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Sustainability and Resilience Education Framework for Interdisciplinary Course Development

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Climate change has redirected the global focus towards creating a more sustainable and resilient built environment. As natural disasters have been occurring at a higher frequency, buildings and infrastructure systems need to be prepared to withstand the more disastrous events. Furthermore, with an increase in the world's population and the shortage of resources in various parts of the world, it is necessary to think about sustainability and resilience in conjunction with every aspect of the built environment, including the Architecture, Engineering, and Construction (AEC) education. Therefore, this research study proposes a unique sustainability and resilience educational course structure that improves the understanding of these concepts in the built environment. This research study introduces a framework that can act as a guideline for sustainability and resilience education integration within various courses across any college campus to further the awareness about sustainability and resilience. The study introduces the course structure and development methods in creating new, flexible, and innovative modules that can be customized to the different educational needs and cover several student learning outcomes which can help prepare the new generations to become conceptually, spatially, and temporally aware while they interact and develop the built environment of the future.

Key Words: Sustainability, Resilience, Interdisciplinary Education, Multidisciplinary

Introduction and Background

Challenges such as climate change, increased natural disasters frequency, and income inequality, and other global issues, have compelled the AEC industry to promote, implement and improve sustainability and resilience practices adopted in various building and infrastructure projects. Effective sustainable development improves the three pillars in our built environment: environmental sustainability, social equity, and economic development. However, any sustainable approach is an empty gesture without ensuring a strong resilience adoption. Through resilience, the built environment can overcome natural and man-made disasters and disruptive events to continue its sustainable development. With the current national and global challenges, sustainability and resilience education is imperative for the next generation to develop a sustainable future.

It is essential that educators utilize engaging approach to facilitate active participation from students which can assist with understanding the concepts in a systematic manner. Murray and Cotgrave (2007), in an earlier study, found the presence of policy drivers essential to incorporating sustainability in educational modules across different areas. Although this seemed easily achievable, academia's participation was sparse. Wang (2009) observed the need to develop a standardized course structure focusing on sustainability for construction management students. Wang's study proposed various sustainability topics such as health, atmosphere, ecosystem, energy, land consumption, erosion, and materials, and gathered students' feedback for continuous curriculum improvement. Enhanced collaboration between academia, industry, and researchers is needed to further sustainability curriculum development (Wang, 2009). In addition to the inclusion of sustainability concepts through structured coursework, suggested that existing courses should assimilate these concepts to improve sustainability education in existing coursework (Lim et al., 2015).

Amaratunga et al. (2018) interviewed 87 stakeholders and detailed several key knowledge areas for resilience education namely, legal frameworks, disaster response, contracts, resilience technologies, engineering, knowledge management, social and cultural awareness, sustainability and resilience, ethics, human rights, financing mechanisms, stakeholder approaches, post-disaster project management, and hazard risk assessment. Educating current and future students about disaster resilience is essential to provide them with the necessary skills to initiate positive changes and respond effectively to disaster events (Dufty, 2021). Adhikari et al. (2020) conducted a survey of higher education students on their source and level of knowledge of various disasters and determined that university-level education needs to be improved to be aware of and prepared for future disaster response education.

Some examples on the national level discussed here inform about the need for a comprehensive sustainability and resilience education. The University of Colorado-Boulder offers a "Sustainability and Resilience in Practice" course (ENVM 5041) wherein decision-making strategies supplemented with community engagement are discussed. The University of Washington also offers a "Sustainability, Resilience, and Society" online course which includes five modules that address the broader concepts of sustainability and some resilience aspects. However, both courses do not comprehensively address the sustainability and resilience dimensions. The Sustainability and Resilience course (INPR 2183) at the Northeastern University is more comprehensive in addressing the sustainability and resilience dimensions yet it does not connect the overarching goal of sustainability and resilience (Northeastern University, 2022).

Though some universities and organizations offer courses that capture siloed aspects of resilience and sustainability, seldom does a course capture the sustainability and resilience of the built environment from multiple perspectives while incorporating project-based concepts learning and application approach. This research proposes a novel and simple approach to create a sustainability and resilience coursework with the flexibility to fully or partially integrate into different course modules through a universal toolkit.

