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An Analysis of Sustainability within Construction and Civil Engineering Curriculum

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Sustainability is crucial for minimizing environmental impact, ensuring the responsible use of resources, and creating resilient and socially conscious spaces that contribute to harmonious coexistence between the natural, built, and social environments. Because sustainability principles are embedded across the full life cycle of the built environment, sustainability should be an integral part of construction and civil engineering-based curriculum. This research performed an analysis of construction and civil engineering program curriculum to explore where sustainability is being taught, what types of content have been developed, and how prominent a role it plays across the curriculum. The results showed that although generally acknowledged in program descriptions as a prominent industry practice, many programs do not explicitly acknowledge sustainability within course titles or descriptions. Other institutions generally use it as a coupled descriptor for other key built environment topics, such as materials or infrastructure. Programs that seem to have most effectively incorporated sustainability have made a deliberate effort to emphasize it beyond just trendy terminology. This paper identifies trends in sustainability education and provides examples of how programs explicitly focus on sustainability. The results of this research can help generate ideas for strengthening sustainability education within built environment-based curriculum.

Key Words: Sustainability, Construction Education, Civil Engineering Education, Curriculum

Introduction

Sustainability is an important topic within the built environment because of the growing challenges centered around the processes of planning, design, construction, and operation of the infrastructure and buildings necessary for society to function. Key challenges include environmental impact, resource consumption, climate change mitigation, longevity, and resilience to natural disasters (Mohammadi & Jimenez, 2022). Sustainability related issues affect the full life-cycle spectrum of the built environment, creating intertwined interdisciplinary challenges that span the natural, built, and social environments. In addition to environmental challenges, sustainability requires balancing social and economic related constraints by doing the right projects and doing them right (ASCE, 2023). To achieve this vision, it is essential that sustainability continue to play a more prominent role in industry

practice. Therefore, it is equally important that sustainability principles are an integral part of construction and civil engineering-based curriculum in educating the next generation of built environment professionals. Although the call for strengthening sustainability within higher education is not new, it is not known how well sustainability has been incorporated within civil engineering and construction curriculum. This research was initiated to analyze construction and civil engineering curriculum to address the following three research questions: 1) Where is sustainability being taught within the curriculum? 2) What types of sustainability specific content have been developed? 3) How prominent a role does sustainability play across the curriculum?

Literature Review

Sustainability is slowly permeating the values, policies, and practices of government, business, and education (Cullingford & Blewitt, 2013). Unfortunately, there is disagreement in defining what it means and confusion regarding how it should be used, because the “*notion of sustainability... has become a cliché*” (Cullingford & Blewitt, 2013, p. 17). Still, much has been written about its importance and how it ought to be integrated within higher education curriculum. Lengyel (2019) discussed the need for authentic sustainability curriculum within all higher education disciplines and stressed the importance of students learning sustainability literacy and valuing nature and fellow humans. One author emphasized this urgency by indicating that “*society cannot wait for universities to establish integrated programs of sustainability – and neither can the planet*” (Stubbs, 2011, p. 265). Gaard (2017) identified barriers to implementing sustainability within higher education curriculum, including reliance on faculty volunteers, unclear and unenforced expectations, challenges with establishing an interdisciplinary approach, and conceiving sustainability education as transmission of knowledge rather than transformation of thought. Cotgrave & Kokkarinen (2011) further emphasized that academic staff often lack the willingness to develop the required knowledge or spend the time to prepare materials regarding sustainability. The literature clearly indicates that not only is sustainability education important, but that there are challenges to doing so effectively.

A great deal of literature focuses on teaching sustainability broadly across higher education, including construction and engineering applications. Wang (2009) identified key sustainability-related topics that should be incorporated into construction-based curriculum, including atmosphere, ecosystems, land consumption, water quantity and quality, energy, materials, waste, erosion, energy, lifecycle cost, community, and health. These include aspects associated with the ‘triple bottom line’ concept. Tan et al. (2017) demonstrated that students value sustainability in construction related curriculum. Unfortunately, Jung (2019) identified that our current methods for delivering sustainability content have a limited effect on motivating student’s environmental attitude and behaviors. Rather, more focus is needed on incorporating general sustainability principles and ethical concepts coupled with domain specific knowledge and its implementation in the construction industry. In short, a better way of incorporating sustainability within the curriculum is needed, to inspire graduates to become better stewards of the environment and create positive social impact (Jung, 2019).

