Effectiveness of Green-BIM Teaching Method in Construction Education Curriculum

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Abstract:

This paper presents the results from an ongoing NSF TUES project that develops a unique and innovative virtual approach, named as Green-BIM teaching method, to deliver sustainability practices using Building Information Modeling (BIM) technology for undergraduate students and implement it as a hands-on laboratory-and project-based course in the construction education curriculum. This NSF TUES project aims to inspire undergraduate students with green building practices associated with BIM for the sustainable development of a built environment. The Green-BIM teaching method is designed and used to teach a construction management course offered at California State University Long Beach. The approach starts with the BIM-based teaching method developed in the previous study and incorporates the knowledge of sustainability in a built environment. The effectiveness of the Green-BIM teaching method was evaluated by using an assessment rubric. The evaluation results indicated that the method overall helped students to effectively learn materials. It was found that the Green-BIM teaching method provides dynamic representations of knowledge and increases classroom interaction and students’ personalized learning experience.

Introduction

The growing need for professionals with specific training in sustainable building practices will increase significantly over the next decade as the importance of accelerating sustainability in a built environment has been well recognized all over the world. Thus, undergraduate students need to advance their career and maintain their competitive edge with training in the green building areas. Many schools, with undergraduate engineering programs in many disciplines, attempt to include environmental sustainability and sustainable design in their curricula. The challenges and opportunities are laid out in construction engineering management disciplines as to how to incorporate sustainability practices into their educational formation. Russell et al. reviewed the past and present of construction engineering and prescribed practical changes to revitalize construction engineering education to meet future demands. Kelly proposed an approach to general education for civil engineers, which showed that sustainable development is a good theme for a civil engineering program. Pocock et al. proposed a problem-oriented approach to incorporating sustainable design into a construction engineering curriculum. 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.\(^9\)
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.

In line with the movement of sustainability in a built environment, Building Information
Modeling (BIM) is a mainstream, emerging tool in the architecture/engineering/construction
(AEC) industry used for design and documentation. BIM is a comprehensive, integrated graphic
and alphanumeric database, through which the collaboration among the stakeholders can be
effectively achieved.\(^8\) However, the lack of personnel with BIM skills is a significant constraint
retarding use of the technology in the AEC industry.\(^7\) The demand for specialists in these two
emerging fields, which are BIM and green building practices, is increasing tremendously due to
the fact that green buildings education, research, and practice issues are becoming driving forces
in academia and industry. The Green-BIM teaching method proposed in this paper provides
students with building models containing integrated architectural information to implement
sustainability practices that goes beyond both conventional 2D solutions using electronic drafting
board and 3D modeling for purely visualization purposes. Students are expected to enhance their
learning ability of sustainability practices through an innovative virtual approach using BIM. The
objective of this paper is to present the Green-BIM teaching method and its effectiveness using
the partial assessment results obtained during the course of the NSF TUES project. The Green-
BIM teaching method was designed and used to teach a construction management course offered
at California State University, Long Beach. An evaluation of the effectiveness of the teaching
method was conducted using an assessment rubric.

### Methodology

To utilize the Green-BIM teaching method as an integrated learning tool for green building
practices in construction education, the writer of this paper conducted a series of assessment in
an undergraduate-level course, CEM 225 Residential and Light Commercial Construction
Practices and Estimating, in the Department of Civil Engineering and Construction Engineering
Management (CECEM) at California State University Long Beach (CSULB). The CEM 225
course is a three-credit course required to all CEM students. The class is designed to meet the
three program objectives such as (1) an ability to use the techniques, skills, and construction
knowledge to develop appropriate levels of cost estimates necessary for project planning and
control, (2) an ability to communicate effectively using oral, written, and graphic communication
skills, and (3) an ability to function on multi-disciplinary teams. Every semester, 25 to 30 CEM
students who took the two prerequisites, Construction Drawing and Fundamentals of
Construction, take this course so that the consistence of the previous knowledge of students is
maintained. It is noteworthy that these two prerequisites do not deal with the necessary
information on BIM and green building practices.

Prior to the offering of the class in Fall 2013, the writer realized that the BIM-based teaching
approach developed in the previous study alone was not very effective to deliver sustainability in
a built environment, even though it enhances students’ ability to visualize the building projects.\(^3\)
Realizing the problems that students experienced in gaining insights to both visualization of
building projects and understanding of sustainability in a built environment, the writer designed a Green-BIM teaching method and utilized it to teach CEM 225 to foster the enhancement of visualization ability about construction details, quantity takeoff of building projects and better understanding of green building practices. Before and after study is presented in this paper to analyze the assessment results using students’ works and exit surveys.

**Green-BIM Teaching Method**

The Green-BIM teaching method integrates sustainability practices into the BIM-based teaching method developed in the previous study in order to enhance students’ ability to visualize the building projects from the foundation to the roof and to understand sustainability in a built environment. The proposed method starts with the BIM-based teaching approach. Figure 1 shows 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.

