AC 2012-4868: INTEGRATING BUILDING INFORMATION MODELING (BIM) IN TEACHING PROJECT SCHEDULING AND CONTROL

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Integrating Building Information Modeling (BIM) in Teaching Project Scheduling and Control

Abstract

In order to determine how to integrate Building Information Modeling (BIM) with current construction engineering education, this paper reports a suggested approach of integrating BIM in project scheduling and control in various courses within the current construction engineering curriculum. The methods used are to find (1) how, when, and how much BIM knowledge should be introduced, and (2) how a course framework should be set up. It was found possible to use an existing construction curriculum to fully teach and apply BIM tools. Although the proposed approach still needs a full assessment with more rounds of teaching practice and modification depending on feedback being obtained from students and the construction industry, this pilot study can provide some insight and generate further discussion to teaching similar contents in other construction engineering programs,

Introduction

Technology and new tools always play an important role in the construction process. Usually, employers in the construction industry expect new employees to have a better capacity on new technologies. It is crucial that students in construction engineering programs have an opportunity to learn about the most current technologies that are used in the construction industry. Building Information Modeling (BIM) is one of such technologies and has obviously been used by the construction industry. With BIM, the traditionally used two-dimensional (2D) drawings in the construction industry is replaced with a data-embedded three-dimensional (3D) model that can directly generate lists of materials, quantity take-offs, preliminary schedules and of course the 2D drawings if necessary, working together with other computer software [1]. Local construction companies and the Industry Advisory Council for construction programs provide intensive feedback and suggestions regarding the needs and uses of BIM technology. More and more construction companies are integrating BIM in their construction project design and management process, especially for project scheduling and control. Accordingly, more and more design firms and contractors who regularly hire our construction engineering students are asking for an expertise of BIM from students and are expecting BIM knowledge and capability from new graduates of construction engineering programs. More calls from those companies are asking the programs for recommendations of "BIM" students. Obviously, having BIM skills will provide construction students a positive element when they enter the construction industry and for their future construction career. Therefore, adopting BIM to construction curriculum is necessary and beneficial. However, a change of technology contents in courses requires significant updates on an instructor's knowledge and much time and effort are required. This paper reports a suggested approach of integrating BIM in training construction engineering students to obtain knowledge and skills of project scheduling and control in various courses within current construction engineering curriculum, with a layout of course framework.

Background of BIM Technology

As discussed in the literature[2], many definitions of BIM are available in research and practice depending on how people use it. Probably the most popular definition is that BIM is "a model-based technology linked with a database of project information" (American Institute of Architects) [3]. One can easily understand and relate BIM to a once popular technology of Object-oriented CAD [4], which provided much project information with 3D models and allowed users to visualize the project before it is actually built. A new industry standard called National Standard for Building Information Modeling (NBIMS), developed by the National Institute of Building Sciences (NIBS), "allows all the users of building information models to be able to easily utilize the information[5]" by standardizing the data formatting of BIM. However, the construction industry does not only treat BIM as a technology tool, but rather defines it as a process. It is true that BIM is a tool that allows viewing project data and information directly on a 3D model. It does not stop here though. Information carried by BIM models are reused over and over throughout the entire design and construction process among different project parties. Additionally, these models may be updated each time they are used and these updates are shared among all users instantly with proper levels of authorization. Moreover, BIM is integrated with many existing computer programs in the construction industry such as software for construction estimating, scheduling, and project management. These functions of a BIM ultimately allow updates on construction documentation done directly on BIM models[6] and therefore provide much better project scheduling and control – a key component of managing a construction project.

Statement of Needs

Currently, it is very typical for an architecture program to have BIM courses in its curriculum. In a construction engineering undergraduate program, however, it is not likely to have a BIM course that covers all the details that fit the industry need. Actually, an independent BIM course requires many components from other courses; therefore, it might not be too hard to establish such a course but is hard, if not impossible, to make students realize BIM is a process that has many applications involved from other courses as well. Also adding or deleting courses might be a challenge under the current accreditation system of construction engineering. In our construction programs, within recent years, concepts, functions and techniques of BIM, have been briefly introduced to students in many different ways but in pieces here and there. However, it is desired by the student and their potential employers to set up a systematic approach to adopt BIM technology and process into the construction engineering curriculum.

