively measure students' learning outcomes [37]. To ensure students understand the complexity of sustainability issues and effectively integrate their knowledge into the design process, a sustainable design rubric has been found beneficial for assessing their sustainability competencies. In this initiative, students are expected to employ the rubric found in the literature [38]. This sustainable design rubric serves as a mechanism for evaluating project outcomes, pinpointing aspects for refinement, and justifying design decisions throughout the project's lifecycle. Each group's design work was assessed by both the instructor and their peers using the same sustainable design rubric. Peer evaluation is an effective collaborative learning strategy [38]. Related to self-assessment, peer evaluation encourages students to critically examine peers' work and reflect on the meaning of quality work more generally, particularly when consulting a detailed rubric as a guide. Students themselves provide feedback to one another, while the instructor focuses on more targeted guidance toward a learning outcome. Through peer evaluation, students ultimately learn to better self-assess themselves [39]. In addition, students learn to examine varied viewpoints and assume greater responsibility in the learning process [40]. By adding an element of accountability and critical review, students are more likely to exert effort to ensure a positive peer review. Table 3 shows the assessment rubric and ratings of each criterion that address the environmental, economic, and social benefits. Students rated how each team's work tackles each pillar of sustainability on a scale 1 to 7 (1 = Inadequate Demonstration; 7 = Inspiring Demonstration). The class was divided into seven groups (N = 7), and the rest of the class evaluated each group during the presentation.

Table 3. Sustainable Design Rubric and Peer Evaluation Results (*N* = 7) [41]

Criterion	**Mean**	**Standard Deviation**	**Cronbach's α**
Environment	6.16	0.97	0.99
A1. Minimizes the use of non-replenishable raw materials; requires minimal energy input or uses renewable energy sources			
A2. Minimizes quantity of consumable waste (e.g., water, materials) output; manages quantity and quality (benign, usefulness) of waste			
A3. Protects or enhances natural ecosystems (water, air, soils, flora, fauna, etc.)			
Society	6.14	1.01	1.00
B1. Identifies and engages stakeholders in the design process			
B2. Addresses needs of diverse stakeholders, acknowledging culture and other differences among individuals and groups			
B3. Protects human health and physical safety of users and society			
B4. Promotes human well-being and enhances the quality of life for users and society			
Economy	6.18	0.93	1.00
C1. Evaluate the economic impacts of the environmental design criterion			
C2. Evaluate the economic impacts of a social design criterion			
C3. Considers affordability for users and/or demonstrates cost competitiveness or cost reduction for client/sponsor			
C4. Evaluates economic costs and benefits to inform decisions			

Twenty-five students in this course completed a course evaluation survey at the end of the term. The first part of the survey measured students' perceived performance and understanding of the learning objectives in support of sustainable development before and after entering the course and project. Students rated their agreement with the statements on a 1-5 scale (1 = No Understanding; 5 = Complete Understanding). As shown in Table 4, students' overall understanding of sustainable development increased significantly after completing the course and the term project. In addition, a qualitative question was posed to the students to explore their feedback on the strength of the course. Most responses show an increased comprehension of the topics through the term project. The following are examples of students' comments regarding this course term project "*Term project planning was helpful in applying everything we learned throughout the term. Green practices*," *Working with other students and being able to use what we learned and our own research to create a sustainable community*." *"I liked learning about the different types of green building along with the simulated project assignments. I felt like I was more involved in a "competition" setting as opposed to a classroom."*

Table 4. Assessments of Results of Learning Outcomes

Evaluation Item	**Pre**	**Post**
Understand sustainable design and construction of buildings and civil infrastructure	2.70	4.29
Understand how public, private, and facility owners practice approaches to sustainable built environments.	2.54	4.21
Comprehend elements of “green” projects to make informed decisions about systems design, water use, energy use, materials selection, and life cycle determination	2.52	4.42
Quantify the environmental, social, and financial impacts of sustainable development	2.58	4.42

