AC 2012-5582: BIM TEACHING STRATEGY FOR CONSTRUCTION ENGINEERING STUDENTS

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BIM Teaching Strategy for Construction Engineering Students

Abstract

After the introduction of Building Information Modeling to the construction industry in 1987, today we are facing an increasing demand for the new technology and the well-trained professionals capable of implementing it. Recently, the new idea of having a comprehensive 3D intelligent model with the ability of being extended to a 4D model has caught a lot of attention and forced the construction companies to move toward adopting the new knowledge and implementing it in their projects. This is due to a variety of reasons such as 1) acquiring the new technology to optimize project cost and schedule, and 2) being competitive in the job market. However, there are loopholes associated with the integration of this new technology which is basically due to the lack of well-trained individuals in the field. These loopholes are basically twofold, the first is the scarcity of construction engineering programs within universities with a dedicated course in Building Information Modeling and the second is the lack of consensus on what should be the main focus of the syllabi. While some courses are centered on the modeling aspect of the technology, the other tend to capture the gained benefits from its application for different phases of project development.

This highlights the need for a proper teaching strategy for building information modeling from the academia perspective. This paper aims to capture the current state of practice with regard to BIM modeling in the construction industry and the current expectation from new construction engineering graduates within the area of information modeling. Furthermore, this study will pinpoint the topics which require more teaching emphasis to bridge the existing gap between the expectation from industry and BIM curriculum.

Introduction

Building Information Modeling (BIM) is a process of creating an intelligent virtual model which integrates the project data from design to construction and operation. This facilitates project documentation, project quantification and estimation. Also BIM models enhance the process of communicating the progress of construction to stakeholders; facilitate integrated project delivery, coordination, and clash detection by visualizing the different phases of project development.

According to Eastman et al. [1], in 2004 Construction Industry Institute estimated that 57% of money invested in construction will be wasted. Considering the estimated U.S. construction market of US$ 1.288 trillion in 2008, this translates to a US$600 billion annual waste. Building Information Models help control these wastes by reducing conflicts during construction, improved collective understanding of design intent, improved overall project quality, reduced changes during construction, reduced number of RFIs and better cost control/predictability [2]. Also, statistics from 10 US based projects showed an average of 9486% return on investment (ROI) which strongly supports the immense economical contribution of BIM models in construction industry [3].

Due to its data-rich structure, BIM models can be applied to achieve a multitude of objectives. These objectives cover the whole cycle of project development. The BIM applications for different project phases are summarized in Table 1.
Table 1. BIM applications in construction industry

<table>
<thead>
<tr>
<th>Construction Phase</th>
<th>BIM Application</th>
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<td>Design</td>
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<td>Detail Design</td>
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<td>Construction</td>
<td>Site Planning and Logistics</td>
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<td>Schedule/Work Sequence</td>
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<td>Simulation</td>
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<td>Quantity Take Off</td>
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<td>Clash Detection</td>
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<td>Training</td>
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<td>Operation &amp; Maintenance</td>
<td>Asset Management</td>
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<td>Renovation Prioritization</td>
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The importance of BIM models has also led to publishing National Building Information Modeling Standard [4]. This has also caused an average increase of 144% in the number of companies who have adopted this new technology. Local governments have begun supporting this modeling technology as well. In July 2009, Wisconsin became the first state to require all state building projects with a total budget of $5 million or more and all new construction projects with a budget of $2.5 million or more to use a building information model throughout the construction process [5].

Features available in BIM such as reduced wastes & energy optimization have led to the convergence of BIM and green building and formed green BIM. In addition, BIM has been endorsed by the U.S. General Services Administration for public building projects [6]. Also statistics show that 80% among nation’s largest AEC firms has adopted BIM [7] and 83% of the largest United States engineering, architecture and design firms have at least one in-house BIM seat license, half have more than 30 seats and 23% have 100 or more BIM seats. According to McGraw-Hill Construction [8], 43% of architects, 35% of engineers and 23% of contractors use BIM on more than 60% of projects.

The statistics show an increasing trend toward application of BIM in construction industry but the flip side of the coin is the lack of well-trained professionals and proper education to help advance this application. The objective of this study is to bridge this gap by distinguishing the current BIM needs and propose a tentative BIM syllabus that can address them. The next section will provide a review of current literature and is followed by research methodology, survey results and conclusions.
Literature Review

Although there is a variety of benefits associated with application of BIM in construction industry, lack of well-trained individuals [9], proper training [8], and effective inclusion of BIM education in construction curriculum [2] have been cited as the major constraints with regard to adopting the new technology and preparing the next generation of future employees. Sabongi and Arch [10] reported a rate of 9% for the universities and colleges with a BIM-related coursework and a rate of 1% for those with a dedicated BIM classes in their study of 45 members of Associated School of Construction. This lack of proper modeling education was denoted to be a barrier for adoption of technology even in highly BIM-innovative countries [11].