Instead of establishing an independent BIM course, this paper proposes an alternative approach to integrate BIM within a current construction engineering curriculum, regarding project scheduling and control, by providing BIM components in various courses gradually. Discussions in the paper are to find how, when, how much and at what levels BIM knowledge and applications should be introduced and taught. The authors believe that a method of gradually introducing undergraduates to BIM and its applications through several sequenced courses should be one of the best approaches for students to fully understand project scheduling and control with BIM skills.

Methodology

The approach of integrating BIM in several classes is proposed below. This approach integrates BIM technology in a systematic way that helps student learn the knowledge and skills of project scheduling and control in many different perspectives. It can be forecasted that students can gain BIM knowledge and skills more thoroughly within a current curriculum. The steps are listed below:

- Determine the goals to be achieved by applying BIM into teaching.
- Choose method(s) to apply BIM into courses. At this step, it was determined to use several existing courses.
- Employ different teaching styles. The selection of teaching style depends on various stages of BIM knowledge and applications, the nature of courses, and the teaching expertise of course instructors.
- Set up a course framework that integrates BIM concepts and determine changes to be made to the current construction courses.
- Determine assessment and evaluation methods of student learning and teaching effectiveness.
- Report the results to program constituents.

Outcomes and Course Framework

After talking to many construction professionals, it was determined that two major BIM concepts and skills must be learned in order for students to provide benefits to the construction companies quicker. The first one is BIM software operations. The second one is, more importantly, about changes of construction engineering processes due to BIM implementation. In the classroom, these two skills can be gained by not only relating students' basic training along with construction activity requirements but also with a focus toward skills of project scheduling and project control.

Course layout and components can be established similarly to the one in the literature[7, 8]. BIM has to be learned while students are learning typical construction knowledge with a concentration on skills of project scheduling and project control along with other aspects such as field layout and management. As discussed above several related courses in the existing curriculum of a construction engineering program are used. Courses selected based on the nature of courses are Graphic Communication (CAD), Construction Planning and Scheduling, Construction Contract, Field Management, and Construction Information Technologies and/or Senior Design (Capstone). The development of instructional materials is critical, and is different at each level of teaching depending on teaching style. It was determined that formal lecture, hands-on laboratory, guest speakers, and comprehensive/intern projects are employed in order to achieve active and cooperative learning, along with the nature of each course and instructor's preference.

First, students must know the BIM basics before they can use BIM for project applications. Similar to many construction curricula, our construction engineering and management programs

have a course of Graphic Communication (CAD). In the past, the focus of this course was using AutoCAD to produce 2D drawings with basic sketching skills and graphic theories. Now the course is reshaped with BIM components and provides a basis for BIM applications in other courses later. Also the classroom is equipped with various BIM programs (Autodesk's Revit[9], Bentley's Architecture[10], and Graphisoft's ArchiCAD[11]). Some professional tutorial materials or instructional materials from professional workshops are used to speed up the class progress without deleting too much of the original content of the course. Although in-class work focuses on the basic operations of software, a final class project is used without requiring students to understand the project in this stage. The final project is based on an actual construction BIM project obtained from a local engineering/construction firm. Typical components covered during this process are outlined as:

- Define common BIM terminology and learn basic operation commands.
- Obtain BIM modeling skills.
- Compare BIM with existing 2D CAD.
- Discuss how BIM is used in the industry and benefits that can be provided.

Secondly, in later courses, students can apply what they learned from CAD class to detailed construction applications. Courses selected are Construction Surveying, Construction Planning and Scheduling, Construction Contracts and specifications, and Construction Management. Typical components covered during this process are outlined as:

- Apply BIM in visualization.
- Practice using BIM for spatial coordination.
- With a real project, simulate using BIM for scheduling and project control as well as resource management.