Research Study Main Objective and Novelty

Most courses offer a siloed representation of concepts without relaying the interdependent nature of systems and disciplines in a more practical and detailed approach. As discussed previously, sustainability cannot continue without resilience. Therefore, understanding the interconnectivity between these concepts and between the components of the built environment will help elevate the students' comprehension of the concepts and provide a depth of learning. This paper also proposes creating a universal toolkit to widen knowledge sharing across university campuses. To educate a

more diverse student population and build effective leaders who can advocate for sustainability and resilience, this paper emphasizes the importance of a multidisciplinary effort to develop more comprehensive sustainability and resilience coursework with some flexible and practical modules which can be shared and implemented across multiple disciplines.

Course Structure and Development Methodology

This paper focuses on developing collaborative, campus-wide sustainability and resilience promotion and adoption. This section will outline the framework structure of an interdisciplinary course and the course development process. Reference Figure 1.

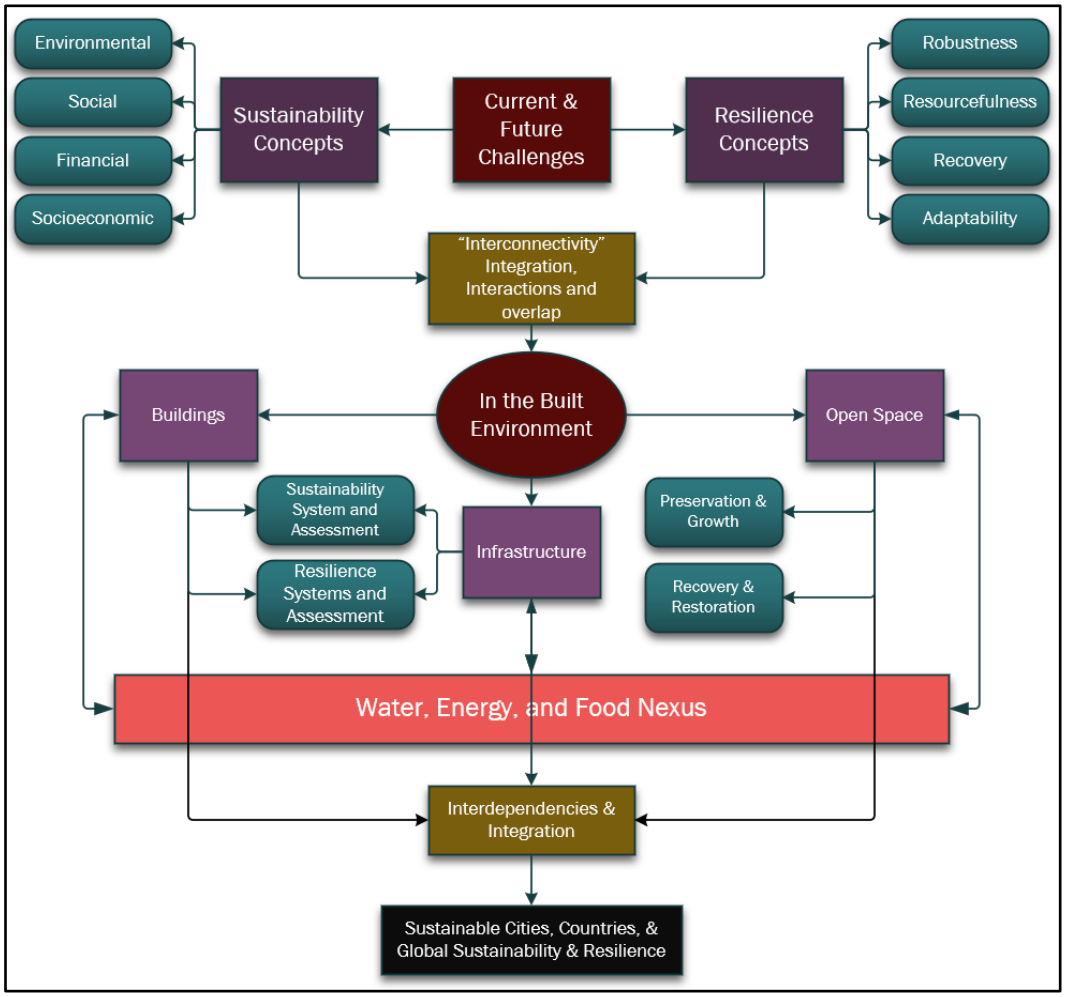

Figure 1 - Course Structure Flowchart

Current challenges, such as climate change and economic inequity, and future challenges, such as food and water security will inform students about the current local, national, and global challenges which is the motivation to understand the concept of sustainable and resilient development. Although, this is not part of the course structure, it is highly advisable that the coursework include these challenges, maybe in the form of a module, as the main introduction to this course which serves as the justification and the purpose of taking these types of modules whether it is a standalone course or several modules in different courses.