As construction curriculum has evolved to include more sustainability, a common focus has been on teaching green building strategies associated with the design, construction, and operation of built environments and indoor environmental quality (Jung, 2019). Cullingford & Blewitt (2013) described two principal ways that sustainability evolution has occurred within architecture-specific curriculum: a general “greening” of traditional coursework and the addition of a few sustainability-related design courses. While this latter evolution seems to make sense for a design-based curriculum, the former approach seems to more adequately represent the evolution that is most commonly described within construction specific literature. Cotgrave & Kokkarinen (2010) proposed a model for developing sustainability literacy in construction curriculum design, including defining specific sustainability-

based learning outcomes, using a project-based approach, and simply ensuring that sustainability issues are integrated throughout the program. Clevenger & Ozbek (2013a) further proposed that a service-learning course can be an effective way of teaching sustainability in construction education. Because of the unique nature of this latter approach, students not only become familiar with sustainability concepts, but also gain a greater understanding of interconnectedness, long-term foresighted thinking, stakeholder engagement, and group collaboration (Clevenger & Ozbek, 2013a). The literature demonstrates that effective sustainability education seems to require a stronger approach than simply sprinkling sustainability related content throughout the curriculum.

There is a strong presence of literature recommending that sustainability education requires a stronger sense of interdisciplinarity (Gaard et al., 2017; Cullingford & Blewitt, 2013, Woo et al., 2012). O'Byrne et al. (2015) explored sustainability specific degree programs and found that, although they generally showed a high degree of disciplinary variety, there was surprisingly little curricular coherence between them. This occurs because there is not a core set of subjects universally recognized as essential to teaching sustainability (O'Byrne et al., 2015). This can be problematic since the individual application of sustainability principles is heavily rooted in many disciplines. Bacon et al. (2011, p. 205) indicated that integrating engineering with social and ecological sciences helps students establish a contextual understanding of "*sustainability citizenship in a global world.*" Chau (2007) further indicated that because civil engineering is a key profession for incorporating sustainability into society, pedagogical frameworks of sustainability must therefore utilize a multidisciplinary analysis. Unfortunately, sustainability is all too commonly introduced in a generic manner that leads to siloed thinking. Built environment-based sustainability topics (e.g., environmental policy, ethics, resource efficiency, life cycle assessment, etc.) all warrant a multidisciplinary approach (Chau, 2007).

Another subset of literature has explored how sustainability should be incorporated within the curriculum, whether integrated into core course offerings or as stand-alone courses (Stubbs & Schapper, 2011) Thurer et al. (2018, p. 614) acknowledged that although many engineering schools have incorporated sustainability to some degree within their curricula, it has often been done in a "*piecemeal fashion*" that doesn't actually reorient the institution towards sustainability. Cullingford & Blewitt (2013, p. 58) proposed that effectively integrating sustainability into higher education means shifting from "*transmissive learning to learning through discovery, from a teacher-centered approach to a learner-centered approach, from individual learning to collaborative learning, from learning dominated by theory to praxis-oriented learning linking theory and experience, and from focus on accumulating knowledge and content orientation to focus on self-regulative learning and a real issues orientation.*" Kelly (2021) further proposed shifting away from simply learning about sustainability (an accommodative approach) to reconceptualizing to capacity-building learning (a transformative approach). Dmochowski et al. (2016) suggested that this is accomplished as programs "*think deeply about their courses and how they relate to sustainability, create or revise courses, and collaborate with one another regarding best teaching practices.*" Programs should therefore evaluate how sustainability fits within their curriculum (Dmochowski et al., 2016; Thurer et al., 2018; Woo et al., 2012), focusing on graduate attributes, learning outcome alignment, and pedagogy and assessment strategies (Kelly, 2021). Integration of sustainability across the curriculum is significantly more important than creating individual courses (Jung et al., 2019; Hayles & Holsworth, 2008). Lin et al. (2015) indicated that construction students prefer incorporation of sustainability topics throughout a course rather than being presented as individual topics. In addition to integrating sustainability practices within frameworks of existing curriculum, faculty should further consider how elective courses can contribute to the overall sustainability program (Sullivan & Walters, 2013).

