

Curricular innovation to integrate sustainability for global grand challenges

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ABSTRACT

Educating future generations of engineers and construction managers who will be well prepared to tackle the sustainability grand challenges in the global context will require a paradigm shift from traditional engineering education. There has been much debate in recent years that traditional engineering education has failed to adequately prepare the graduates to face ever-changing complex and multidisciplinary problems in a sustainable and global context. Thus, an innovative transformation of the curricula is needed to educate future engineering graduates to successfully solve sustainable grand challenges. Not only must they be grounded in the latest technical knowledge and tools, future engineers are expected to have adequate understanding of the societal, economical, and political issues and be able to work in diverse team environment and have excellent communication skills. Furthermore, the future generations of engineers and construction managers should possess a highly developed knowledge of the environmental sustainability. “*Education for sustainable development is not an option but a priority*,” is the vision of the UN Decade of Education for Sustainable Development (2005-2014). It is the guiding principle of this paper to provide an overview of the fundamental concepts that should be integrated within engineering and construction management curricula for sustainability in the context of global grand challenges. The curricula innovation from authors’ own individual institutions will be presented as successful examples.

Keywords: sustainable, innovative, construction management, building information modeling (BIM)

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1. INTRODUCTION

It is now recognized that higher education can play a key role to help societies develop more sustainably, characterized by an “*ability to meet the needs of the present without impeding the ability of future generations to meet their own needs.*”¹ The concept of sustainability or sustainable development pertains to all aspects of life in the world and is generally expressed as using methods, systems and materials that will not deplete resources or harm natural cycles.² In order to ensure sustainability and ecosystem well-being, attention must shift to acquiring more output from less resource, with less waste, and less damage to the environment. The main objective is to attain sustainable ecosystems that integrate human society with its natural environment for the benefit of both.³

Architects, Engineers and Constructors (AEC) are in a unique position to take steps to protect the environment from damage and to correct existing problems. Educating a new generation of AEC who recognize the importance of sustainability and are able and willing to cooperate with people from a variety of other disciplines is a major challenge for educators around the world. The new generation should be equipped with highly developed knowledge of the environment and natural systems and their contributions to human well-being.⁴ This is an essential element of environmental sustainability. Every AEC student should be provided with at least a minimum understanding of environmental issues. The education system has to make students aware of the social, economic, political, and environmental effects of their chosen field and the technologies that they will develop.⁵ The aim of this paper is to present an overview of the sustainability education in engineering and construction management programs offered at two distinctly different universities; University of Florida, a research-intensive institution, and California State University, Fresno, a comprehensive Hispanic Serving Institution (HSI).

2. SUSTAINABILITY INITIATIVES AT UNIVERSITY OF FLORIDA

In 1990, the Rinker School of Construction Management at the University of Florida began a process for developing a program in sustainable construction. At the undergraduate level, there is a required freshman course called: International Sustainable Development. In addition, sustainable construction topics are included as a thread in the wide range of undergraduate construction courses.

At the graduate level, a Master of Science (MS) degree with a major in sustainable construction was created in 1997. An online degree version of graduate courses has also been made available to the industry professionals interested in a certificate program in sustainable construction. A combination of several graduate courses and a 3-semester hour thesis constitute the core of the M.S. degree program. Graduate courses comprise the Principles of Sustainable Development and Construction, Construction Ecology and Metabolism, High Performance Green Building Systems, and Building Energy Modeling.

The Powell Center for Construction and Environment was created in 1991 to integrate environmental issues into the research programs of the Rinker School. The Center has developed a strong research agenda in the area of building materials, to include reducing construction waste, recycling construction and demolition waste, deconstruction, water recycling and reuse, and rammed earth block and construction. Life cycle assessment (LCA) is an active area of research in the Center, and the research is focused on both methodology and applications. Numerous MS and PhD students have completed their theses and dissertations on sustainable construction related topics. Also, the Center has been actively involved in organizing and hosting international conferences and workshops relating to sustainability since its inception.⁶ Members of the Powell Center started Greening the University of Florida, a campus organization to foster greening of campus operations and curricula and were also instrumental in the formation of a Sustainability Committee appointed by the University President and the Faculty Senate. Furthermore, the Powell center has developed continuing education courses such as the Build Green and Profit and Learning to LEED, which have been delivered to many professionals in the State of Florida.

3. SUSTAINABILITY INITIATIVES AT CALIFORNIA STATE UNIVERSITY, FRESNO

The faculty of the Construction Management (CM) Program in Lyles College of Engineering (LCOE) at California State University, Fresno (‘Fresno State’) has incorporated sustainability related education in two separate but interrelated approaches. First, sustainability is integrated vertically

throughout the CM curriculum via a series of existing and new courses. Secondly, it is introduced through extracurricular activities, national student competitions, and via interdisciplinary research projects.

