BIM (Building Information Modeling) and Pedagogical Challenges

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BIM is a new building design and documentation methodology that makes the construction process easier and faster for everyone involved. It allows all of the graphical and non-graphical building information for a construction project to be readily available by the use of relational databases. With the emerging concept of BIM, AEC (Architecture, Engineering, and Construction) professionals face new opportunities for enhancing efficiency and refining the practice of building construction. AEC professionals admit that the basic concept of BIM is sound and is the direction in which the AEC industry needs to move.

However, there is no accepted instruction strategy for teaching BIM in AEC-related curriculum. The Department of Engineering Technology at Western Illinois University recently offered residential and commercial design courses employing Autodesk Revit Building Version 8.0, BIM-based software, to its current undergraduate students in the Construction Management program. This paper describes some key insights into the successful employment of BIM in construction educational environments. This paper also introduces several pedagogical challenges from the courses.

Keywords : Building Information Model, Parametric CAD, Autodesk Revit, Residential Design

Introduction

Traditional architects have manually expressed building components in symbolic language and orthographic drawings by means of T-squares and pencils. In the early 1980's, architects automated these practices by using geometry-based CAD (Computer-Aided Design), such as AutoCAD but did not fundamentally change the manual method of symbolic expressions. This change continued with the introduction of object-oriented CAD, such as Architectural Desktop in the early 1990's. Recently, BIM (Building Information Modeling) is emerging as a new way to manage complicate construction projects.

The information produced in a contemporary construction project has become much more complicated, but the methods of managing information flows have not been improved so far. It is now widely recognized that BIM will take over geometry-based CAD systems (Ibrahim and Krawczyk, 2003; Khemlani, 2006). With the emerging concept of BIM, construction managers face new opportunities for expanding their roles, enhancing efficiency and refining the practice of building construction. Construction professionals admit that the basic concept of BIM is sound and is the direction in which the construction industry needs to move. Such a revolution in the construction industry has the potential to transform how professionals work, learn and manage projects and then lead to the explosive creation of new business (Bedrick, 2005).

However, there is no accepted teaching strategy for educating students about BIM in construction-related programs. The Department of Engineering Technology at Western Illinois University recently offered residential and commercial design courses employing Autodesk Revit Building, BIM-based software, to its current undergraduate students in the Construction Management program. This paper describes some key insights into the successful employment of BIM and also introduces several pedagogical challenges from the courses.

What is BIM (Building Information Model)?

BIM is a new approach of "Virtual Building Construction" based on parametric CAD technology. It is a building design and documentation methodology that significantly improves building design practice and makes the construction process easier and faster for everyone involved. It allows all of the graphical and non-graphical building information for a construction project to be readily available by the use of relational databases that store, access, and retrieve all of the information about building components.

The relational databases specify relationships between the various building components to quickly and effectively produce digital representations for the building project. The relationships are predefined based on architectural functions. It also allows any and all components of the building model to be constantly responsive to changes and automatically regenerates the model. Figure 1 shows an example of the "Edit Assembly" dialogue window that explicitly manages component-related information using various parameters. The information in "Edit Assembly" includes materials, size, geometric positions, structures, and other design constraints.

