Framework for Sustainability Practices in Construction Education Curriculum using BIM

Jin-Lee Kim, Ph.D., P.E., LEED AP BD+C
Department of Civil Engineering & Construction Engineering Management,
California State University Long Beach,
1250 Bellflower Blvd., Long Beach, CA 90840 - U.S.A
Email: jinlee.kim@csulb.edu

Abstract

This paper presents a framework to develop a unique and innovative virtual approach in order to deliver sustainability practices using Building Information Modeling (BIM) technology for undergraduate students and implement it as a new hands-on laboratory- and project-based course in the construction education curriculum. The demand for specialists in these two emerging fields is increasing tremendously due to the fact that green buildings education, research, and practice issues are becoming driving forces in academia and industry. The BIM-based teaching approach developed in the previous study is a stepping stone for the proposed innovative virtual approach. The BIM will provide students with building models containing integrated architectural information to implement sustainability that goes beyond both conventional 2D solutions using electronic drafting board and 3D modeling for purely visualization purposes. Therefore, it is expected that students enhance learning ability of sustainability through an innovative virtual approach using BIM. As an effort, this paper mainly focuses on a proposed framework to bridge the gap between the current theoretical courses and hands-on experiences. The ultimate goal of this research project is to inspire undergraduate students with green buildings associated with BIM for the sustainable development of a built environment.

Introduction

The AEC/FM industry is accelerating sustainability in built environment. The industry now heavily relies on the integrated sustainable design and construction and computer-aided automated solutions. To meet the challenges and opportunities for future employment, the integrated and practical sustainable building education is heavily required for construction engineering management students. Thus, the need for skilled and knowledgeable project managers must be addressed to survive in a competitive environment. The demands for the two emerging fields have been clearly outlined in the previous studies on BIM technology[1, 3, 4, 5, 14, 17, 28] and sustainability in construction education[2, 10, 12, 13, 15, 16], respectively. A recent research recommended that a study of sustainable or green construction needs to be added to the Construction Management curriculum in the context of estimating, scheduling, and building techniques, to prepare Construction Management professionals for construction in the 21st century.[21]

Practical sustainable buildings education is needed for construction engineering management students destined for employment in the AEC/FM industry. The ultimate goal of this research project is to develop a new, innovative instructional approach on sustainable buildings for

undergraduate students and implement it as a hands-on laboratory- and project-based course using BIM technology. This innovative course is unique in construction education curriculum in the sense that these two revolutionary movements will create environmentally friendly design and construction through a streamlined process and it will help students to deeply understand the construction processes by using sequential computerized simulation and modeling.

Sustainability in Built Environment

Over the past decade, the importance of accelerating sustainability in a built environment has been well recognized all over the world. The World Commission on the Environment and Development offered the best definition for sustainable design as "Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs."[26] The built environment consumes about 40 percent of extracted resources in most industrialized countries, as well as consuming approximately 40 percent of all primary energy.[6] According to the U.S. Green Building Council, buildings are responsible for 38% of carbon dioxide emissions, 71% of electricity consumption, 39% of energy use, 12% of water consumption, and 40% of non-industrial waste in the U.S.[24] Green building has been developed as a practical answer to the environmental and health burdens of the built environment.

McDonough and Braungart developed the concept of cradle-to-cradle design to follow nature's model of eco-effectiveness based on Five Steps.[29] The concept has been popularized because it provides a framework for designing materials and products, and focuses attention on waste and on the proliferation of toxic substances. Sustainable and high performance buildings and infrastructures have shown dramatic increases in the U.S.A. The growing need for professionals with specific training in sustainable building practices will increase significantly over the next decade. Thus, undergraduate students need to advance their career and maintain their competitive edge with training in the green building areas.

Sustainability in Construction Education

Many schools, with undergraduate engineering programs in many disciplines, attempt to include environmental sustainability and sustainable design in their curricula.[18] The challenges and opportunities are laid out in CEM disciplines as to how to incorporate sustainability into their educational formation.[6, 18, 19, 25] Russell et al. reviewed the past and present of construction engineering and prescribed practical change to revitalize construction engineering education to meet future demands.[19] Kelly proposed an approach to general education for civil engineers, which showed that sustainable development is a good theme for a civil engineering program.[6] Pocock et al. proposed a problem-oriented approach to incorporating sustainable design into a construction engineering curriculum.[18] Wang shared the experience gained from developing and teaching a sustainability course by identifying sustainability knowledge areas, course planning, and lessons learned from the class. The study recommends that engineering educators need to develop appropriate class content and effective teaching techniques to prepare students with sustainability knowledge and techniques.[25] From the standpoint of the education situation, sustainability issues should be incorporated into the construction engineering management education curriculum to respond to the needs of the industry.