![BIM-based teaching approach](image)

**Figure 1. BIM-based teaching approach**

The proposed teaching framework for sustainability practices consists of a 16-week laboratory- and project-based course for a 3-hour credit unit. Figure 2 shows the schematic diagram for fifteen hands-on laboratory- and project-based course modules. The first five weeks (15 hours) are 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) are devoted to hands-on laboratory-based work. In the second six weeks, the applications and techniques of BIM technology are 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) are devoted to hands-on project-based work to understand the relationships between BIM technology and
sustainability practices. In these last weeks, how these two revolutionary movements will change the way the construction business operates and transform traditional processes into new workflows is discussed during the presentation of final class projects, so that green solutions from the beginning of the project can be achieved in the AEC industry. Also, guest lectures on sustainability, BIM technology, ethics, and green markets potential are delivered.

Figure 2. Schematic diagram for the proposed framework

Students in the proposed course are expected to gain (1) understanding of 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 practices 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.”

Implementation of Green BIM-Based Learning Approach

In the spring of 2013, the writer developed the new teaching method proposed in the NSF TUES project by integrating sustainability in a built environment into its existing curriculum, CEM 225 Residential and Light Commercial Construction Practices and Estimating course. The course is a mandatory introductory course in planning, design, and construction of residential and light commercial buildings including materials, equipment, construction and assembly methods, quantity take-off, and building codes and standards. The course objective is to expose the students to the basic knowledge and skills of methods of building construction, which include sitework, foundations, structural framing, floor, roof, and wall systems. This class aims to provide an intensive and interactive hands-on approach to understand residential and light commercial construction practices. Figure 3 shows students working on their building models in the laboratory.

Figure 3. Students working on the models in the laboratory

Students are provided a specific and detailed description on the approach at the beginning of each semester. During the course of the semester, students should follow the instruction to deliver the assignment given each week so they complete all the assignments within the semester. The proposed Green-BIM teaching method is implemented in the lab as a team.
assignment. The students in the class are to form groups of four students to do this team assignment. The objective of this team assignment is to encourage students to gain an ability in using the techniques, skills, and construction knowledge on sustainability practices, to develop appropriate levels of construction details and material quantity takeoff, to effectively communicate using oral, written, and graphic communication skills, and to function on multi-disciplinary teams.

Assessment Plan and Effectiveness Results

The proposed Green-BIM teaching approach seeks to deepen the knowledge and skills for BIM technology in order to deliver the state-of-art skills and knowledge of sustainability practices. To assess the impact of the proposed approach, a nonequivalent control groups design is employed. The evaluation plan determines the degree to which the proposed course has been successful in enhancing student knowledge, enhancing teacher pedagogical skills in BIM technology associated with sustainability practices, and improving student learning, thus closing the achievement gap. The evaluation plan will occur at two levels: formative evaluation of the implementation of project activities, and summative evaluation of the project’s impact upon student achievement.

Research questions to be addressed for student achievement along with the American Council for Construction Education (ACCE) requirements include (1) is participation in the proposed course associated with increased green resources and sustainability content knowledge by CEM students? (ACCE 4.3), (2) is participation in the proposed course associated with increased BIM technology content knowledge by CEM students? (ACCE 4.4, 5.1, 5.2, 5.4, 5.5), (3) is participation in the proposed course associated with increased implementation of key individual and team collaboration hands-on laboratory exercises by CEM students? (ACCE 1.2), and (4) is the proposed course associated with a higher level of student learning that closes the achievement gap? Are higher levels of student implementation of the proposed course associated with higher levels of student performance on sustainability?

In this paper, the effectiveness of the Green-BIM teaching method was evaluated by means of student laboratory exercises using final class projects and student surveys. The rest of the assessment will be conducted in a later study and presented to the NSF TUES program. A rubric assessment tool was developed and used to evaluate the overall student achievements with respect to the learning objectives of the course. Once the course of study has been established, the overall expectations are determined through reviewing course-learning objectives, lecture notes, handouts, final projects, and materials collected on assessment strategies. To ensure the overall expectations are being met, the performance criteria and evaluation methods should be established for assessment.

Results on Student Laboratory Exercises

In terms of summative assessment for the development of the proposed course, students’ knowledge and skill of BIM technology and sustainability practices are evaluated through several hands-on laboratory-based exercises for a final class project. The evaluation team creates constructed responses using exercises that would measure both deep knowledge and the use of
the appropriate skill level for BIM technology and sustainability. To statistically test significant
differences between the skills and knowledge of students who take the proposed method and
students who do not take the method, a two sample T-Test assuming equal variance is conducted.
In most cases, we do not know the actual variance or standard deviation of either of the two
student groups. We assume that the student samples are randomly and independently drawn from
respective students that are normally distributed and that the population variances are equal.
Thus, the experiment method using a two sample T-Test assuming equal variance is appropriate
because it determines whether or not there is a significant difference between the means of the
two populations. The assessment results consist of two folds: (1) the effectiveness which
evaluates the overall student achievement with respect to the learning objectives and (2) the
potential for continuous utilization of the proposed Green-BIM teaching method by showing
significant difference in student performance between two consecutive semesters. We graded
their works not only for the purpose of grading against answer keys but also for the assessment
to demonstrate the achievement of outcome. Direct assessment data of 27 and 24 students are
collected for Spring 2013 and Fall 2013, respectively. Figures 4(a) and 4(b) show the
distributions of overall student performance based on the rubrics for Spring 2013 and Fall 2013,
respectively.