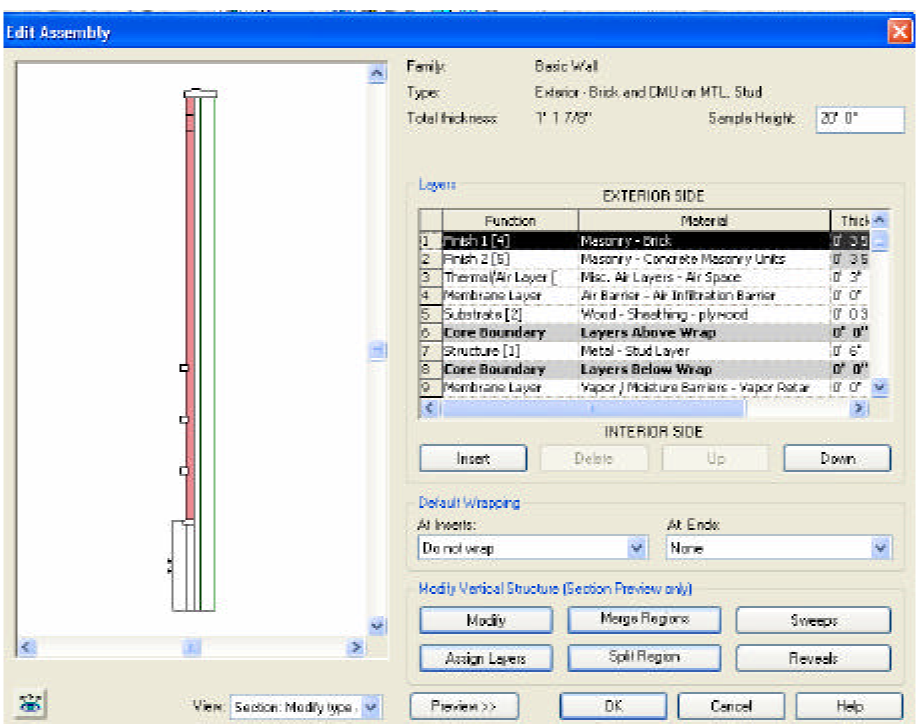


Figure 1: Screen shot of a Edit Assembly window.

The concepts of BIM are broadly implemented by AEC professionals working in the field of building design, construction, and facility management. BIM is getting more attention because BIM offers lots of benefits - saves time and money, improves productivity, produces more detailed and accurate drawings, allows for better design decisions faster, produces high-quality construction documents, and ultimately provides more business opportunities.

Post (2006) states that "with the time saved from submittals, review and rework, we finish early and under budget. This is all done by the use of BIM that architects can create 3D, 4D and 5D models that show every little detail." Miner and Thompson (2006) also explained the relevance and importance of BIM not only for 3D modeling, but for 4D and 5D modeling which include scheduling and cost projection. They also pointed out that it is more imperative for architects to make accurate decisions in the earlier design phase.

Condit (2006) also pointed out that the use of BIM on complex projects reduces costs by acknowledging design conflicts early enough to eliminate rework. BIM solutions allow architects to devote more time to design rather than drafting resulting in more precise and accurate construction documentation. There are lots of successful case studies of AEC firms that are using BIM solutions. Examples include SOM (Revit Building), HKS (Revit Building), RTKL (Revit Building), and NBBJ (Bentley Architecture).

According to Barbra Heller, CEO of Design and Construction Strategies, BIM will not only change the existing delivery system, but BIM will change the job description of most people involved in design and construction. Post (2006) shows a survey chart that states that 74% of architects use some level of 3D digital modeling. Some reasons why to begin using BIM included: owner's request, potential improvement in productivity, and competition with other companies. There are few architects still hesitant to adopt BIM. According the survey, 26% of the respondents were not using BIM because of lack of owner's interest, lack of expertise, lack of familiarity with BIM and expensive implementation.

BIM Software: Autodesk Revit Building

There is a lot of BIM-based software; Autodesk Revit Building (Revit), ArchiCAD, Bentley, and SolidWorks. The Freedom Towers project, one of the most important construction projects in the United States, is producing construction documentation by using Revit (Day, 2005). Disney World and GSA (US General Services Administration) have used this software to complete and manage some of their projects and report it as a successful tool (Khemlani, 2006). Many architectural firms, such as SOM, RTKL, and HKS are currently testing to employ Revit as the next generation of CAD system.

Revit uses building components such as walls, doors, and windows as opposed to geometric entities such as lines, squares, or circles. A good example is a soffit under an overhang that is created in Revit (See Figure 2).

