Integrating BIM into Construction Management Education

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Abstract

Construction education needs to embrace the opportunities and overcome the challenges presented by Building Information Modeling (BIM) to remain current and relevant. Although a growing number of university architecture, engineering and construction (AEC) programs have begun to offer courses that include BIM content, few programs have strategies in place to fully integrate BIM across curriculum. This paper presents Colorado State University's (CSU) Construction Management Department's approach to promote BIM-enabled learning. Fundamental to this effort is balancing student and industry desires and faculty domain expertise, while leveraging industry support and guidance. This paper presents the authors' development of exploratory teaching modules and preliminary research findings to better understand and evaluate the contribution of BIM to students' educational experiences.

The role of BIM as both tool and method in education and industry is not yet fully understood. Industry leaders understand that BIM requires new working processes and are eager to leverage BIM in the education of their future employees. Our pilot program plans to include a course that focuses on the modeling aspects of BIM as a software tool, and currently focuses on the development of "BIM teaching modules" to demonstrate the power of BIM processes across construction management practices. These modules, being developed in collaboration with industry, highlight how BIM impacts best practices and core competencies in a range of applications, while not changing the underlying principles of construction. Through on-going investigation and pilot implementation, the authors seek to understand and accommodate the imminent transformational shift in construction management education and evolve curriculum to facilitate better learning and understanding through the use of BIM.

Keywords

BIM, curriculum, learning environments, construction management

1. INTRODUCTION

Nearly 50% of the construction industry is using BIM today. Industry members are generally enthusiastic and propose that BIM can provide better project construction outcomes, reduced errors, omissions and conflicts, and assist business development. Employers who currently use BIM seek students capable in and comfortable with BIM processes, but do not require software expertise. The effective inclusion of BIM into the construction education curriculum will be critical in the preparation of future employees for industry (McGraw Hill, 2009). Educational institutions currently lack strategies and capabilities to effectively introduce and lev-

erage BIM into existing or future coursework. Proper training currently presents a significant hurdle on the path to increased adoption of BIM in industry (McGraw Hill, 2008).

Until recently architecture programs have led in the implementation of BIM into curriculum with engineering and construction programs lagging significantly behind. Sabongi and Arch from Minnesota State University recently conducted an exploratory study of members of the Associated Schools of Construction. Of the 119 universities and colleges polled, 45 responded. Only 9% of respondents currently address BIM in their coursework. Less than 1% teach BIM as a stand-alone class. Reported problems of implementation include: no room in the current curriculum for additional classes (82%), the impossibility of adding additional required or elective classes and still graduating in eight semesters (66.7%), problems with faculty having the time or resources to develop a new curriculum (86.7%), and the availability of BIM specific materials and text books for use by the students (53.3 %) (Sabongi and Arch, 2009).

On-going efforts to incorporate BIM into construction management curriculum currently documented in literature include the use of BIM software in an undergraduate capstone class at Auburn University in Alabama. Construction students at Auburn are required to learn a BIM software package of their choosing and complete their capstone project schedules and estimates accordingly. Students report a greater ability to communicate with team members from their adjoining architecture department, as well as a greater overall ease in completing the entire project (Taylor, Liu, and Hein, 2008). Additional research studying this use of BIM for educational purposes reports that students gain greater understanding of construction divisions, most particularly mechanical, electrical, and plumbing due to BIM's ability to detect clashes and provide visual details (Azhar, Sattineni, and Hein, 2010).

Other research documents the use of BIM by the construction management department at California State University, Chico for homework assignments in cost estimating. Results of the research conclude that the use of BIM increased the overall speed and accuracy in which estimating students completed a quantity take-off assignment. The author of the study, however, recognized that lab skills particular to the BIM software will offer the greatest challenge to the students, and that the overall success of using BIM in construction education is still unknown (Gier, 2008).

While limited initial research regarding the use of BIM in construction management education suggests promise and potential, current educational efforts struggle to meet industry or academic expectations. Results of several university studies demonstrate dissatisfaction among students and educators with the advancement of technology based curriculum development; especially BIM (Sylvester and Dietrich, 2010; Sabongi and Arch, 2009).

