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Teaching Building Information Modeling in Construction Management through a Process-Oriented Approach

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ABSTRACT
The development of building information modeling (BIM) is widely acknowledged to be having a growing impact on construction management professionals' duties in the architectural, engineering, and construction (AEC) sector. Construction management professionals' information management practices are impacted by the usage of BIM as the switch from 2D drawing to BIM is more of a process change. BIM education in construction engineering and management (CEM) curricula needs to place more of a focus on teaching BIM as a technique for process improvement than just a technology. To teach the next generation of construction managers how to comprehend building information modeling (BIM) and use an existing BIM in plan execution for building construction projects, a graduate-level course named "Building Information Modeling for Capital Projects" was developed. This paper describes the implementation of this course. Students in this project-based course learn how to use building information modeling (BIM) ideas at every stage of a building's life cycle. This article presents a process-oriented teaching technique that was used in the course.
Keywords: Build Information Modeling (BIM), Process Oriented Teaching, Construction Management, Construction Education

I. INTRODUCTION

Since its introduction to the architectural, engineering, and construction (AEC) sector about ten years ago, building information modeling, or BIM, has undergone constant evolution. According to **Eastman et al.** (2008) and **Krygiel** and **Nies** (2008), BIM is recognized as an inventive methodology and comprehensive procedure that facilitates effective design, information archiving and retrieval, model-based data analysis, visual decision making, and stakeholder communication. While many definitions of BIM have been offered with varying emphasis, most academics and practitioners feel that BIM is a method that, when used across the project life cycle, may help projects succeed rather than a technology or product (Autodesk 2003). AEC companies use BIM in nearly half of their projects, according to McGraw-Hill Construction's 2009 Smart Market Report. The largest obstacle to BIM adoption is a lack of proper BIM training. Given the widespread recognition of Building Information Modeling (BIM)'s significance in the AEC sector, it is imperative that upcoming construction management professionals acquire BIM knowledge during their university education.

To prepare the next generation of AEC professionals to comprehend BIM and use an existing BIM in plan execution for a building construction project, a graduate-level course named "Building Information Modeling for Capital Projects" was developed. This paper describes the implementation and lessons learned from that course. Instead, then using BIM as a design tool, this course emphasizes using it as a collaborative process. Since all the models used in the course were given, preparatory modeling was not required. Students were required to complete activities such as model-based scheduling and 4D simulation, energy modeling, mechanical, electrical, and plumbing (MEP) design coordination, and cost estimation using pre-existing models. To: (1) highlight how important it is to comprehend BIM as a process; and (2) give students active learning opportunities by promoting critical thinking and self-directed learning throughout the course, a process-oriented teaching method was used. Lessons learnt from the teaching experience thus far are detailed in the following sections, which also present the process-oriented teaching strategy for BIM education.

II. LITERATURE SURVEY

Presented to the AEC sector. The transition from two-dimensional (2D) manual drawing to computer-aided design and drafting was a cultural and technological change experienced by designers and engineers. Drawing and designing using AutoCAD became a popular course offered by many undergraduate programs. CAD to BIM is a new transition that AEC professionals must make these days as BIM gains widespread acceptance and acknowledgment. Building Information Modeling (BIM) is a new breed of virtual models that is based on parametric modeling and functions as a database rich in information that holds multidimensional structural elements. Academic institutions are looking for ways to include BIM education in their undergraduate and graduate curriculum in response to this promising technology and industry demands for relevant skills. Although BIM pedagogy is still developing, researchers discovered that BIM is one of the most difficult and recent developments for construction management programs (Johnson and Gunderson 2009; Casey 2008).

In response to the necessity for these talents in business, an increasing number of academic institutions have been incorporating this new technology into their curricula in recent years. Several universities have effectively included BIM education into their curricula, including Penn State, Georgia Tech, University of Southern California, Technion-Israel Institute of Technology, and University of Texas at Austin. According to a survey by Becerik-Gerber et al. (2011), out of 101 AEC programs in the United States, 60% of construction management programs and 81% of architectural schools and 44% of engineering programs provide BIM courses. Design and visualization, particularly the switch from CAD to BIM, are the main topics of BIM teaching in architectural and engineering curricula (Berwald 2008; Denzer and Hedges 2008).