To overcome these hurdles, a variety of research studies examined the inclusion of BIM related education in the construction education curriculum mostly through industry-academia collaboration. Among these studies, Woo [12] researched the advantages of a successful BIM employment in construction education. Sacks and Barak [13] highlighted the lack of adequately-trained personnel as the leading barrier for application of BIM technology in the architecture, engineering, and construction industry and proposed a mandatory freshman-level course to overcome the problem. The course was designed to capture both theoretical and practical aspects of BIM and was designed to replace the traditional engineering graphic course. Clevenger et al. [14] studied the effect of a two-stage pilot strategy to integrate BIM in their construction management curriculum in response to its vast application in industry. This strategy included a freshman-level BIM class with a focus on BIM basic modeling skills and BIM teaching modules for upper level courses and had a promising initial feedback. Clevenger and Carey [15] examined the collaboration of industry and academia to develop a curriculum for application of BIM in Mechanical, Electrical, Plumbing and Fire Protection (MEPF) coordination. Azhar et al. [16] highlighted the role of BIM features such as 3D visualization and clash detection to create a better understanding of construction divisions among students. Barison and Santos [17] studied the current state of BIM integration into academic curricula by universities around the world. Peterson et al. [18] studied the benefits of using BIM models in teaching construction engineering project management courses. Wong et al. [19] reviewed the variety of BIM teaching approaches and methodologies around the world while presenting the current implementation of BIM education at Hong Kong Polytechnic University.

Finally Ku and Taiebat [20] studied the state of practice with regard to BIM in construction industry and their expectations from new hire from the constructors’ perspective. The objective of this research study, much like the study of Ku and Taiebat [20] is to collect feedback from construction industry with regard to their BIM needs and propose a list of focus areas regarding a tentative BIM teaching strategy for construction engineering students. Unlike the previous study, considering the fact that the current focus was on the companies’ current BIM needs, this study’s assumption was to consider the current needs as the current expectations from construction engineering students and academia.
Research Methodology
The study methodology included four sequential efforts. The first was to perform a comprehensive review of the literature with regard to integrating BIM in construction engineering education. Among the reviewed documents, some described the state of practice, and others provided an initial evaluation of BIM integration. Analyzing these references provided insight into the current BIM integration approaches; created sound knowledge of existing implementation issues and barriers, and established a platform for evaluation of the survey data. The next was to brainstorm on what type of information should be collected to address the objective of this research. For this purpose, a committee consisting of construction engineering faculties and BIM specialists were formed. The objective of the committee was to focus on the current construction industry needs and as a result minimize the number of survey questions. The survey structure had two sections. The first set of questions intended to capture the company’s demographic data. The next section was designed to capture company’s BIM exposure and experience. After the completion of survey design, the survey was first internally tested by committee’s BIM specialists and feedbacks from this pilot study were used to revise the survey. Finally the fourth was to develop an electronic survey including quantitative and qualitative questions. The sample population for this survey was primarily the members of TEXO construction association. TEXO is a construction association representing commercial contractors in North and East Texas. The association was formed by a merger of the North/East Texas Chapter of the Associated General Contractors and the Associated Builders and Contractors North Texas [21]. The developed online survey was electronically published in the association online newsletter to be distributed among the members. According to TEXO website, the association holds a membership of more than 1,900 commercial contractors. Overall 20 companies participated in the survey, however one of the submissions was partially answered and skipped the majority of the questions and therefore was excluded from the analysis.

Survey Results Analysis
The first section of the survey included questions about companies’ demographic data. It started with the type of company according to its contractual role. The majority of respondents (68.4% were either general or subcontractors. Construction Management was ranked second with a 42.1% of the respondents which is shown in Figure 1. It can be concluded from the results that companies did not necessarily had a single contractual role in their projects and primarily had a contractor’s standpoint.
The next question in the first section was about the nature of companies’ projects. As expected 90% of survey participants indicated commercial construction as the selected type for their projects. The distribution of responses is shown in Figure 2. As shown in the figure, institutional, educational and healthcare projects were respectively ranked second, third and fourth. Also it can be concluded from the graph that some of the companies were involved in more than one project type.

The next two questions were about the size of companies with regard to their annual projects and projects monetary values. Figure 3 shows the distribution of responses average annual projects. Among the participants, 35% indicated having more than 100 projects annually while 25% expressed to have between 20 to 40 averages annual. The graph also shows that %80 of the participants have more than 20 projects annually. This indicates that the data is primarily derived from medium to large companies.
To complement the previous question, the next questions asked about the average annual size of the projects. The results are shown in Figure 4 in which 68.4% of respondents indicated an average annual size of less than $50M.