To address this challenge, the Construction Management (CM) Department at Colorado State University (CSU) is currently piloting a program to test a strategy for the wide-spread adoption of BIM across its construction management curriculum. In a united effort, six faculty members, each with different domain expertise, are serving as co-PIs overseeing research and implementation of the following two stage strategy:

- Replace the Department's existing CAD class with a BIM class at the freshman level. The course objectives will be to introduce students to the techniques and capabilities of a specific modelling program, and to arm them with basic BIM modelling skills.
- Develop and integrate BIM teaching modules into numerous upper level courses (e.g., structures, estimating, safety, scheduling, construction methods) to demonstrate BIM's effectiveness as a new working process. Include recurring opportunities to apply basic BIM modeling skills in a variety of applications through these teaching modules while high-

lighting industry best-practices and innovative opportunities. Leverage information in model databases to streamline communication and reduce redundancy in class exercises.

This paper discusses faculty motivation, summarizes student input, outlines academic material development, and presents preliminary student feedback for this strategy.

2. STUDENT INPUT

In spring 2010, the authors administered a survey that included 133 respondents (juniors and seniors) to seek the input of students with respect to the incorporation of BIM into the Department of Construction Management's curriculum. The survey explained that the Department is in the process of incorporating BIM and asked the students how to best accomplish this integration. The question presented the following three options to the students and also encouraged the students to provide approaches other than these options if they thought those approaches to be better:

1. Create a standalone BIM course that discusses all different uses of BIM with a focus on the use of software
2. Add BIM modules to the existing courses to discuss how BIM is relevant to the subjects presented in those courses, or
3. A combination of the two approaches mentioned above.

A majority (62%) of the students chose option (3) suggesting that a standalone BIM course offered as a lower level class would introduce the BIM concept and the BIM software. According to the students, this course would enable them to learn how to use the software at a simple level, mainly as a modeling/drawing tool. Students, further, suggested that this course could replace the existing CAD course. Students suggested that after taking this course and learning basic software skills, they should be exposed to BIM modules in specific higher level courses to expand their understanding of how BIM can be implemented to improve different aspects of construction management. Students noted that this approach would keep them updated with the software as well since they will be exposed to BIM and BIM software in these modules offered throughout their college tenure. Students also mentioned that this is the reason why BIM standalone course should replace the CAD course; i.e., they forget the CAD software since they do not use it after their freshman year. It is also important to note that a few students, along with the approach above, suggested adding a BIM capstone course. This way, students would first learn the software in a standalone BIM course, then understand the application of BIM and BIM software through the BIM course modules, and finally get a chance to fully utilize BIM in a capstone course that brings everything together.

The creation of a standalone BIM course (1) was the second choice of the students (29%). The main reason that these students did not want BIM modules was that they believe that existing courses already cover a significant amount of information; and adding BIM modules would make those courses overloaded. Only 9% of the students selected option (2), adding BIM models to existing courses only.

3. PILOT IMPLEMENTATION FOR CONSTRUCTION CURRICULUM

Efforts are underway in to implement option (3), a combination of creating a stand-alone course and adding BIM teaching modules across existing coursework. This paper reports on preliminary efforts involving the development of BIM modules for individual core curriculum classes and does not focus on the addition of an introductory, stand-alone, BIM course since this stage of the strategy has yet to be implemented. To date, BIM-enabled teaching

modules are under development for core construction management courses with a focus on structures, mechanical, electrical and plumbing (MEP) coordination and sustainability. Additional courses under consideration for the development of teaching modules include: pre-construction, cost estimating, scheduling, contracts, and material and methods.

Development of these modules is partially supported by direct academic-industry partnerships. Significant support has been provided by Mortenson Construction through the Mortenson Faculty Scholar program and consecutive grants from CSU's Institute of Learning and Teaching (TILT). In kind support also includes on-going access to TILT's educational resources and expertise in e-learning software such as Abode Captivate, licenses and training from various software companies, and BIM models supplied by GE Johnson Construction Company and KL&A Engineers.

The primary objective for the BIM teaching modules is to enhance educational communication effectiveness by employing visual and interactive teaching techniques to illuminate core concepts while, simultaneously motivating and exposing students to new BIM-enabled working processes and industry opportunities. The modules rely on leading construction companies' pioneering experience to demonstrate the impact of BIM-based processes in construction practice. However, rather than recounting example case studies, these teaching modules are carefully crafted to explore and illuminate core concepts such as information inputs and outputs to critical analyses and decisions.

As a 3D modelling platform, BIM provides a robust environment for exploration and visualization. An example of leveraging BIM to explore and visualize core concepts exists in teaching the basic connection types in structures. Traditional structures classes use pencil diagrams to denote and distinguish the properties of a roller, versus a pin, versus a fixed connection (Figure 1, a). At CSU, as at several other leading construction management programs, educators may also have access to fabricated "steel sculptures," demonstration steel structures that materially depict numerous common steel connections for direct observation and inspection by the students in a laboratory environment (Figure 1, b). This allows students not only to "touch and feel," but also to directly experience steel connections in 3-dimensions. A limitation, of course, is that access to such a steel sculpture if existent, is limited to the laboratory and laboratory hours. In addition, the sculpture is fixed and unalterable. Finally, this demonstration of a connection cannot be directly integrated into other student projects or applications.