While teaching BIM as a design tool in a Design Studio or modeling course is important, it should also be taught in construction and facility management courses because BIM is defined as "the process of creating and using digital models for design, construction, and/or operations of projects" (McGraw-Hill Construction 2009). BIM's data-rich nature allows the model to serve as an electronic document repository, quantity takeoff tool, model-based computations, collision detection, and energy efficiency analysis in addition to being a digital representation of the design. Thus, in addition to teaching BIM in design education, it's crucial to impart to students the knowledge and skills necessary to operate, maintain, and effectively use the model, as well as the possible applications of BIM application across the project life cycle. Construction management BIM education is relatively recent. Some academic institutions included BIM as a new module (Clevenger et al. 2010; Gier 2008) or as a teaching tool to already-existing courses (Kim 2012; Meadati and Irizarry 2011). BIM is only offered as a new, stand-alone course at a few numbers of universities (Bur 2009; Dupuis et al. 2008). According to a Sabongi (2009) survey, less than 1% of the participating universities provide BIM as a stand-alone course.

It is difficult to teach BIM in construction management for several reasons. First and foremost, it's important to assist students in developing accurate BIM concepts. According to Kymmell (2008), the biggest obstacle in BIM teaching is the issue of misinterpreting BIM ideas. BIM is more than just a fresh piece of software or an independent tool for one field. Thus, knowing how BIM facilitates a building project's cooperation process is far more crucial than being an expert with software (Hietanen and Drogemuller 2008; Kymmell 2008). Secondly, given the rapid pace at which information technology is evolving, it is quite probable that the material covered in the classroom, particularly the practical instruction on BIM software, will become obsolete very soon. Therefore, by emphasizing the learning process rather than just the information, university instructors should lay greater attention on students' abilities to study on their own. Furthermore, throughout the training process, there should be a significant emphasis on critical thinking because BIM is still developing. The authors created the course "Building Information Modeling for Capital Projects" in response to these difficulties, using a process-oriented teaching methodology that is discussed in the parts that follow.

III. PROPOSED SYSTEM

Construction management students will learn the fundamentals of building information modeling (BIM), how to apply BIM as a process and as a fresh way of thinking throughout the project life cycle and get practical experience with BIM software. Group projects and individual assignments will also give students the chance to practice critical thinking and international teamwork. Students who successfully complete this course will be able to: (1) define building information modeling (BIM); (2) explain the workflow of using BIM in the building life cycle; (3) explain model-based cost estimating; (4) conduct 4D simulations; (5) use BIM to lower error and change orders in capital projects; (6) assess how 3D point clouds can support construction and asset management; and (7) conduct building energy performance simulations.

The three main methods of education are group-based learning (question-and-answer sessions, practical exercises, case studies, group presentations, and discussions), individual learning (reading assignments and synthesis reports), and lecture (subject instruction and lab tutorials). This course differs from other attempts in that it emphasizes understanding BIM as a new construction management process and its effects on project success. This is achieved through a process-oriented teaching method and assessment concept. BIM is a technique as well as a technology. Particularly with the growth of information technology, BIM products are also developing quickly; thus, the emphasis of BIM education in colleges shouldn't be on how to use one or more software programs. The utilization of a process-oriented approach enables students to comprehend the function of BIM across all project stages, enabling them to understand why this tool is employed, how it enhances project performance, and how it might be enhanced even more. For instance, the recipes-methods-resources approach, which forms the foundation of model-based cost estimate, is intended to be familiar to students through the model-based cost estimating module. Fall 2010 and Spring 2011 saw the initial release of this module utilizing Vico Constructor and Vico Estimator in conjunction with paperback RSMeans (Waier 2010). In Spring 2013, Assemble was later released as an alternate quantity takeoff software solution to improve user-friendliness.