Entrepreneurial Leadership Mindsets Assessment

Students were asked to complete another post-course questionnaire designed to understand how the term project influenced their perceptions of entrepreneurial leadership mindsets. The questionnaire was developed using a standardized assessment tool for the KEEN framework [5]. One recent work, such as London et al. [42], is developing a framework for documenting student outcomes related to the 3Cs, which leads to assessments supported by valid evidence. The mindset outcomes developed for the 3Cs in the study of London are applied in the assessments of this project. Students were asked to provide feedback on a Likert-scale survey about how effective the term project was in presenting 3Cs of entrepreneurial leadership mindsets, with 1 indicating “Strongly Disagree” and 7 indicating “Strongly Agree.” Common question themes related to Curiosity included sustainable, societal, and economic trends, as well as contrarian and alternative views, which parallel challenging accepted solutions and interest in a wide variety of topics [42].

Common themes in questions about Curiosity included sustainable trends, societal and economic developments, and alternative viewpoints, showing a challenge to conventional solutions and an interest in a wide variety of subjects [42]. Common themes in questions related to Connections encompass gathering information from various sources, acquiring innovative perspectives, and engaging in self-discovery or innovation, which reflect an appreciation for (a) diverse disciplinary knowledge and skills, along with (b) a recognition of one’s limitations. Common themes in questions about Creating Value included economic and societal values, the process of value creation and its impact, and addressing societal needs, which correspond to the motivation to make positive contributions to society from London et al.[42]. The assessment was administered at the end of class and was completed anonymously by each student in this class. Overall, students found the term project helpful in encouraging the 3Cs critical to instilling entrepreneurial leadership mindsets. Average scale ratings and distribution of each element are shown in Table 5. All average ratings are higher than 5, with some above 6. The lowest-rated category was Curiosity, with an average rating of 5.88. The highest-rated category was Connection, with an average rating of 6.32.

Table 5. Survey Results for Measuring Students' Entrepreneurial Leadership Mindset (*N* = 25) [42]

Survey Question	Rating
Curiosity	**5.88**
Q1. The project helped me improve my ability to anticipate sustainable trends and developments in the AEC industry.	6.4
Q2. The project motivated me to explore and investigate sustainable innovations to achieve novel discoveries.	6.24
Q3. The project helped me in challenging the "status quo," exploring contrarian views	5.44
Q4. The project helped me improve my ability to understand other people's feelings.	5.2
Q5. I have become more comfortable asking others for help after finishing this course/project.	5.72
Q6. I believe that my role in sustainable development could be important and influential after this project.	6.32
Connection	**6.32**
Q1. The project helped connect information or technologies from different sources.	6.4
Q2. The project helped me to ''think outside the box,'' pursue new knowledge, and integrate it into new contexts	6.4
Q3. The project helped me pursue self-discovery and recommend innovative solutions.	6.16
Q4. The project made me recognize the importance of other fields, even if I don't know much about them.	6.44
Q5. After this project, I learned to consider ideas put forth by people with backgrounds different from my own.	6.24
Create Value	**6.01**
Q1. The project helped explore unique opportunities and suggest solutions to create economic and societal value for the industry.	6.4
Q2. The project helped us to understand value creation and its impact on others.	6.28
Q3. The project provided an opportunity to anticipate and meet the needs of the industry.	6.08
Q4. I tended to change things that were done by the book when I was working on this project.	5.68
Q5. The project motivated me to challenge adopted solutions rather than blindly accept them.	5.72
Q6. I re-imagined existing ideas a lot for this project.	5.92

Discussion and Limitations

Summary of Results

Overall, the results suggest that the proposed pedagogical strategy, which combines the KEEN 3Cs with community development, effectively supports learning outcomes aligned with sustainability and enhances students' entrepreneurial leadership mindsets. In particular, the average rating on the sustainable design rubric, above 6 on a 7-point scale, indicated that students' in-depth understanding of the three pillars of sustainability goes beyond isolated technical solutions. The course evaluation results could add additional support to this. Students were able to recognize that sustainability is a complex concept that goes beyond solely environmental issues and received training that encouraged them to think systematically and multidimensionally. This is consistent with previous research in construction education that highlights the value of cross-disciplinary methods for developing sustainability competencies.