Incoming freshmen enrolled in the CM program are exposed to the concept of sustainability in CM-1(S), Orientation to Construction Management course. The stand-alone technical elective course, CM-177, Sustainable Construction, specially deals with all aspects of sustainability and green construction. Recently, a collaborative project-based approach has been implemented between this course and another CM course, CM-132, Advanced Architectural Design –BIM. The goal is to evaluate the synergies between BIM implementation in green building design and LEED certification requirements through a collaborative project-based approach, via the Jordan Research Center, which is under construction on Fresno State's campus. To add more credibility to this joint course project, the instructors have discussed with one of the leading BIM software vendors – Autodesk, to offer an online Building Performance Analysis Certificate (BPAC) program that is gaining substantial recognition in the building industry. This certificate program is a great supplement to the joint course project and it is expected to better prepare students for the proposed joint course project-based learning experience. The certificate may also reward the students by enhancing their resume and improving their employment marketability.

In addition, the senior capstone sequence of courses, CM 180-A(S) and CM 180-B, incorporate the eco-village project as one of their two-semester long projects, whereby multidisciplinary teams of students (from CM, Interior Design, Engineering, and other majors) work collaboratively to design and build sustainable modular homes ('shelters') for homeless people in Fresno. The structures are built with mostly recycled and/or renewable materials such as wood pallets, cardboard, fabric, straw-bales, locally harvested bamboo, railroad ties, aluminum can lids and so on.^{6,7}

Another tool to reinforce sustainable topics is to integrate student competitions into courses. Many governmental and industry organizations offer competitions for students. The most notable student competition is the United States Department of Energy's Solar Decathlon. This competition encourages students to design and build energy efficient houses. The competition has grown in size and scope over the years. Many of the participating schools integrate portions of or all of the competition into their courses. This is an effective approach that not only benefits the students competing, but all students in the degree program.⁸ In response to the success of the Solar Decathlon, the U.S. Department of Energy ('DOE') added a second competition called the "Challenge Home" student design competition. This competition required teams of students to design a zero net energy home that met "Challenge Home" design requirements. This competition was first offered during the 2013-2014 academic year and culminated with students presenting their designs. Twenty-eight student teams participated in the inaugural competition and the Department of Energy plans to offer the competition on an annual basis in subsequent years.⁹

The CM program at Fresno State has been participating in the aforementioned DOE competition. In order to maximize the students learning experience, the CM Program created a technical elective course to prepare students for the competition. The course was open to all upper division students in CM, engineering, interior design, and business.

The course includes three primary assessment methods to ensure that students are adequately prepared for the competition: (1) completion of the "Houses That Work" online certificate, (2) submission of interim designs and analyses, and (3) periodic team presentation of the designs. The "Houses That Work" (HTW) online certification is provided by EEBA as part of the competition. This offers a baseline of sustainability content for class discussions and design work in the course. The interim designs and analyses provide documentation of the application regarding the basic sustainability content. Finally, the class presentations are developed to help students prepare for public speaking required in the competition.

Furthermore, comprehensive efforts have been directed in both scholarly research and teaching innovation to address the challenge and opportunity of Green BIM in the CM program. Faculty have conducted exhaustive literature reviews to understand the state-of-the-art research and practices in professional and academic settings and to reflect the findings in research publications and course redesign. An exemplary case is the joint research conducted by two faculty members from Fresno State and University of Florida, Wu and Issa,¹⁰ which specifically investigated the BIM execution planning in green building projects and provided insights into the strategic decision-making in Green BIM practices. This research enhanced the understanding of synergies between sustainability and BIM in

real-world scenarios and delineated best practices through the use of deliberately created process maps and relevant case studies.

4. CONCLUSIONS

In summary, as sustainability and BIM maintain the strong momentum in the industry, college curricula should reflect such trends and cultivate pertinent competencies among the students. Faculty in the CM programs are proactively exploring the best practices of Green BIM education, from both research and teaching perspectives. Students who go through Green BIM education are expected to attain the desired knowledge and skill sets that are crucial to their future career development. In addition, various student competitions provide an added incentive for students to not only learn the content, but also to effectively apply the concepts they have learned. The goal of sustainable design and construction is to mitigate the negative environmental impacts of buildings through resource efficiency and to produce green buildings that are environmentally responsible. Sustainable building focuses on using energy, water and materials more efficiently in the design and operation of buildings.

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