IV. METHODOLOGY

The course material is arranged into learning modules that address different subjects. Each module has four sessions in it:

1. Topic overview: An introductory talk supported by extra reading assignments.
2. Lab session I: A teaching assistant (TA) leads a step-by-step, hands-on lesson.
3. Lab II: The question workshop is where students ask questions, look for assistance, collaborate in groups, and engage with one another.
4. Delivering and presenting the task, reflecting, and having a conversation

These classes give students a foundational understanding of BIM, practical experience with cutting-edge BIM systems, and the opportunity to collaborate with students from all backgrounds and nations. Groups complete all homework based in the lab. Students divide into groups of three to four at the start of the lesson. Students are urged to form teams with a range of backgrounds and degrees of industrial expertise. The following are thorough descriptions of every lesson in the learning modules.

4.1: Topic Introduction: The purpose of lectures is to give students an introduction to the fundamentals of BIM, equipping them with the information they need to successfully complete course requirements. Topics include design collaboration, construction scheduling, 4D simulation, model-based cost estimates, construction progress tracking with 3D point clouds, and energy simulation. Students are given book chapters, articles, journal papers, and other documents as supplemental learning materials to help reinforce, broaden, and deepen their knowledge on subjects. The teacher gives lectures and facilitates group discussions on a range of subjects linked to the assigned readings or course materials.

4.2: Lab Session 1: All hands-on activities include in-class software tool demonstrations. These detailed instructions are not meant to fully teach students how to use the tools; rather, they are meant to provide them with an introduction to them. To use the tools properly, students must conduct their own independent study. In addition to giving students firsthand exposure to cutting-edge BIM systems, this course teaches them how to learn independently.

4.3: Lab Session II: Workshop: During these lab-based sessions, students can collaborate in groups, share ideas with other groups, and discuss assignment-related problems with their peers, the teacher, or a teaching assistant. Students can improve their communication and social learning abilities through these sessions. The TA creates frequently asked question (FAQ) files throughout the process to provide the students with enough direction. Additionally, these files are kept on file as references for upcoming course development. Every time a new question was asked of the instructor or a teaching assistant, the FAQ file was updated, and the most recent version was uploaded to the course website. A few of the often-asked questions include, "How can I tie the same activity to various activities.

4.4: Reflection and Discussion: It is mandatory for every group to provide a report that includes an overview of their work, a discussion of the challenges they faced, their solutions, and a wish list for the next technological advancements. For the duration of the course, each team selects one task to deliver. Using process-oriented training requires this session. Students are encouraged to share and talk about their experiences modifying software, how specific tasks are completed, the advantages and difficulties of implementing BIM during the process, group collaboration techniques, and recommendations for future advancements in the technology utilized. "How to incorporate sculpture installation analysis in the 4D model" and "What are some characteristics of a project that would benefit most from a 4D system" are a few of examples of the debate points.

V. MODULES

5.1: LAB BASED ASSIGNMENT AND LEARNING MODULES

Model-based cost estimation, scheduling, and 4D simulation, MEP design coordination, 3D points clouds, and energy simulation were the learning modules created for this course. Every learning module has one lab-based task, as was previously mentioned. There are designs, specs, models, instructions, and all required software available. In Fall 2010 and Spring 2011, the computer-aided estimation activities for the model-based estimating module were carried out using Vico Constructor and Vico Estimator; in Spring 2013 and Fall 2013, Assemble Systems and Autodesk Revit were utilized. Microsoft Project was utilized for scheduling, with Primavera as an alternative. MEP design coordination and 4D simulation were conducted using Autodesk Navisworks Manage. The 3D Point Clouds module uses Autodesk Photofly (now named Autodesk 123D Catch) and Autodesk AutoCAD.

5.2: MODULE – BASED COST ESTIMATING

This module presents the idea of model-based cost estimates to students by automatically connecting a quantity takeoff from a given model to an already-existing cost database. For a given segment of a commercial structure, teams oversee calculating the cost of constructing the columns, beams, slabs, walls, and windows. Students begin with a project file indict (building SMART 2013) format, refer to blueprints for design specifications, and create an estimate based on the specified scope of a structure. To produce a complete recipe for the practice of cost estimating, teams must select one aspect and identify the resources, construction techniques, and related costs using RSMeans (Waier 2010). Along with an estimate, the groups are invited to talk about issues such:

- "What are the advantages and restrictions of utilizing Vico Estimator for cost estimation?"
- "How was the estimating task improved by this tool?"
- What aspects of the system require enhancement?
- "What are the things to keep in mind when estimating with Vico Estimator versus paper-based estimation?"
- What stage of the design process would the present iteration of this tool be most helpful for (i.e., is it more helpful for 30% or 90% full design)?