BIM technology can be used for subcontractor coordination. Subcontractor selection is important for a general contractor and will become an important parameter in the project scheduling and control process. Subcontractors' qualifications and coordination can be enhanced by applying BIM models. The models with different levels of authority provide better coordination and updates among subcontractors. In the classroom, instructors can simulate different parts of the models based on the work scope of a subcontractor. They can then ask students analyze the impact among subcontractors within models. Reflected on a scheduling chart, some adjustments will be automatically generated due to changes on models.

The construction site layout is a very important aspect of project scheduling and control. Traditionally, site planning is done by checking various documents such as drawings, specifications, area regulations, and waste control along with construction systems. BIM models can automatically and virtually layout the site in its best way and generate scheduling for material delivery and others in a more accurate way. In the classroom, in order to make models work, industry inputs must be used. A set of real project data is preferred for students working as a group. Ideas from different groups can be exchanged as to practice the construction change

orders.

Of course the most critical component in the project control process is construction estimating and scheduling[2]. The detailed dimensions, specifications, and product information embedded in BIM models allow a detailed and accurate takes-off generation. A cost estimate can then be produced by considering the waste factors and the overhead margin that is applicable to certain contractors by either on BIM models, or by exporting takes-off to specific estimating software such as Timberline or just a spreadsheet. The former requires working together with other estimating programs [12] such as Timeline via Innovaya Visual Estimating[13]and Vico Software Estimator[14] via a plug-in tool. Then, similar information can be exported to scheduling programs such as Microsoft Project or Primavera P6 generating a construction schedule. Now BIM models contain project components, specifications, quantities, cost and schedule information, in addition to the typical design information that can be found in 2D drawings[15]. Obviously and excitingly, now every project team member has this model during the entire construction process and all updates will be shared[16]. With actual progress measurements an optimal project control can be easily and accurately achieved. Overall, the project can be scheduled and controlled more efficiently. In the classroom, this process is simulated by deploying a real past project with real project information provided by a local contractor.

Lastly, in the Construction Information Technologies or Senior Design course, after students have learned the BIM basics and applications, they have an opportunity to work with a local firm to apply their knowledge and skills to a real construction project. During this process they will get familiar with:

- Identifying challenges of applying BIM for project scheduling and control.
- Developing an action plan in the future for a typical construction firm.

The class project mentioned above requires students to generate the following project scheduling and control components:

- Overview of the project
- Project start and finish dates,
- Project milestones
- Project cost
- Assumptions or results of the Request for Information
- Work Breakdown Structure (WBS) and the code numbering system as well as BIM model components
- General project specifications contained in the model
- Project resources including labor, material, equipment, and subcontractors
- Construction sequence and initial schedules
- Construction crush analysis

- Mobilization
- Site layouts including project waste removal and disposal, on-site material storage, material delivery checks, and utility connections
- Safety and quality plans
- Temporary structures
- Cost estimates and cost reports
- Project progress schedules
- Controlling methods between schedule and field progresses
- Explain any discrepancies in the schedules or changes
- Establish a typical BIM action plan for an average contractor

After this entire learning process, students should be able to:

- Realize the importance of BIM and potential benefits BIM provides.
- Understand the terminology of BIM and its capability to meet the needs of the construction industry.
- Recognize the scope of construction activities for BIM that are applicable and potential impacts by BIM to the existing construction process regarding project scheduling and control.
- Select appropriate software and hardware for an action plan of using BIM to improve construction performance.
- Locate future study directions to reshape project scheduling and project control process.

Conclusion

An integrating approach was proposed to bring BIM to construction engineering education. The paper has addressed needs, methodology, and course framework to help students learning BIM in order to meet the construction industry's requirements. The framework of integrating BIM in project scheduling and control in various courses defines how, when, and how much BIM knowledge should be introduced. It was found possible to use the existing construction curriculum (instead of establishing a new independent course) to fully teach and apply BIM tools. Integrating the BIM technology and its applications in the existing courses prevents a program from frequent modifications of its curriculum. Students will gain the knowledge and skills in an effective and efficient way. Real projects used in the classroom will help students better understand how to plan, schedule and control the construction project. It is believed that gaining BIM technology will benefit the students' future career, while meeting the ABET accreditation objectives of (j) a knowledge of contemporary issues, and (k) an ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

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