To achieve more interdisciplinarity within sustainability education, programs should identify how various disciplines across campus contribute to the comprehensive discussions of sustainability

(Dmochowski et al., 2016; Hayles & Holdsworth, 2008) and get industry feedback regarding curriculum development (Thurer et al., 2018; Wang, 2009; Cotgrave & Kokkarinen, 2010). Abd-Elwahed & Al-Bahi (2021) denoted that sustainability concepts must become part of the student culture, and not merely imposed as a necessary design standard. This holistic interdisciplinarity lends itself well to project-based learning (Chau, 2007), especially through senior and capstone type projects (Abd-Elwahed & Al-Bahi, 2021). To validate the effectiveness of sustainability efforts, educators should perform comprehensive course analyses that focus on pedagogical design, teaching resources and materials, and curriculum and program assessment (Zhang et al., 2016). This comprehensive approach to sustainability should be rooted in helping students build an ethical foundation (Lengyel et al., 2019) promoting ethical thinking in sustainability decision making (Biedenweg et al., 2013). This broader approach further ensures that programs adequately account for the social aspects of sustainability (Kordi et al., 2020; Stubbs & Schapper, 2011). Courses that naturally develop social sustainability include service learning (Clevenger & Ozbek, 2013b), introductory courses, and culminating capstone courses (Valdes-Vasquez & Klotz, 2011).

In summary, sustainability is an essential part of construction education, should be rooted in multi-disciplinary perspectives, and is most effective when incorporated throughout the entire curriculum. Although all faculty should be involved in integrating sustainability into the curriculum (Stubbs & Schapper, 2011), only a small number of academic staff need to be fully knowledgeable in sustainability to positively affect overall program attitudes and abilities (Cotgrave & Kokkarinen, 2011). Although the literature provides a good overview of the need for sustainability education and how it should be incorporated, the literature does not indicate how effectively construction education as a whole is doing. The purpose of this paper is to explore how sustainability is currently incorporated within construction and civil engineering curriculum.

Methodology

This research utilized a cross-sectional approach for investigating the use of sustainability within construction and civil engineering curriculum. Accreditation information was utilized to identify 307 different construction management, construction engineering, and civil engineering bachelor degree granting programs located throughout the United States. It should be noted that some universities had multiple programs. Three general sources of information were utilized for investigating the curriculum associated with each program: 1) course titles, 2) course descriptions, and 3) overall program descriptions. Identifying explicit use of the words “sustainability” or “sustainable” was the initial thrust of the investigation, although other key words including “LEED” and “green” were also added to the investigation after recognizing that other sustainability related terminology was sometimes used in these contexts without explicitly using the term sustainability. A student researcher gathered the necessary data from university websites over several weeks during the Fall of 2022. Simple descriptive statistics and a broader qualitative analysis of the use of sustainability-based terms in these contexts was then performed to address the research questions.

The researchers acknowledge that it is likely that sustainability-related content is incorporated within the curriculum in all programs, without being explicitly acknowledged in course titles and descriptions. However, the point of this research was to investigate the prominence that sustainability has within built environment-based curriculum. Given this context, the researchers were able to investigate how programs utilize the term sustainability within course titles and descriptions, and to what extent sustainability is emphasized within their curriculum. The research detailed within this paper is merely a starting point for truly addressing the research questions. Although the approach used in this research provides some interesting insights, a more thorough investigation of program curriculum, including achievement of sustainability-based learning outcomes is recommended.

Results

Out of the 307 different programs investigated, 126 did not contain any explicit indication of sustainability within the course titles or descriptions for their respective curriculum. In some cases, there was general language within the program descriptions that indicated that sustainability is something that students are prepared for within the educational components of the program. However, it seems that sustainability is playing a lesser role within the overall educational scheme, since it is not explicitly acknowledged in course titles, descriptions, or even program outcomes. Although there is most likely some level of sustainability embedded within the curriculum, in a little more than a third of the programs, sustainability does not appear to play a very prominent role.