Building Information Modeling in Construction Education

Building Information Modeling (BIM) is an emerging tool in the design industry used for design and documentation. BIM is also used as a vehicle to enhance communication among all the project stakeholders.[11] BIM is a comprehensive, integrated graphic and alphanumeric database, through which the collaboration among the stakeholders can be effectively achieved.[22] BIM is a methodology of continuous refinement. One needs to understand the process and workflow, make gradual changes and enhancements to the individual project process to achieve better results, and repeat the concepts for innovation and best performance.[11] BIM modeling and analysis requires higher training efforts because it might be more difficult, for people who were previously 2D users, to learn the BIM approach and to handle complex geometry such as freedom structure. The development of BIM triggers a new approach to teaching and learning at architecture, engineering, and construction schools. However, the lack of personnel with BIM skills is a significant constraint retarding use of the technology in the AEC/FM industry.[20] Berwald compared a class of students using BIM programs with a class of students who were using traditional 2-D CAD programs. The study showed the different experiences of each method and contrasted the efficiency of both 2D and BIM.[4] Barnes and Castro proposed a BIM-enabled integrated optimization tool for LEED decisions.[2] The construction educator should encourage construction engineering management students to acquire the skills and knowledge of the BIM technology as more AEC companies integrate BIM into their fields and require the new labor force to be able to collaborate and communicate with 3D/4D/5D BIM technologies.

Research Project Objectives

This paper aims to develop a unique and innovative virtual approach to deliver sustainability using BIM technology for undergraduate students and implement it as a new hands-on laboratory- and project-based course in construction education curriculum. The intended contribution is to influence undergraduate students with green buildings associated with BIM for the sustainable development of a built environment. The proposed approach is unique in that it covers both sustainability and BIM in a single undergraduate course as the two subjects are currently taught in separate courses in the nation. The objectives of the proposed project are as follows:

(1) To attract students with an interest in BIM technology and sustainability,
(2) To prepare students for employment in the AEC/FM industry such as BIM, LEED (Leadership in Energy and Environmental Design), preconstruction services, and project risk management, including ethical, environmental, and sustainability concerns,
(3) To train the students on the application and techniques of BIM technology to provide a fundamental theory and application to the students' approach to solving the problems encountered in the workplace,
(4) To encourage a team approach in the laboratory process simulation to develop skills and learn the importance of collaboration efforts rather than individual advancement, especially in emerging technology fields in the AEC/FM industry,
(5) To provide students with sustainable building toolkits designed specifically for the needs of the construction industry including internship programs for undergraduate students.

Proposed Laboratory-based Teaching Framework for Sustainability

This section describes the proposed laboratory-based teaching framework for sustainability. The framework will make a stepping-stone of the BIM-based teaching approach that has been developed in the previous study.[8] The BIM-based teaching approach integrates BIM technique into an existing course to enhance students' ability to visualize the building projects from the foundation to the roof. Figure 1 shows the framework of the BIM-based teaching approach and illustrates the sequence of the approach, the tool needed to implement each step, and the deliverable produced as a result of each step. The BIM-based teaching approach begins with the understanding of the physical models for residential buildings (See Figure 2). 2D drawings are then generated based on the physical models using traditional Computer Aided Design (CAD) programs. 3D BIM model is finally developed to better understand the buildings in detail and to accurately takeoff the material quantities.