The results also show that the project is effective in enhancing students' entrepreneurial leadership mindsets. All three components of the KEEN 3Cs received high average scores, with Connections standing out as the most significant outcome. This finding emphasizes the project's focus on interdisciplinary collaboration, stakeholder involvement, community impact, and system integration. The results indicate that students were able to connect classroom theories to real-world challenges, especially in areas such as environmental risk mitigation, regulatory compliance, and cost estimation. Nevertheless, while students successfully engaged with practical constraints, some struggled to manage conflicting priorities, such as balancing budget limitations with sustainability goals. To solve the problems, students learned how to navigate trade-offs in decision-making by identifying synergies among the project's systems. Lastly, although Curiosity received slightly lower ratings than the other areas, the overall score was still strong, indicating that, from Charette to the detailed designs, students' curiosity is improved by exploring new ideas, redefining established design assumptions, and engaging in innovative problem-solving.

Taken together, these results indicate that integrating entrepreneurial leadership mindsets into sustainability-centered construction projects can improve both sustainability competencies and entrepreneurial thinking. This combination addresses an acknowledged gap in construction management education, where sustainability and entrepreneurship are often treated as secondary or isolated subjects. The findings support the statement that construction education can benefit from a pedagogical approach that bridges value generation, interconnected systems, and community influence.

Limitations and Future Study

The current study should be interpreted with its limitations. First, due to the project's limited resources and time, knowledge of business strategy and entrepreneurship primarily relied on students' self-learning rather than in-class interactions. Although the instructor closely communicated with students and tracked their work progress, it could have been more effective and informative for students if professionals or faculty with a business background had been involved in the project. Second, the assessment rubrics used in the case study were drawn from the literature and were not specifically designed for construction students. Although the overall assessment results were positive, they would be more convincing if a customized assessment were adopted. Third, the methodology needs further validation. To the best of our knowledge, no previous study has developed and applied a similar strategy in construction education. Therefore, this project is a pilot study that primarily focuses on the applicability and effectiveness of the proposed pedagogical strategy. Future studies should run more technical tests to validate the study methodology. The study relied mainly on self-reported survey data and peer assessments, which may be subject to bias or social desirability effects. Therefore, larger-scale measures and analyses should be incorporated into future studies, such as longitudinal tracking of students' learning effectiveness and regression analyses to identify influential relationships among entrepreneurial leadership mindsets and sustainability competencies. Fourth, while the results are encouraging, the data were collected from students in a single course at a single institution, with a relatively small sample size ($N = 30$). Future studies should include schools from various geographic locations and students with various academic backgrounds to enhance the generalizability of the findings.

Students' Perspectives

Like with business and entrepreneurship skills, limited time and resources resulted in several instances of student-self learning being required for success in the term project. One such example was familiarization with individual LEED certification goals. It was the role of students themselves to determine which LEED criteria they were designing for, as well as eventual project certification evaluations, which were also completed by the design teams themselves. With more time and industry involvement, students may have had the opportunity to better understand not only the standards themselves, but also the iterative design process of designing, defending, and redesigning that is essential to sustainable design. Furthermore, the course had no built-in motivation for students to achieve regional or innovation credits, as those are much harder to self-verify, and not necessary to reach LEED Certification. The inclusion of more rigorous and rewarding pathways to achieving some of these points may have encouraged students to think more innovatively about their projects, and to develop a better understanding of the key roles of location selection and industry innovation in the sustainable design process, even those students who opted not to pursue such a path. This course is also relatively new. Because of this, there is no long-term basis for best practices or a tenured history of course review and revision. As this course continues to evolve through instructor learning, student feedback, and the continual development of sustainability education, the resources provided to participants and the project itself will continue to improve.

Conclusions

This study introduced a teaching strategy that combines sustainability skills with entrepreneurial leadership in construction management education. Using a project-based sustainable community design term project, the approach promoted systems thinking, teamwork across disciplines, and value creation. The results show that students gained a solid understanding of sustainability in environmental, social, and economic areas, while also building their entrepreneurial mindset, especially in making connections and creating value for communities. By working with real-world challenges and trade-offs, students improved their ability to handle complexity and apply sustainability in practical decisions. While this pilot study was limited to one course and a small group, it suggests that including entrepreneurial leadership in sustainability-focused construction education can help prepare students for the rapidly changing demands of the industry.