Construction Management Curriculum Examples

There are strong examples of sustainability specific courses within construction management curriculum. Construction management and construction engineering programs were significantly more likely to have these types of courses than civil engineering programs. This is likely the result of accreditation requirements requiring students to become familiar with sustainability principles. This seems to lead to stronger outcome-based demonstration of sustainability learning. Typical examples of courses with a strong sustainability focus as well as those with minor integration include:

Sustainability Specific Courses

- Ex. 1 - Title: *Green Building and Building Science*. Description: “*This course is a study in the concepts of green building and building sciences, which includes alternative building techniques designed to allow building practices that result in energy efficient, healthier, and economically sustainable buildings. Students will learn about alternative sources of heating and cooling, electricity, water efficiency, and alternative building materials... Course content also includes study of energy efficiency rating systems such as LEED and its impact on the current construction industry.*”
- Ex. 2 - Title: *Sustainable Construction*. Description: “*Introduces current green building technologies and practices, LEED and NAHB green building guidelines. Examines the environmental impact of the building industry and strategies for mitigating environmental impacts by the use of green technologies.*”
- Ex. 3 - Title: *Sustainable Built Environment*. Description: “*This course presents how sustainable construction materials and methods contribute to meeting the needs of the present without compromising the ability of future generations to meet their own needs; identifies and analyzes those international, national and local programs promoting sustainable construction; characterizes the components of successful sustainable construction projects; analyzes design as well as construction aspects of Green Building and LEED certification; identifies project strategies to achieve LEED certification; explores industrial ecology; and reviews construction environment impact studies.*”

Minor Sustainability Integration

- Ex. 1 - Title: *Building Construction Lab*. Description: “*Students will explore career paths in the construction industry which may include commercial construction, green building, small business ownership, and more.*”
- Ex. 2 - Title: *Framing*. Description: “*The course includes terminology and identification of components involved with types of construction, floor and wall frames and green building products used with these systems.*”

- Ex. 3 - Title: *Masonry*. Description: "... *LEED and green concepts will be introduced in this course as they pertain to masonry.*"

Civil Engineering Curriculum Examples

Civil Engineering programs were less likely to have sustainability related curriculum appearing to cover the topic with any semblance of depth. More often than not, the term sustainability seemed to be more commonly used in a generic manner. There were a few examples of sustainability specific courses within civil engineering curriculum. Although the concept of sustainability is integrated within one of the civil engineering accreditation criteria, it seems to play a more minor role within overall curriculum focus. It also appears that the term sustainability is commonly used as a general descriptor for other aspects of civil engineering, such as materials or infrastructure. It also appears to be more commonly integrated within other core engineering topics, such as environmentally friendly roadway design. Typical examples of courses with a stronger sustainability focus as well as those with minor integration include:

Sustainability Specific Courses

- Ex. 1 - Title: *Infrastructure Project Impacts, Policy and Sustainability*. Description: "*Evaluation of infrastructure impacts. Impacts regulation and mitigation. Effects of environmental and other policies on infrastructure. Infrastructure relations to sustainability. Energy consumption, transportation efficiency and infrastructure recycling.*"
- Ex. 2 - Title: *Principles of Sustainability Analysis*. Description: "*Key principles of sustainability and its analysis. Quantification of environmental impact/assessment using target plots, mass/energy balances, and life cycle analyses (cradle to gate/grave) applied to products, processes, or systems.*"
- Ex. 3 - Title: *Introduction to Sustainable Infrastructure*. Description: "*History and future of civil infrastructure; engineering problem solving; environmental sustainability and life-cycle assessment; social sustainability; engineering economics; problem-driven, sustainability-focused case studies related to different aspects of civil infrastructure.*"

Minor Sustainability Integration

- Ex. 1 - Title: *Engineering Materials for Sustainability*. Description: "*Environmental impact of materials; life-cycle assessment; material selection to optimize performance; design, evaluation, and production of green construction materials.*"
- Ex. 2 - Title: *Masonry and Wood Design*. Description: "*Introduction to masonry and wood terminology and materials as well as ASTM-related specifications... Introduction to prestressed masonry. Connection design. Sustainability and energy efficiency, fire rating, and cost analysis.*"
- Ex. 3 - Title: *Introduction to Transportation Engineering*. Description: "... *Sustainability issues and environmental impact of transportation systems with focus on urban design, planning and regulation.*"