As shown in figure 1, the course structure can be divided into 2 phases. The first phase will focus on the sustainability and resilience concepts and their interconnectivity while the second phase will educate the students about how that interaction occurs within the built environment systems (Buildings, open space, and infrastructure).
During the first phase, sustainability and resilience are broken down into their respective dimensions and the interaction of both these concepts will be discussed by studying real-world examples. For example, while constructing a highway, it is imperative to consider the impacts of various natural and man-made disasters which could be experienced throughout the life cycle of the highway project, thus making it more resilient. Meanwhile, it is also important to adopt sustainable strategies such as using materials which have low embodied energy. This can facilitate the reduction of greenhouse gas emissions which can help to control some of the impacts of climate change.
After the interrelationship and importance is established, the second phase will teach students about how the built environment components and interact, and the affect these interactions have to balance sustainability and resilience issues. The integration of food, energy, and water nexus is introduced hereafter, to understand how these different systems interact with the center of basic global livelihood while maintaining a sustainable and resilient future. The final focus of this proposed course will discuss the national and global-level sustainable development and improvement practices.

In addition to a vision outlining the intended course structure, input and feedback from experienced academics and industry professionals is crucial to develop a well-rounded interdisciplinary course structure. The course development process as shown in Figure 2 provides a roadmap for the creation of such interdisciplinary modules.

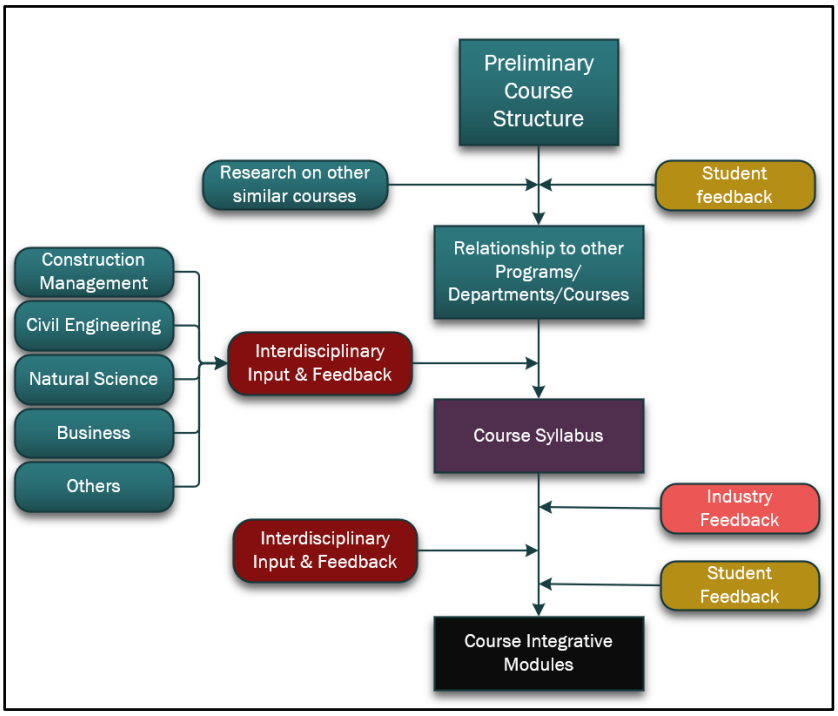

Figure 2 - Course Development Flowchart

The course development process in Figure 2 begins with extensively researching existing courses that address sustainability within the university system such as in the department of natural sciences, ecosystem sciences, construction management, civil engineering, and business among several others. Some global examples include, but are not limited to, Green labs to promote sustainability research course in Harvard (Harvard University, 2021), Co-creating sustainable cities course by TU Delft (TU Delft, 2021), HELSUS co-creation lab at University of Helsinki (Helsinki Institute of Sustainability Science, 2021). Student feedback from former and currently enrolled students (undergraduate and graduate levels) should be sought regarding their opinion of the course content and experience. Second, the course developers should also engage different faculty from the aforementioned schools and departments (if they are available within the university system) to create a diverse interdisciplinary curriculum that can be branched into different modules that are beneficial to different disciplines and courses within those different departments/schools. Finally, thereafter, to ensure practical validation and address current issues, industry and community and campus leaders should also be engaged to provide input and feedback to establish applied and practical sustainability course modules. The tri-level feedback from industry, interdisciplinary faculty, and students can act as a final validation phase to ensure the buy-in from the different stakeholders that can be engaged or benefitting from such course or curriculum modules.