Reference

[1] M. Baek, H. Kim, R. Manuel, and S. Chang, "Assessing the Sustainability Skills Gap between Industry Needs and Academic Training in Construction Management," *CIB Conferences*, vol. 1, no. 1, June 2025, doi: 10.7771/3067-4883.1816.

[2] U. Iyer-Raniga and M. M. Andamon, "Transformative learning: innovating sustainability education in built environment," *International Journal of Sustainability in Higher Education*, vol. 17, no. 1, pp. 105–122, Jan. 2016, doi: 10.1108/IJSHE-09-2014-0121.

[3] M. Loosemore and A. McCallum, "The situational and individual determinants of entrepreneurship in the construction industry," *Engineering, Construction and Architectural Management*, vol. 29, no. 2, pp. 1038–1060, Apr. 2021, doi: 10.1108/ECAM-09-2019-0521.

[4] T. Puteri Fadzline, A. Juhary, and I. Nazaruddin, "Entrepreneurial Competencies and Networks in the Construction Industry," *International Journal of Applied Engineering Research*, vol. 12, no. 23, pp. 13374–13380, 2017.

[5] Kern Engineering Entrepreneurship Network (KEEN). *Entrepreneurial mindset 101*, 2017. Accessed from http://engineeringunleashed.com/keen/em101/

[6] A. Redman, A. Wiek, and M. Barth, "Current practice of assessing students' sustainability competencies: a review of tools," *Sustain Sci*, vol. 16, no. 1, pp. 117–135, Jan. 2021, doi: 10.1007/s11625-020-00855-1.

[7] K. Argyriou, M. Marinelli, and D. Melissas, "Exploring the Integration of Passive Design Strategies in LEED-Certified Buildings: Insights from the Greek Construction Sector," *Buildings*, vol. 15, no. 17, p. 3194, Jan. 2025, doi: 10.3390/buildings15173194.

[8] A. Redman and A. Wiek, "Competencies for Advancing Transformations Towards Sustainability," *Front. Educ.*, vol. 6, Nov. 2021, doi: 10.3389/feduc.2021.785163.

[9] K. Sposab and M. Rieckmann, "Development of Sustainability Competencies in Secondary School Education: A Scoping Literature Review," *Sustainability*, vol. 16, no. 23, p. 10228, Jan. 2024, doi: 10.3390/su162310228.

[10] B. Škrinjarić, "Competence-based approaches in organizational and individual context," *Humanit Soc Sci Commun*, vol. 9, no. 1, p. 28, Jan. 2022, doi: 10.1057/s41599-022-01047-1.

[11] A. J. Sulkowski, W. Kowalczyk, B. L. Ahrendsen, R. Kowalski, and E. Majewski, "Enhancing sustainability education through experiential learning of sustainability reporting," *International Journal of Sustainability in Higher Education*, vol. 21, no. 6, pp. 1233–1247, Aug. 2020, doi: 10.1108/IJSHE-06-2019-0185.

[12] M. Podgórska and I. Zdonek, “Interdisciplinary collaboration in higher education towards sustainable development,” *Sustainable Development*, vol. 32, no. 3, pp. 2085–2103, 2024, doi: 10.1002/sd.2765.

[13] V. Ratten, “Entrepreneurship: Definitions, opportunities, challenges, and future directions,” *Global Business and Organizational Excellence*, vol. 42, no. 5, pp. 79–90, 2023, doi: 10.1002/joe.22217.

[14] V. Barba-Sánchez, M. Mitre-Aranda, and J. del Brío-González, “The entrepreneurial intention of university students: An environmental perspective,” *European Research on Management and Business Economics*, vol. 28, no. 2, p. 100184, May 2022, doi: 10.1016/j.iedeen.2021.100184.

[15] X. Wang, S. Hasanzadeh, K. M. Short, C. M. Fiori, and K. S. Sands II, “A Pedagogical Framework for Enhancing the Entrepreneurial Leadership Mindsets of Construction Students: A Pilot Study,” *International Journal of Construction Education and Research*, vol. 20, no. 4, pp. 464–482, Oct. 2024, doi: 10.1080/15578771.2024.2404023.