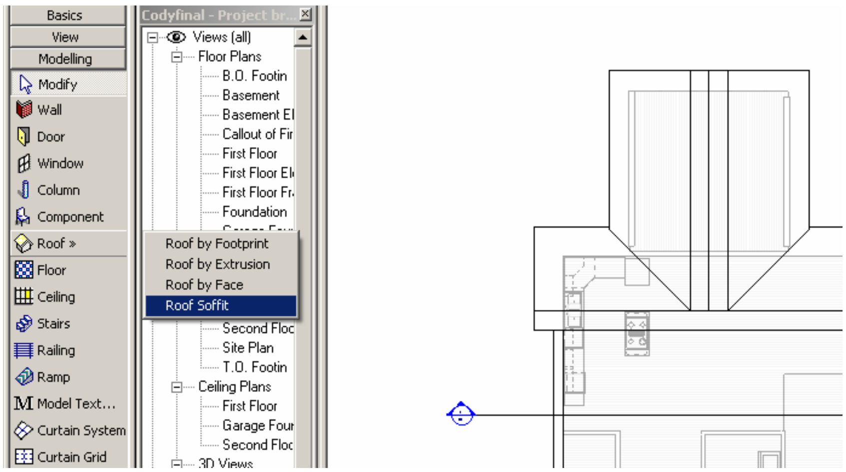


Figure 2: Creating Roof Soffit.

Settings

During academic year 2005 and 2006, the Department of Engineering Technology at Western Illinois University offered residential and commercial design courses employing Autodesk Revit Building to its current undergraduate students in the construction management program. These courses were open to any student who had already taken an introductory AutoCAD course and was enrolled in the construction management program. Twenty undergraduate students registered for each semester. They were required to attend lectures and labs and work on all class assignments. As a part of the course requirements, they developed a building project using Revit as a term project. The author was solely responsible for the course, and duties ranged from preparing software tutorials, lectures regarding building structures, supervising individual projects, grading quizzes and exams and designing web-based course interfaces. The course schedule is shown in Figure 3.

Autodesk Revit Building Version 8.0 was employed and taught in the course. The course started from software tutorial sessions to help students understand the basics of Revit. Then, several lecture sessions were given to the students about building structures, construction materials, methods and architectural programming. After obtaining the necessary knowledge-base, students started their own design projects. At the end of the semester, students produced graphical presentation boards and made oral presentations about their project (See Figure 4). Project critics were invited to evaluate the students' final projects. Students completed a short survey concerning the use of Revit. The survey was distributed on the last day of the semester as a part of the final exam and is primarily designed to obtain feedback about the perceptions of software usability, ideas and satisfaction.

Week	Date	Topic
Week 1	16-Jan	Introduction to CSTM 302
	18-Jan	Introduction to BIM/Autodesk Revit
Week 2	23-Jan	Revit tutorial 1: Massing
	25-Jan	Revit tutorial 2: Floor plan: Wall, Floor, Door, Window
Week 3	30-Jan	Revit tutorial 3: Floor plan: Stair, Roof, MEP system
	1-Feb	Revit tutorial 4: Lineworks and modifying tools
Week 4	6-Feb	Revit tutorial 5: Foundation plan
	8-Feb	Revit tutorial 6: Roof plan
Week 5	13-Feb	Revit tutorial 7: Elevation/Section
	15-Feb	Revit tutorial 8: 3D Rendering/Walkthrough
Week 6	20-Feb	Revit tutorial 9: details
	22-Feb	Midterm Review
Week 7	27-Feb	Midterm
	1-Mar	Masonry structures
Week 8	6-Mar	Concrete structures
	8-Mar	Steel structures
Week 9	13-Mar	Spring Break
	15-Mar	Spring Break
Week 10	20-Mar	Space programming 1: Site analysis & POR
	22-Mar	Space programming 2: Sustainability & IBC
Week 11	27-Mar	Conceptual Design Presentation 1
	29-Mar	Conceptual Design Presentation 2
Week 12	3-Apr	Building Construction Illustrated: Chapter 3
	5-Apr	Building Construction Illustrated: Chapter 4
Week 13	10-Apr	Building Construction Illustrated: Chapter 5
	12-Apr	Building Construction Illustrated: Chapter 6
Week 14	17-Apr	Building Construction Illustrated: Chapter 7
	19-Apr	Building Construction Illustrated: Chapter 8
Week 15	24-Apr	Individual project development
	26-Apr	Individual project development
Week 16	1-May	Final Project Presentation 1
	3-May	Final Project Presentation 2
Week 17	8-May	Final exam week

Figure 3: Course Schedule.