Sustainability Curriculum Trends

The focus of this research was to explore the prominence of sustainability within curriculum. Given the importance of the topic, it was assumed that programs with a strong emphasis on incorporating sustainability within their curriculum, whether as singular courses or integrated throughout the curriculum, would have some degree of explicit indication. There were several observable trends associated with the prominence of sustainability within the curriculum, including the following:

- Sustainability curriculum occurs in lower division, upper division, and graduate coursework. Integration at the lower division typically occurs in conjunction with introductory courses or as a descriptor of some other aspect of the discipline (such as sustainable materials). It is significantly more common that true sustainability courses, introducing theory, design, and/or application, appear at the upper division or graduate level.
- Most institutions only have a single course explicitly associated with sustainability. However, there are several programs with multiple sustainability-related courses, demonstrating a deliberate emphasis on integrating sustainability as a cultural element.
- LEED is mentioned as a topic in 32 construction management, 24 civil engineering, and 5 construction engineering degree programs (45% of construction management, 26% of civil engineering, and 31% of construction engineering degree programs).
- Many programs offer courses related to sustainable infrastructure (i.e., sewage, roadways, wastewater, and the city). These courses are almost exclusively engineering-related courses.
- Civil engineering programs with a strong environmental engineering component were more likely to emphasize sustainability-based coursework related to environmental issues, environmental systems/technology, and environmental design.
- Some schools explicitly mentioning sustainability tie the term to systems-based coursework such as mechanical or electrical systems.
- Many programs had a sustainable design course that emphasized high performance construction assemblies, efficient material selection, water efficiency, and sustainable site planning. Both civil engineering and construction management degrees had similar learning outcomes for this type of course, although construction management degrees seem to emphasize material selection.
- Some schools have specific environmental engineering or even sustainability degree offerings. Although environmental engineering programs were commonly associated with civil engineering, sustainability degree options were available in a variety of disciplinary contexts. Unfortunately, the sustainability degree options were not normally associated with the civil engineering or construction management programs, and these programs offered their own sustainability related coursework. It was not readily known whether coursework from these other programs was accessible for civil engineering or construction management students. In addition to noting that these kinds of programs exist, integration of cross-disciplinary sustainability coursework might be an option to broaden sustainability-based coursework in civil engineering and construction management education.

Conclusions

The purpose of this research was to explore the magnitude of sustainability integration within curriculum for civil engineering and construction management programs. This was done by identifying the prominence of sustainability within course titles, course descriptions, and overall program descriptions for 307 construction management, civil engineering, and construction engineering programs in the U.S. The research addressed the following three research questions. 1) Where is sustainability being taught within the curriculum? Various forms of sustainability education occur across the full spectrum of lower division, upper division, and graduate curriculum. The topic is generally introduced in lower division coursework. On the other hand, the strongest sustainability related courses appear to occur at upper division and graduate curriculum levels. Programs with multiple courses are more likely to introduce sustainability in earlier curriculum. Unfortunately, most programs tend to only identify sustainability as a prominent theme in a single course. 2) What types of sustainability specific content have been developed? LEED is one of the most common sustainability

subjects taught, occurring throughout all of the majors. Design-type courses in both civil engineering and construction management tend to show the largest variety of sustainability topics. Some construction and operations-based coursework focuses on sustainable decision making associated with material selection or systems-based thinking. 3) How prominent a role does sustainability play across the curriculum? This study demonstrates that only about 2/3 of the programs investigated have curriculum with an explicit focus on sustainability. The authors acknowledge that it is likely that sustainability principles are still being covered within the curriculum; however, without an explicit focus it is assumed that coverage may be superficial and ancillary to other topics that receive more attention.

The literature makes it clear that sustainability is an important topic within built environment-based education. The results generally support the growing body of literature supporting stronger sustainability education by demonstrating that sustainability shows up as a prominent theme within the majority of the programs explored. Unfortunately, this research is insufficient to evaluate the effectiveness of the associated sustainability education. We propose that programs evaluate their approach to teaching sustainability within their curriculum. Programs should consider how prominent a role the topic plays, and where appropriate make adjustments by more explicit integration throughout the curriculum. The results of this research can be used by programs as they consider the effectiveness of sustainability education occurring at their respective institutions by providing ideas for evaluation and change. Future research should include a more in-depth analysis of sustainability integration within the curriculum focusing on HOW sustainability is actually being taught and the effectiveness of outcome achievement within graduates.

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