[16] A. Huang-Saad, R. Schmedlen, R. Sulewski, and K. Springsteen, “Reconceptualizing BME Authentic Learning in the Age of COVID-19 and Remote Learning,” *Biomed Eng Education*, vol. 1, no. 1, pp. 55–59, Jan. 2021, doi: 10.1007/s43683-020-00013-0.

[17] E. J. Hall and E. M. Wagner, “Editorial: The Challenges and Opportunities of Sustainable Development for Entrepreneurship and Small Business,” *Journal of Small Business & Entrepreneurship*, Jan. 2012, Accessed: Dec. 19, 2025. [Online]. Available: https://www.tandfonline.com/doi/abs/10.1080/08276331.2012.10593581

[18] S. Haldar, “Towards a conceptual understanding of sustainability-driven entrepreneurship,” *Corporate Social Responsibility and Environmental Management*, vol. 26, no. 6, pp. 1157–1170, 2019, doi: 10.1002/csr.1763.

[19] V. Veleva, “The role of entrepreneurs in advancing sustainable lifestyles: Challenges, impacts, and future opportunities,” *Journal of Cleaner Production*, vol. 283, p. 124658, Feb. 2021, doi: 10.1016/j.jclepro.2020.124658.

[20] A. Bauman and C. Lucy, “Enhancing entrepreneurial education: Developing competencies for success,” *The International Journal of Management Education*, vol. 19, no. 1, p. 100293, Mar. 2021, doi: 10.1016/j.ijme.2019.03.005.

[21] B. Kotla and L. Bosman, “Redefining Sustainability and Entrepreneurship Teaching,” *Trends in Higher Education*, vol. 2, no. 3, pp. 498–513, Sept. 2023, doi: 10.3390/higheredu2030030.

[22] M. Fanea-Ivanovici and H. Baber, “Sustainability at Universities as a Determinant of Entrepreneurship for Sustainability,” *Sustainability*, vol. 14, no. 1, p. 454, Jan. 2022, doi: 10.3390/su14010454.

[23] M. Suguna *et al.*, “Entrepreneurial education and its role in fostering sustainable communities,” *Sci Rep*, vol. 14, no. 1, p. 7588, Mar. 2024, doi: 10.1038/s41598-024-57470-8.

[24] S. Adhikari, R. Zhang, K. Bedette, and C. Clevenger, “Sustainability Related Issues among Construction Students: Analyzing Through Source of Knowledge, Education Preparation and Future Aspiration,” presented at the ASC 2021. 57th Annual Associated Schools of Construction International Conference, pp. 635–625. doi: 10.29007/8cfs.

[25] D. Ismael, “Developing Entrepreneurial Mindsets in Construction Management through Experiential Projects,” presented at the 2025 ASEE Annual Conference & Exposition, June 2025. Accessed: Dec. 19, 2025. [Online]. Available: https://peer.asee.org/developing-entrepreneurial-mindsets-in-construction-management-through-experiential-projects

[26] P. Shekhar, “Engineering Entrepreneurship Program Participation: Differences Across Men and Women,” *IEEE Transactions on Education*, vol. 66, no. 2, pp. 188–196, Apr. 2023, doi: 10.1109/TE.2022.3208524.

[27] B. Sababha, A. Basal, E. Al-Qaralleh, and N. Daher, “Entrepreneurial mindset in engineering education,” *Journal of Entrepreneurship Education*, vol. 23, p. 14, Nov. 2020.

[28] B. Hassanpour, R. Alpar Atun, and S. Ghaderi, “From Words to Action: Incorporation of Sustainability in Architectural Education,” *Sustainability*, vol. 9, no. 10, p. 1790, Oct. 2017, doi: 10.3390/su9101790.

[29] P. Prus and M. Sikora, “The Impact of Transport Infrastructure on the Sustainable Development of the Region—Case Study,” *Agriculture*, vol. 11, no. 4, p. 279, Apr. 2021, doi: 10.3390/agriculture11040279.