The experiment aims to compare the overall student performance between two groups for the
proposed Green-BIM teaching method. The research hypothesis is to show that there is a
significant difference in student performance between two semesters so that the teaching method
has a potential to effectively promote students’ understanding and interest in sustainability in a
built environment through visualization. A two-sample T-Test for the difference was conducted
for the hypothesis using Minitab 16®. The hypothesis to test whether or not the overall student
performance (µ1) obtained from the class of Fall 2013 exceed those (µ2) obtained from the class
of Spring 2013 are Ho: µ1 – µ2 = 0 and Ha: µ1 – µ2 > 0. Table 1 tabulates the statistical results
for overall student performance.
Table 1. Statistical Analysis for Overall Student Performance

<table>
<thead>
<tr>
<th>Class Group</th>
<th>Spring 2013 (Control Group)</th>
<th>Fall 2013 (Experimental Group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of students</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>Mean</td>
<td>90.96</td>
<td>95.13</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>19.50</td>
<td>3.57</td>
</tr>
<tr>
<td>t-score (p-value)</td>
<td>-4.29 (0.00004)</td>
<td></td>
</tr>
</tbody>
</table>

At a 0.05 level of significance, the null hypotheses are rejected because the p-value is much smaller than 0.05. We have sufficient evidence to show that the null hypothesis is not true. From this we conclude that the proposed Green-BIM teaching method is effective between before and after its introduction. The proposed teaching method is different from other studies in that it not only utilizes the BIM technique to reinforce the lack of understanding the buildings in a 3D form, but also incorporates green building practices. It is expected that the Green-BIM teaching method can take a position within the existing body of knowledge gap in the AEC education because it addresses a current lack of research with regard to the utilization of the two evolutionary movements in the construction engineering management classroom.

Results on Student Surveys

To measure the impact of the proposed course on students’ laboratory practice, the Student Survey developed by the evaluation team is used. The survey asks for information on the students’ background with sustainability practices, self reports of their knowledge, and the extent to which students express support for sustainability. The surveys are administered at the beginning and the end of each semester. The surveys includes 10 “course learning objective outcome” items on a 5-point scale. Figure 5 compares the results of student self evaluations on learning objectives between the beginning of the class and the end of the class in Fall 2013.

- Objective 1: The concept and philosophy of sustainability practices and BIM
- Objective 2: The relationships between sustainability practices and building materials, building forms, and building systems.
- Objective 3: Use of BIM technology to visualize the buildings and demonstrate 3D Walk-through.
- Objective 4: Hands-on experience to determine the quantities of the building materials using BIM technology
- Objective 5: The concept of building assessment such as USGBC green building rating system, LEED (Leadership in Energy and Environmental Design).
- Objective 6: How to resolve the environmental issues that arise from the GHG emissions due to the building materials and energy use of the buildings.
- Objective 7: A strategy of building green with WOOD by considering the following:
  - Energy content, construction process, indoor air quality (IAQ), building life cycle, and preservative-treated wood.
- Objective 8: A strategy of building green with MASONRY by considering the following:
  - Energy usage, cost and fuel consumption of masonry production, and thermal mass effect of natural heating and cooling strategies such as solar heating and nighttime cooling.
- **Objective 9:** A strategy of building green with CONCRETE by considering the following: Improvement of quality of concrete, reuse of waste materials, conservation of heating and cooling energy, and demolition and recycling.
- **Objective 10:** Development of a BIM model to conduct energy efficiency analysis, structural analysis, and check California Green Building Code Compliance.

![Chart showing comparison of student self evaluations on learning objectives](image)

**Figure 5.** Comparison of student self evaluations on learning objectives

### Conclusions

This paper proposed the Green-BIM teaching method as a part of an ongoing NSF TUES project and presented the evaluation results for its effectiveness. The project aims to develop a unique and innovative virtual approach to deliver sustainability practices using BIM technology for undergraduate students and implement it as a new hands-on laboratory- and project-based course in the construction education curriculum. It was concluded that the Green-BIM teaching method was effective between before and after its introduction. Student evaluation results revealed that the Green-BIM teaching method help them learn and understand better sustainability in a built environment over the semester. For the future study, the proposed Green-BIM teaching method will be calibrated to enhance its contents and deliver better knowledge of green building practices while the comprehensive assessment plan designed for the NSF TUES project will be implemented to provide reliable and robust research outcomes on the Green-BIM teaching method.
Acknowledgment

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References


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