5.3: SCHEDULING AND 4D SIMULATION:

Because BIM is data-rich, the model acts as a store for data and makes it simple and accessible to add, remove, update, or edit digital data at any moment. Through the integration of a 3D model with time, BIM facilitates a four-dimensional (4D) simulation. 4D modeling enhances students' comprehension and learning of building processes by offering a virtual reality environment.

Students are required to utilize Autodesk Navisworks Manage 2012 for 4D modeling and Microsoft Project for scheduling during this subject. With the help of this task, students will learn how to depict and evaluate building processes by connecting actions to model components. For the construction of a portion of a commercial building's slabs, walls, columns, beams, and windows, they are required to create two schedules. On the off chance that there aren't any significant time constraints at the project site, the first timetable should be made. An enhanced fast-track timetable with the goal of finishing the project in the shortest amount of time should be the second schedule. Activities and procedures related to the installation of a sculpture should also be included in the second timetable. In order to find any potential constructability difficulties in their schedules and areas for improvement to deliver the facility in less time, the students are requested to incorporate both schedules into a 4D environment and examine the construction processes developed. On the day of the presentation, the benefits and difficulties of utilizing 4D simulation for scheduling and planning are covered in both the reports and the classroom.

5.4: MEP DESIGN COORDINATION:

The AEC industry's most common usage of BIM now is for MEP design coordination, which is typically led by the general contractor (GC) and coordinated among the subcontractors. Students use Autodesk Navisworks Manage to investigate BIM-based conflict detection in this assignment. The training module explains how to utilize Navisworks to automatically find conflicts between transactions and examine which of the automatically recognized disputes are true positives through a practical example. The software's ability to check for conflicts instantly impresses students, but this module's main goal is to highlight the fact that BIM is not a flawless tool.

Evaluation type	Deliverable	Value (%)
HW 1: manual cost estimating	Individual assemblies estimate	5
HW 2: scheduling and 4D simulation	Group presentation + report based on lab assignment	10
HW 3: MEP design coordination	Group presentation + report based on lab assignment	10
HW 4: 3D point clouds	Group presentation + report based on lab assignment	10
HW 5: energy simulation	Group presentation + report based on lab assignment	10
Case study	Group presentation + report	15
Quiz	Quiz	10
Synthesis report	Individual report in the format of a conference paper	20
Class participation	Class participation (instructor's discretion)	10

Table No. 1: Evaluation Summary Table

The identification of actual positive collisions is the most difficult and time-consuming task in clash detection. Experts and scholars concur that, as compared to the antiquated, labor-intensive, two-dimensional (2D) design coordination method, MEP coordination using BIM results in reduced installation rework. It's also critical to note that, although it comes at the expense of false positives, the automatic collision detection procedure utilizing BIM allows for a more thorough identification of clashes (Leite et al. 2011). This program challenges students to think critically and not rely solely on technology by highlighting the existence of false clashes and outlining the basic efficacy of automated collision detection.

5.5: ENERGY SIMULATION

In this module, the teams are required to use Autodesk's Green Building Studio to analyze energy usage and simulate the energy of an existing building. It is the responsibility of the teams to investigate a design approach that will increase the building's energy efficiency and lower its energy costs by at least 20% when compared to the basic model. By altering the characteristics of the roof, wall, or glass, the students maximize energy performance and assess which, in terms of energy savings, would be a better investment for the building owner. The team's ultimate savings % will not be used to evaluate this assignment; instead, the report's analytical method and the lessons learned from the energy simulation process will be taken into consideration.