The next three questions were designed to collect information about the BIM personnel in the company and companies’ expenditure for BIM services. This was primarily intended to find the ratio of investment in BIM services compare to project monetary values in the companies. Among the participants, 95% indicated having in-house BIM personnel while the rest denoted outsourcing their BIM needs. Among the companies with dedicated in-house specialists, 50% indicated having between 0 to 5 BIM personnel while 22.2% denoted having more than 20. This distribution is shown in Figure 5.
Figure 5. Distribution of Respondents’ Number of in-house BIM Personnel

Finally the last questions revealed companies’ average annual ratio of their BIM services cost to their project costs. The majority of respondents indicated to spend about less than 5% of their project costs on their BIM needs (77.8%).

The second section of the survey was focused on companies’ exposure to BIM technology and their related needs and challenges. This section consisted of three questions, the first asked about companies’ main BIM applications, the second was to collect data regarding challenges associated with BIM applications, and finally the third intended to gather information regarding the BIM tools and programs being utilized in the companies. The analysis of responses revealed that all the participants used BIM for the purpose of clash detection and coordination. The next main application of BIM was spotted in scheduling and 4D visualization cited by 64.7% of the participants. Quality control and Quantification/Estimation came third and forth in the ranking. This is shown in Figure 6 below.

Figure 6. Distribution of Respondents’ Main BIM Applications
Challenges associated with application of BIM in companies from the perspective of the participants were as follow:

1) difficulty with engaging owners in 5D and 6D models and educating them to pay for the services, owners tend to overlook the true value of BIM application in project cost, schedule and quality (3)
2) lack of owner-specific BIM requirements in the project scope
3) difficulty with training personnel and getting acquainted with the multiple software related to BIM,
4) software incompatibility between designers/subcontractors during the design process and building maintenance
5) model incompatibility with regard to the level of details among all the disciplines
6) difficulty with extracting useful information for quantification and estimating purposes
7) lack of subcontractors with BIM capabilities

Among the cited challenges, difficulty with engaging owners and educating them was referred to as the main challenge by the respondents with a respective weight of 33.3%. The rest shared an equal weight of %11. The last question of the survey, asked participants about the programs they use for their BIM needs. The majority of respondents (73.7%) indicated using Autodesk Revit Architecture and Autodesk Navisworks for the purpose of modeling, coordination, and clash detection. This is shown in Figure 7 below.

As shown in Figure 7, 63.2% of the participants cited other software tools to assist them with their BIM needs. These additional tools are shown in Figure 8. As shown in the graph, among the tools other than the mainstream programs, Google Sketch-up, DProfiler, Innovaya, and Synchro were the most popular ones.
Conclusions

This study investigated the current state of practice with regard to BIM modeling in the construction industry, the challenges associated with its application, and the current expectation from new construction engineering graduates to be included in a tentative BIM course syllabi. The study methodology included four sequential efforts. The first was to perform a comprehensive literature review, the second was to form a brainstorming committee to design the structure of the survey, the third was to develop an online survey, and finally the forth was to perform a pilot study before the final dissemination of the survey. The sample population for this research study was the members of TEXO construction association.

Based on the assessment of the results, the major applications of BIM technology were identified in two areas. The first major area was clash detection and coordination while the next was scheduling and 4D visualization. Quality control and quantification/estimation were ranked third and fourth. Consequently these areas of BIM applications are proposed to form the backbone of a new tentative syllabus for BIM education for construction students. This is mainly due to meeting the existing BIM needs/challenges in the industry. Also it is believed that incorporating these high demand subject areas will significantly contribute to the effectiveness of the course. In addition, the inclusion of integrated project delivery concept in the course syllabi will have a crucial role on properly highlighting BIM modeling values in project cost, schedule and quality.

These results were also aligned with the previous studies by Ku and Taiebat [20] where they cited constructability and visualization as the two major areas of BIM implementation and Taiebat and Ku [22] where they indicated constructability and visualization as the main expectation from new hires for immediate needs and Model-based estimation and cost control as
the main expectations from new hires in the near future. It should also be noted that according to their lexicon, clash detection was included in constructability tasks.

This study also revealed a significantly low rate of 0 to 5% for companies’ average annual ratio of their BIM application expenditures to the cost of their projects for majority of respondents. This contributes well to the high rate of return on investment for BIM application in construction industry that has been frequently cited in the literature [3].

Furthermore this study highlighted a multitude of challenges associated with application of BIM in construction companies among which the lack of owner involvement was cited to be the most prevalent. Lastly, this study pinpointed the popular software tools that are currently utilized by construction companies for BIM applications. According to the responses, the majority of survey respondents cited Adobe Revit Architecture and Adobe Navisworks as the most popular BIM software tools. This result confirmed the result presented by Taiebat & Ku [23]. Also apart from the mainstream software tools, Google Sketch-up, DProfiler, Innovaya, Synchro were detected to be noticeably popular among the companies.
References