Coursework Integration

In order to have a practical application for such a coursework or curriculum modules, they have to be integrable in different curriculums or courses, offered in an incentivized manner and have the ability

to achieve several student learning outcomes (SLOs). The section below will discuss the incentivization process in course offering while being integrated across different curriculums in a universal toolkit model and will also provide an example of addressing several SLOs.

Universal Toolkit Preparation

To develop a universal toolkit as a guidance document for faculty around the campus, and incentivize the course offering, there are three proposed approaches based on the developers' capabilities and resources – (i) in-person and online delivery, (ii) free first module, and (iii) integration fluency of course modules. The proposed course can be more attractive if it is offered in-person and all the lectures were recorded which is a trend that is noted before and after the pandemic experience. The first module of the course can be made available for free, accessible to everyone with internet access, which can pique the interest of different on-campus and online students as well in further pursuing these courses after learning about their potential educational and practical pedigree. This first module will contain an overview of current and future challenges in the society, supplemented by real-world examples, that will identify the need for sustainable and resilient development which should incentivize students to enroll full-time. All course modules should have the ability to be easily merged and adopted within existing courses (e.g. Sustainable practice, design, & construction, Ecological engineering, Ecosystem ecology, Economics of ecosystems and biodiversity, etc.) based on the earlier involvement of the different faculty across the multiple disciplines. Interdisciplinary partners (through input and feedback) will be engaged to encourage adoption of the proposed course's module(s) while a supplemental list of steps and best practices can be made available on the course website for any faculty who would like to incorporate any module(s) into their courses.

Example of Curriculum/Course Modules and SLOs

This section provides a summarized and simplified example of course/curriculum modules which can be utilized and customized based on the developers' capabilities, resources, and educational offerings and concentrations. Table 1 presents general modules example which was also inspired by the course structure introduced in Figure 1. Table 1 serves as one of the many examples of a general course curriculum that can be generated using the course structure and course development methodology introduced in this paper. However, this can be customized towards the need and the capabilities of the educational entity that is trying to implement such as a curriculum or coursework. Therefore, Table 1 is intentionally very generic in nature in order to encompass as many disciplines as possible across a campus university system and maybe also across different universities which are willing to collaborate on creating a comprehensive national or global curriculum or coursework. Table 1 introduces eight different modules and the general intent of the modules.

Table 1

Modules example for general course/curriculum application

	Module General Topics	**Intent**
1	Introduction to sustainability and Resilience Challenges	Understand the national and global challenges (e.g., energy, water scarcity, and climate change, etc.) and how sustainability and resilience application can help in providing practical long-term solutions

2	Sustainability Concepts	Understand the triple bottom line of sustainability (Enviro., Social, Economic) in addition to sustainable institutional policies.
3	Resilience Concepts	Understand the disaster and hazards resilience paradigm including system robustness, resourcefulness, recovery, and adaptability.
4	Sustainability and Resilience interconnectivity	Understand the interrelation between the two concepts and how resilience is essential to achieve sustainable development
5	Built Environment Systems integration	Understand the built environment's main components (Buildings, Infrastructure, and Open space) and the interdependencies between these systems.
6	Sustainability and Resilience Assessment and Application in the Built Environment systems	Understand how to assess qualitatively or quantitatively the sustainability and resilience on the micro (system component) and macro levels (System of systems) within the built environment.
7	Food, Energy, and Water (FEW) Nexus	Understand the broad concept of FEW nexus, its tradeoffs and impacts, and how socioeconomic resilience and sustainability can affect its paradigm.
8	National and Universal/Global Applications and case studies	Apply sustainable and resilience assessment and solutions on national and global case studies and examples

The modules described in Table 1 can have different content depending on the educational settings where they will be taught. For example, in the case of construction engineering and management, sustainability and resiliency modules will focus on building strategies that can achieve sustainability and resilience in buildings or infrastructure systems, civil and structural engineering can address the resiliency concepts from structural robustness and adaptability over time. However, these modules should (to the best of the course developers' ability) embody as much interdisciplinary collaboration and knowledge interchange as possible in order to maximize the educational benefit to the most diverse population as possible.