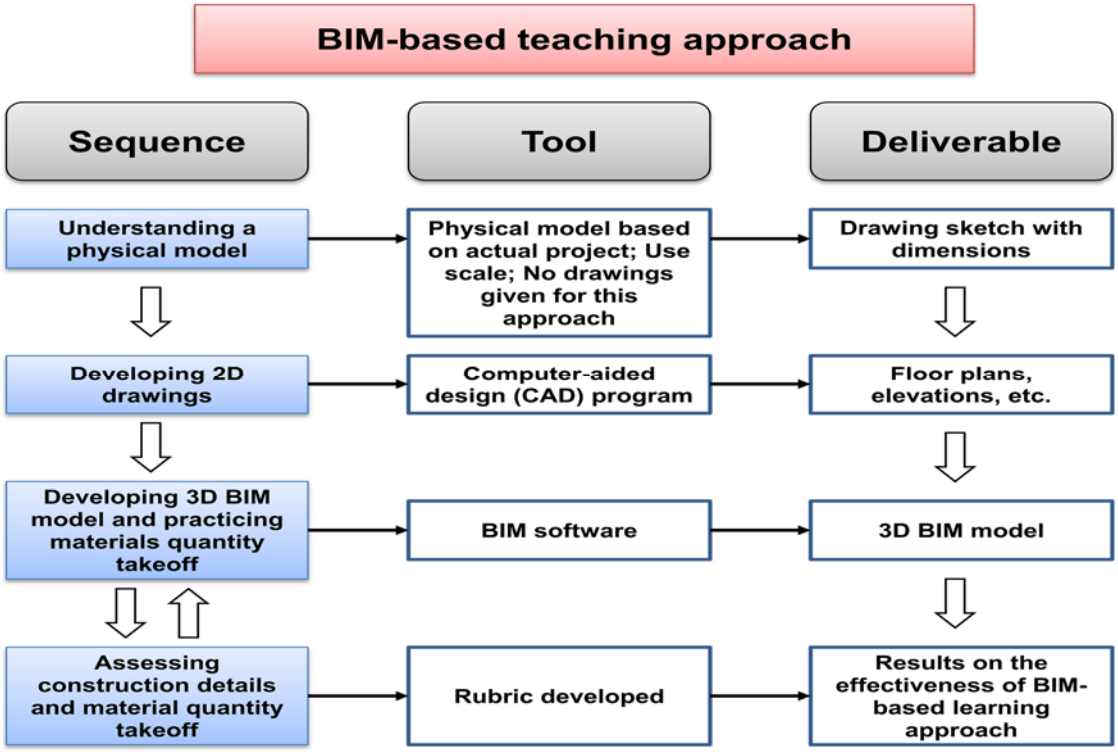

Figure 1. Building information modeling-based teaching approach[8]

Figure 2. Working on a physical model

Laboratory-based Teaching Framework for Sustainability

The proposed teaching framework for sustainability consists a 16-week laboratory- and project-based course for a 3-hour credit unit. Figure 3 shows the schematic diagram for fifteen new hands-on laboratory- and project-based course modules.