An additional exploration and visualization method to support the teaching of the fundamentals of a pin connection is an editable and analyzable 3D-BIM model (Figure 1, c). Benefits include, expanded and remote access, interactive viewing through fly-throughs and rotatable models. Finally, the BIM model can be modified, and analyzed using its associated properties, and may be integrated to additional student work.

Figure 1 illustrates these different, but complementary teaching techniques that can be used to more effectively illuminate the core principles in construction management, in this case a pin connection in a structures class.

Figure 1: Complementary communication techniques to illustrate the fundamental principles of a pin connection in structures. A) a traditional line diagram used to represent a pin connection in calculations and analysis B) a photograph of a pin connection materially constructed in an instructional steel sculpture available at select universities C) a three-dimensional rotatable and interactive computer model of a pin connection.

3D platforms provide an enhanced opportunity for teaching and communication. A primary challenge for educators using such techniques is the logistics of introducing, implementing and maintaining such software platforms in the construction management classroom. Information Technology (IT) departments across universities strive to serve a variety of complex and changing classroom needs. However, even when technical support exists, for many faculty members learning and remaining current with BIM software presents an unattractive and challenging additional responsibility.

To meet this challenge, CSU is developing our BIM teaching modules using Abode Captivate software (Adobe, 2010). This is a program capable of creating a rich electronic learning experience that produces software demonstrations, interactive simulations, branching scenarios, and quizzes outside the original, native software platform. Once created using the native BIM software or other software packages, published products are stand-alone, software independent, and executable using an Abode flash player. Such an approach relieves professional educators of the burden of software management and training thus addressing one of the major obstacles facing educators wishing to implement BIM and reducing the real and perceived time, effort, and interest required to stay current with individual software. In addition, these stand-alone, viewable modules relieve the student of needing direct access to potentially expensive software and computer equipment, as well as provide the opportunity for remote learning environments. Once published, the educational material supports a range of formats including on-line or in-class delivery. The development of these modules collaboratively between industry and academia enables the leveraging of state-of-the-art modelling skills and examples available in industry with the unique teaching expertise provided by educators. The intended result is to deliver the highest quality educational experience to the students.

Several teaching modules are currently under development. Under close supervision and content management from educators but using primarily industry models and modelers, the teaching modules are tailored to be high quality participatory exercises accompanied by student assessments. They highlight process-based best practices as well as incorporate fundamental educational principles. In this effort, CSU faculty and students are working directly with industry to incorporate process diagrams, war- stories, dynamic 3D models, cost implications, and interactive exercises to creatively illustrate BIM as a working process for complex, real-world projects.

As a tool, BIM requires fundamental domain knowledge. For example, Figure 2 is a screenshot from a pilot teaching module under development where students simulate interactions with BIM software to apply core structural concepts. Figure 2 shows an instance in the learning module where a student must enter the equation:

*steel tonnage modeled (tons) = 490 (lb/cf) * material volume (cf) / 2000 (lb/ ton)*

To enter such an equation, a student must know that steel weighs approximately 490 lbs per cubic foot and that 1 ton = 2000 lbs, facts and figures that are otherwise included in the core concepts of the class. Students must also be able to distinguish this software input from common industry practice, which references steel in lbs/lf. Further development of the modules includes elements of direct student assessment of their level of knowledge regarding basic facts and figures. This knowledge encapsulates the same input and output information that would be required in a more traditional student exercise with the advantage of an interactive learning environment and potential for automated grading.