CASE STUDY, Through the case study, students may interact and exchange ideas with professionals in the field, get insight from real-world experiences, and reinforce their classroom learning with applicable applications. Under the guidance of the course teacher, students are expected to get in touch with one organization directly and create a case study on a project that used BIM in some capacity. They must talk about the following issues: what obstacles did the project team face that prompted them to use BIM? What technologies were employed? Why were they relevant to the issue they were trying to solve? How was BIM integrated into the project and at what stage of the project life cycle? How did these technologies contribute to the project's success? Were there any quantifiable results?

SYNTHESIS REPORT, in order to create a synthesis report in the style of a conference paper, students select a topic that was covered in class or any other BIM-related topic of their choice, whether it be technical, managerial, case study-related, or a mix of these. It's a crucial chance to hone critical thinking skills, provide original ideas on BIM-related subjects, and summarize the knowledge they've gained during the course. Additionally, it gives students the chance to hone their academic writing abilities and do in-depth, independent research on subjects that interest them. At the start of the semester, students discuss their chosen themes with the course teacher; by the middle of the semester, they provide an outline and status report. At the conclusion of the semester, a final report is required.

COURSE EVALUATION, fall 2010 marked the beginning of this course's offering. It has since been provided and thoroughly reviewed five semesters: Fall 2010, Spring 2011, Fall 2011, Fall 2013, and Fall 2013. Only a small number of students have been admitted (23 in Fall 2010, 12 in Spring 2011, 22 in Fall 2011, 21 in Spring 2013, and 23 in Fall 2013). Many of the students are master's or Ph.D. candidates from the University of Texas at Austin's Department of Civil, Architectural, and Environmental Engineering's Construction Engineering and Project Management (CEPM) graduate program. Two surveys were carried out, one at the start of each semester and the other at the end, to record the student profiles and the learning outcomes of each semester.

VI. FINAL RESULT

The model-based cost estimating assignment was eliminated in the fall of 2011 in order to achieve a generally balanced workload for each lab-based project. This was because students were spending excessive amounts of time navigating the program because of malfunctions and operational concerns. In the spring of 2013, this module was once more made available using Assemble Systems. Furthermore, in response to student requests, an energy simulation model was introduced to the curriculum in the spring of 2011, a 3D point cloud module was added in the fall of 2011, and a Revit modeling module was added in the fall of 2013. Based on experience, the following software programs have the best usability and learning curves for this course: Microsoft Project for scheduling, Autodesk Navisworks for cost estimation, and Assemble Systems.

Case Study, Students' recommendations also informed modifications to the case study requirements. Now, rather than two case studies, groups are expected to complete just one. In order to understand more about the project and to interact and engage with people in the field, students should get in touch with the firm directly. This will allow them to gain insight from real-world issues and concerns.

Quiz On Reading Assignment, as most of the activities are completed in groups, a midterm quiz was included to evaluate individual student learning. The quiz, in the instructor's opinion, aids in differentiating students' performance on self-directed learning and promotes class discussions on the reading assignments in groups.

Progress was shown in the survey results, which indicated that the course was developed and refined with consideration for student comments. For instance, in the Fall of 2011, about half of the students said the course structure is enough and doesn't require any further work. Some typical ideas include having additional guest lecturers, field excursions, or other practical exposure to BIM usage in actual projects or introducing new software tools and methodologies in the classroom. As was previously noted, numerous student proposals have been effectively implemented. Suggestions from students will be carefully examined, and the course will be updated often to meet changing demands.

Industry Perspectives, Although the introduction of BIM is causing a strategic and cultural transformation in the AEC sector, owners and organizations in this sector are seeking personnel with a high level of BIM expertise. Prior to entering the workforce, university education offers an excellent opportunity for students to acquire a foundational understanding of BIM. Enhancing comprehension of industry demands for BIM education will assist instructors in crafting their BIM courses in a way that will be advantageous to the industry. To find out what the industry expected of Construction Engineering and Management (CEM) graduates in terms of BIM skills, a survey was created. The United States Army Corps of Engineers (USACE), guest lecturers for the BIM class, and the Austin BIM Peer Group were all emailed the survey. 33 replies in all were obtained. Owners (9%), design companies (31%), general contractors (27%), subcontractors (9%), and others (24%; such as the federal government) are among the responders. In the history of the companies, an average of 78 years have passed. Lead architects, senior project managers, BIM directors, BIM coordinators, and CAD/BIM managers are among the respondents.