Student Learning Outcomes SLOs:

Student learning outcomes can vary across the different disciplines according to the accreditation bodies that departments or schools are associated with. However, this section will use a couple of familiar accreditation student learning outcomes as an example represented by the ACCE and ABET as a quick brief example (ABET, 2021; ACCE, 2021).

ACCE SLOs examples: Aside from SLOs 1 "Create written communications appropriate to the construction discipline" and SLO 2 "Create oral presentations appropriate to the construction discipline" which can be easily achieved through assignments or projects across the different modules, the following are several examples within the AEC educational ACCE SLOs.

- ***SLO 6 – "Analyze professional decisions based on ethical principles"***: In a sustainability and resilience-focused curriculum, this SLO can be applied within the conceptual and planning phase when making professional decisions regarding project siting and its impacts (positive or negative) on vulnerable/disadvantage communities based on project-based assessment analysis in ***module 6*** as an example.

- ***SLO 7 – "Analyze construction documents for planning and management of construction processes"***: This SLO can be addressed while analyzing the different sustainable and resilient strategies for application in different systems (buildings or infrastructure) in module ***6*** as an example.
- ***SLO 9 – "Apply construction management skills as an effective member of a multi-disciplinary team"***: This SLO can be easily achieved if the students are interacting within a multidisciplinary team in ***module 8*** as an example.
- ***SLO 13 – "Understand construction risk management"***: This SLO can be addressed in a detailed manner (beyond "understanding" cognition level), especially in the resilience concept ***module 3*** where students learn and understand the concept of system construction robustness which is directly related to risk and vulnerability assessment.
- ***SLO 18 – "Understand the basic principles of sustainable construction"***: This SLO is directly related to the content that can be taught under ***module 2*** and beyond throughout the course/curriculum.

ABET SLOs examples: SLO 7 "ability to acquire and apply new knowledge as needed, using appropriate learning strategies" is directly addressed by all the modules as each module is meant to have a conceptual and an implementation portion. This is to ensure that the students learn the concept and can apply the same to a real-world problem. Following are some more examples of the ABET SLOs being reflected in the proposed course modules:

- ***SLO 1 – "Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics"***. ***Module 6*** directly addresses this SLO as the students will have an opportunity to learn about the assessment of sustainability and resilience and its application to real construction projects.
- ***SLO 3 – "Ability to communicate effectively with a range of audiences"***. This SLO can be achieved through ***modules 7 and 8*** wherein students will have an opportunity to understand and implement the concepts at the national and global levels.
- ***SLO 5 – "Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives"***. This is similar to ACCE SLO 9.
- ***SLO 7 – "Ability to acquire and apply new knowledge as needed, using appropriate learning strategies"***. This SLO can directly addressed across several modules such as ***modules 6 and 8***.

Conclusion

This research intended to create a standardized framework for integrated sustainability and resilience coursework to help the students to develop a better understanding of the built environment and the necessary concepts required for its sustenance. This research also proposes the creation of a universal sustainability toolkit that could facilitate the integration of all (or portion) of the course modules in multiple courses across diverse types of higher educational entities. The outcomes of this research can help in developing a comprehensive understanding of sustainability and resilience among the students, and how they are incorporated within the built environment. The most recent COP26 conference detailed the importance of creating resilient and sustainable cities as the severe effects of climate change are noticeably affecting by countries, worldwide. Implementing concepts presented in this paper in university undergraduate and graduate curricula can empower the next generation of the AEC industry towards building a more sustainable and resilient built environment. Providing the students with the necessary tools and expertise in the area of resilience and sustainability will produce

individuals who are capable of influencing national and global policies. Lastly, the connection of the broader course modules to the ACCE and ABET SLOs will enable faculty to catalog and track the outcomes of the course over a period of time and improve its effectiveness.

The limitations of this proposed educational coursework relate to the available resources within a certain educational institution. For example, a lack of expertise in the area of sustainability and resilience can hinder the adoption of course modules and further development. The absence of graduate schools in many educational institutions may impede the application of the proposed concepts to a real-world problem through a research-oriented solution. Another limitation stems from a lack of industry support to facilitate the learning of these concepts and their application. To provide resiliency against these limitations, the proposed coursework is not a "go, no-go approach", rather it is an effort that can be shaped to suit the educational entity's capabilities and resources.

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