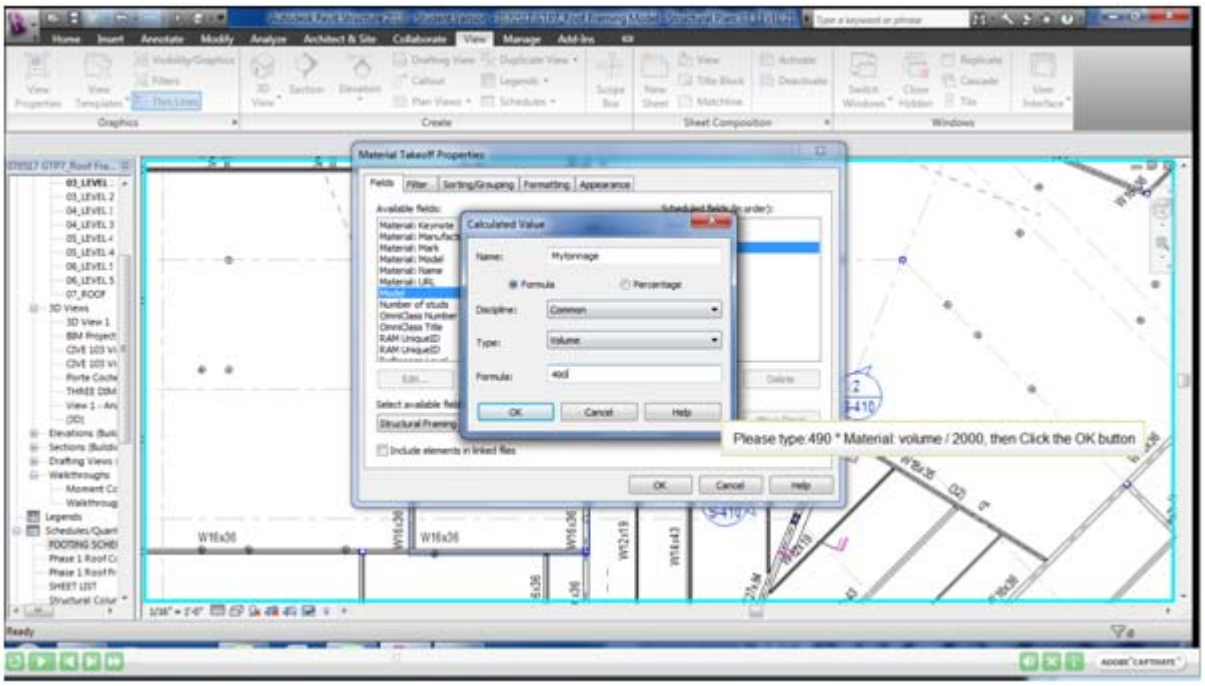

Figure 2: An interactive learning module under-development at CSU where students interact with simulated BIM-based applications of real-world construction projects. These modules are created using Adobe Captivate and are executable in Abode flash, making access software independent and zero-cost to students. Such a learning environment provides expanded and interactive opportunities for students to apply and explore fundamental construction specific domain knowledge. The example screen shot is from a teaching module demonstrating steel structural design priniciples.

An important benefit of independence from native BIM software is to increase the opportunities for dissemination of the educational material while decreasing, or nearly eliminating additional software costs.

4. STUDENT FEEDBACK

In an effort to better focus and understand the student viewpoint on learning the new and complex information presented in construction management, exploratory research was done at CSU. Four CSI categories, concrete, masonry, metals, and woods and plastics, were included in the study of material and methods students based on teacher experience with student learning experiences. Students were asked about their perceptions of the impact the use of 3-D models in the classroom had on their understanding of course material. This was done using data comparisons from students exposed to one of three presentation methods in differ-

ent sections of the same materials and methods course. The results of this study found significant difference exists between the students concerning the perceived impact that the 3-D computer models had on their understanding of the masonry and metals teaching unit when tested at the .05 level. The importance of results like these will help focus limited resources in the areas that impact student learning.

5. CONCLUSION

Construction management programs across the country seek to integrate BIM into their curriculum. Motivations include desire by faculty to enhance student learning environments utilizing effective communication and visualization techniques; student desire to learn current design and analysis tools and methods; and desire shared industry and academia to expose students to emerging BIM-enabled workflows, and industry best practices. CSU is piloting a two stage strategy to integrate BIM across construction management curriculum: establish an introductory BIM software course and develop stand-alone teaching modules for integration into a variety of core courses including, but not limited to structures, mechanical, electrical and plumbing (MEP) coordination, sustainable design and construction, pre-construction, cost estimating, scheduling, contracts, and material and methods. Initial feedback is promising. Students and faculty alike see benefits to utilizing 3D learning environments in the classroom. Furthermore, the use of Abode Captivate allows the learning modules to be platform neutral and relieves much of the IT burden members while minimizing learning curves and logistics for faculty and students as well as cutting costs and expanding access. The content of each teaching module is being carefully crafted to teach core construction concepts while showcasing leading industry best-practices rather than serve as mere software tutorials. The interactive and visual nature of the modules engages a high level of spatial cognition and critical thinking among students. Future research will include further development and refinement of additional teaching modules, and perform more comprehensive cross curriculum assessment of the impacts of such a strategy.

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