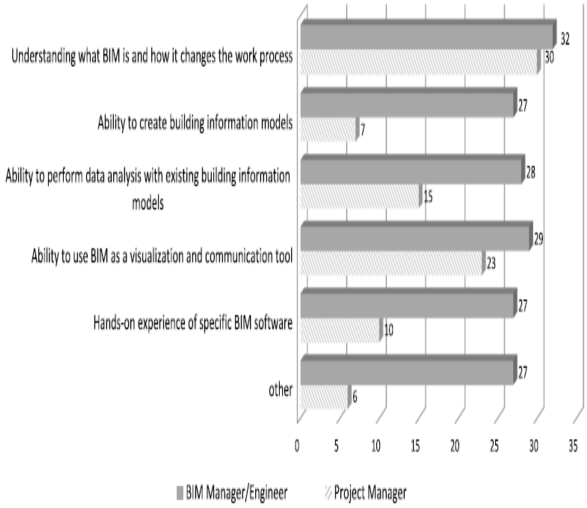

Table 2: BIM Knowledge Requirements

In the survey, participants were asked to verify that they met all the BIM knowledge criteria for their intended roles as project manager and BIM manager/engineer. Fig. 2 presents the findings.

According to the survey results, a BIM manager or engineer must be able to undertake data analysis using current BIMs, use BIM as a visualization and communication tool, and comprehend the basic idea of BIM and how it alters the work process. A certified BIM manager or engineer must also possess the capacity to generate BIM and practical knowledge of a particular BIM program. Additional prerequisites consist of:

- Recognize code concerns and trends in building.
- Enhance data interchange and compatibility between various software programs and file formats, laser scanning and surveying.
- The capacity to promote conventional building operations by facilitating the exchange and utilization of the models and information they contain.
- Possess knowledge of databases and data structures, proficiency with databases.

It is ideal for a BIM manager or engineer to have three to five years of experience. While some firms only demand one to two years of experience for BIM engineers, a BIM management role typically takes five to ten years of expertise.

Although a project manager (PM) may not utilize BIM directly, they must comprehend it and how it affects or is affected by working processes. According to 91% of respondents, a project manager must be aware of how BIM alters the workflow. According to 70% of respondents, a project manager ought to be able to conceptualize BIM and apply it in communications. In the opinion of 45% of the respondents, project managers should be proficient in BIM data analysis. Most firms do not require project managers to have modeling and software navigation abilities. "The PM of the future will be 'BIM Enabled,' which means he/she should be," stated one reply.

VII. CONCLUSION

The course design, teaching strategies, and learning objectives of a graduate-level course on BIM for capital projects are documented in this paper. This course places a strong emphasis on mastering BIM as a crucial procedure that affects a project's overall success in a number of ways. It is significantly more crucial to comprehend the fundamental principles of BIM and its broad impacts through specialized training in creative and critical thinking than it is to become an expert user of a particular piece of software. After taking the course across five semesters, the three key things I learnt were (1) process-oriented teaching and learning, (2) the course design's modular structure, and (3) ongoing monitoring of learning outcomes.

By fostering self-directed learning and critical thinking throughout the course, process-oriented education gives students active learning experiences by highlighting the value of understanding the process rather than the outcome. Students receive well-structured information through lectures, team-based learning, and individual study. They also could practice learning and working in a collaborative setting with the addition of self-reflections. Higher education should focus more on the why and how of emerging technologies and trends like BIM than the what (e.g., Why is the BIM process better than the conventional procedure?). What makes the software program excellent or bad? How can it be made better?). Knowing how to use a tool to study and think would be more beneficial for students than just knowing how to use it.

This course's modular structure allows for flexibility in the course material while also establishing a uniform format for each learning module. Through lectures, readings, lab tutorials, lab-based activities, reflection, and conversations, students receive sufficient training for each module. The content of learning modules may also be changed as needed.

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