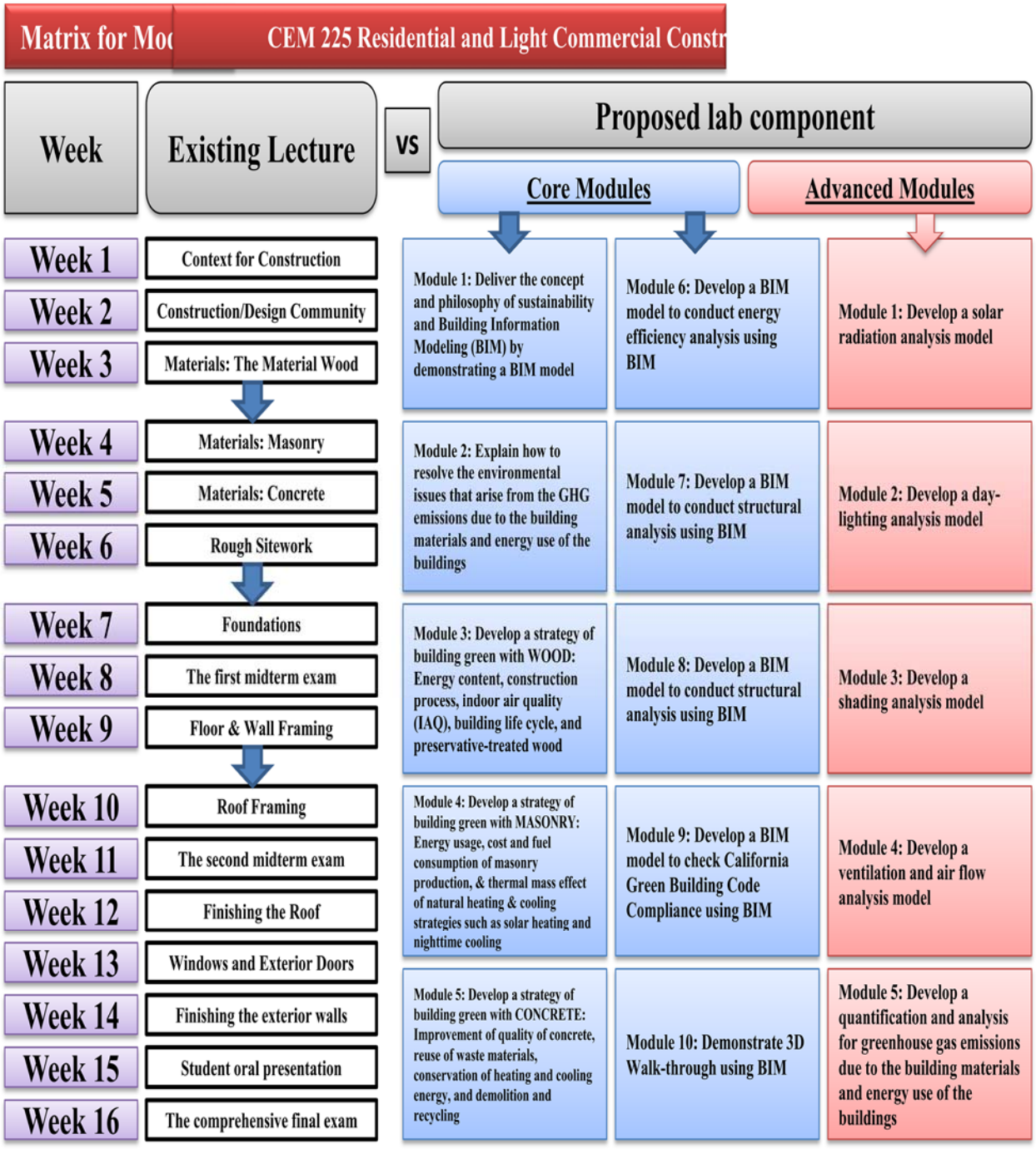

Figure 3. Schematic diagram for the proposed framework

The first five weeks (15 hours) will be devoted to the foundations and effects of green resources such as building materials, building forms, and building systems, on the green buildings. The next six weeks (18 hours) will be devoted to hands-on laboratory-based work. In the second six weeks, the applications and techniques of BIM technology will be studied through experiments that create the BIM model and closely simulate the effects of green resources on the building projects. The last five weeks (15 hours) will be devoted to hands-on project-based work to understand the relationships between BIM technology and sustainability. In these last weeks, how these two revolutionary movements will change the way the construction business operates and transform traditional processes into new workflows will be discussed, so that green solutions from the beginning of the project can be achieved in the AEC/FM industry. Also, guest lectures on sustainability, BIM technology, ethics, and green markets potential will be delivered.

Implementation Strategy

In light of the incorporation of sustainability into the BIM-based teaching approach, three main strategies are implemented. First, the use of building materials is a constant in the AEC/FM industry, regardless of how much we do not use energy nor consume water. Building materials such as wood, masonry, concrete, steel, and others have significant effects on sustainability. The fundamental knowledge of building materials falls into four major building materials: wood, masonry, concrete, and steel. EPA defines green building as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle.[23] A recent research assessed the evolution of students' understanding of sustainability and revealed that the selected group of students made progress in understanding during a Sustainable Construction course by using problem-based and service-learning type projects.[9] Building with wood and masonry has several areas for sustainability implementation, including energy content, construction process, indoor air quality (IAQ), building life cycle, and preservative-treated wood. Building with concrete also has several possibilities, which include aggregates and water, wastes, formwork, reinforcing, demolition, and recycling. Second, to implement the sustainability in a built environment, the understanding for simple design concepts is required for a more sustainably driven outcome. A hands-on laboratory experiment procedure and manual being developed addresses the three main areas: building orientation, building massing, and day-lighting. The impact of climate, how to reduce resource need, how to use BIM to find solar south, how to use BIM for building massing, how to optimize the building envelope, and how to analyze the daylight will be studied and understood at the project level. Finally, to examine the relationship between sustainability and building systems, the understanding for building systems is also required for a more sustainably driven outcome. The manual also addresses the three main areas: water harvesting, energy modeling, and renewable energy. How to analyze and optimize water harvesting using BIM, how to conduct energy analysis using BIM to reduce energy needs, and how to analyze renewable energy and optimize a solar array to reduce energy needs are studied at the project level.

Concluding Remarks

This paper presents a framework to develop a unique and innovative virtual approach to deliver sustainability using Building Information Modeling (BIM) technology for undergraduate students and implement it as a new hands-on laboratory- and project-based course in the

construction education curriculum. The concrete outcomes from this research project are fifteen 3-hour laboratory- and project-based course modules in teaching sustainability using BIM, which is designed to cover a semester. The outcomes of this project will provide a needed component of practical sustainable buildings education for students destined for employment in the AEC/FM industry because the industry is becoming reliant on the integrated sustainable design and construction with BIM technology. Students in the proposed course are expected to gain (1) understanding green resources such as building materials, building forms, and building systems, (2) hands-on experience with BIM, especially 3D geometric models instead of 2D CAD designs, and (3) hands-on experience with the effect of green resources on the projects using BIM analysis tools. Students are expected to build strong foundations for understanding global environmental problems such as climate change and ozone depletion, being familiar with the concept of building assessment, gaining a clear understanding about sustainable development and sustainable construction, and help students understand the relationships between sustainability and building materials, building forms, and building systems, using BIM technology. The visualization approach using BIM will enable students to implement high-performance green building strategies to explore how the buildings would be "greened."

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