[30] R. Taiwo, I. A. Shaban, and T. Zayed, “Development of sustainable water infrastructure: A proper understanding of water pipe failure,” *Journal of Cleaner Production*, vol. 398, p. 136653, Apr. 2023, doi: 10.1016/j.jclepro.2023.136653.

[31] K. Zhalmurziyeva, S. Tokbolat, S. Durdyev, M. Y. Mustafa, and F. Karaca, “Assessment of sustainability indicators for urban water infrastructure in a developing country,” *International Journal of Building Pathology and Adaptation*, vol. 42, no. 3, pp. 337–351, Nov. 2021, doi: 10.1108/IJBPA-09-2021-0121.

[32] M. Bagheri, N. Shirzadi, E. Bazdar, and C. A. Kennedy, “Optimal planning of hybrid renewable energy infrastructure for urban sustainability: Green Vancouver,” *Renewable and Sustainable Energy Reviews*, vol. 95, pp. 254–264, Nov. 2018, doi: 10.1016/j.rser.2018.07.037.

[33] J. Whitton, I. M. Parry, M. Akiyoshi, and W. Lawless, “Conceptualizing a social sustainability framework for energy infrastructure decisions,” *Energy Research & Social Science*, vol. 8, pp. 127–138, July 2015, doi: 10.1016/j.erss.2015.05.010.

[34] P. A. Jayasinghe, S. Derrible, and L. Kattan, “Interdependencies between Urban Transport, Water, and Solid Waste Infrastructure Systems,” *Infrastructures*, vol. 8, no. 4, p. 76, Apr. 2023, doi: 10.3390/infrastructures8040076.

[35] F. G. Renaud, X. Zhou, L. Bosher, B. Barrett, and S. Huang, "Synergies and trade-offs between sustainable development goals and targets: innovative approaches and new perspectives," *Sustain Sci*, vol. 17, no. 4, pp. 1317–1322, July 2022, doi: 10.1007/s11625-022-01209-9.

[36] S. Pollalis, *Planning Sustainable Cities: An infrastructure-based approach*. New York: Routledge, 2016. doi: 10.4324/9781315642352.

[37] M. K. Watson, R. Lozano, C. Noyes, and M. Rodgers, "Assessing curricula contribution to sustainability more holistically: Experiences from the integration of curricula assessment and students' perceptions at the Georgia Institute of Technology," *Journal of Cleaner Production*, vol. 61, pp. 106–116, Dec. 2013, doi: 10.1016/j.jclepro.2013.09.010.

[38] H. Li, Y. Xiong, C. V. Hunter, X. Guo, and R. Tywoniw, "Does peer assessment promote student learning? A meta-analysis," *Assessment & Evaluation in Higher Education*, vol. 45, no. 2, pp. 193–211, Feb. 2020, doi: 10.1080/02602938.2019.1620679.

[39] D. Weaver and A. Esposto, "Peer assessment as a method of improving student engagement," *Assessment & Evaluation in Higher Education*, vol. 37, no. 7, pp. 805–816, Nov. 2012, doi: 10.1080/02602938.2011.576309.

[40] USGBC, LEED Reference Guide for Building Design and Construction, USGBC, Washington, DC ,2009.

[41] M. K. Watson, E. Barrella, C. M. Cowan, and R. D. Anderson, "Validating a Sustainable Design Rubric by Surveying Engineering Educators," presented at the 2018 ASEE Annual Conference & Exposition, Jun. 2018. Accessed: Jan. 20, 2022. [Online]. Available: https://peer.asee.org/validating-a-sustainable-design-rubric-by-surveying-engineering-educators

[42] J. S. London, J. M. Bekki, S. R. Brunhaver, A. R. Carberry, and A. F. McKenna, "A Framework for Entrepreneurial Mindsets and Behaviors in Undergraduate Engineering Students: Operationalizing the Kern Family Foundation's '3Cs,'" *Advances in Engineering Education*, vol. 7, no. 1, 2018, Accessed: Dec. 31, 2025. [Online]. Available: https://eric.ed.gov/?id=EJ1199586