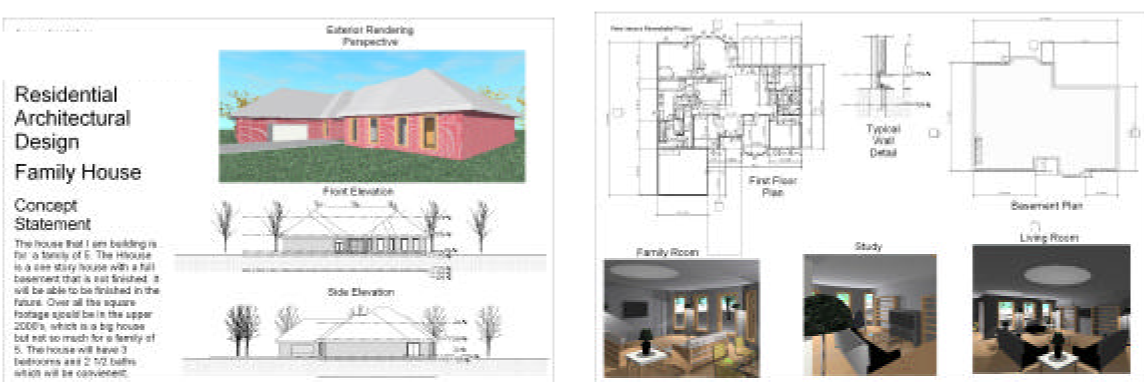


Figure 4: An example of students' project.

Student Perception

In the survey, most students reported that their experience with the software was very enjoyable and that the software is well-designed to enhance the efficiency of building construction. Most students were eager to learn the new software because they wanted to master the latest technology before a competitive situation. The answers from the survey also indicated that the students' perception about the software is very positive from the following aspects:

Students had already taken an introductory CAD class, so they know how time-consuming it is to create a building in AutoCAD. The students were also impressed by the fact that repetitive drafting tasks are significantly reduced by reusing building components on all project drawings. A change made on any building component in a drawing is immediately reflected on every other drawing instead of revising all drawings. When new building components are added, Revit immediately applies the changes and regenerates all the project drawings to be consistent with one another.

The parameters also include non-graphical information about the building components. For example, vapor barriers can be placed under concrete slabs by changing "Slab Properties" if needed (Figure 5). If a staircase is added in the first floor plan, it automatically makes the change in staircase on the section details (Figure 6). Students noted that using parametric building components compared to geometric entities is a much faster and more efficient way to create a building design.

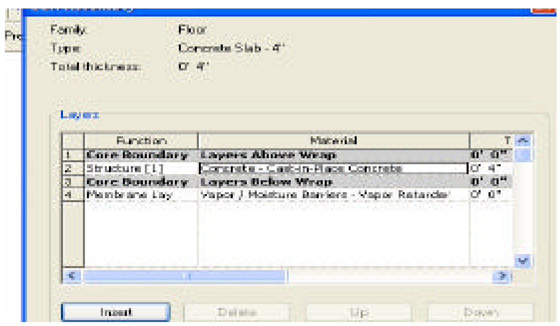


Figure 5: Concrete slab properties.

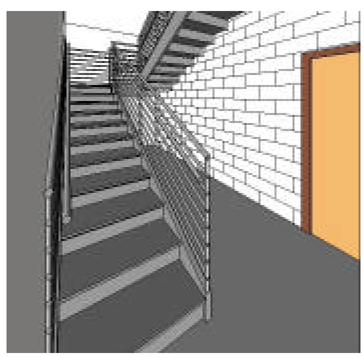


Figure 6: Staircase.

Revit manages all of the project drawings in a single file (See Figure 7). It is also possible to review all the project drawings including 2-D drawings, 3-D drawings, rendered drawings, and animated walkthroughs (virtual tour of a building). In addition, a section cutting line can be added to cut a section anywhere and automatically have a section drawing. In AutoCAD, each section must be drawn manually.

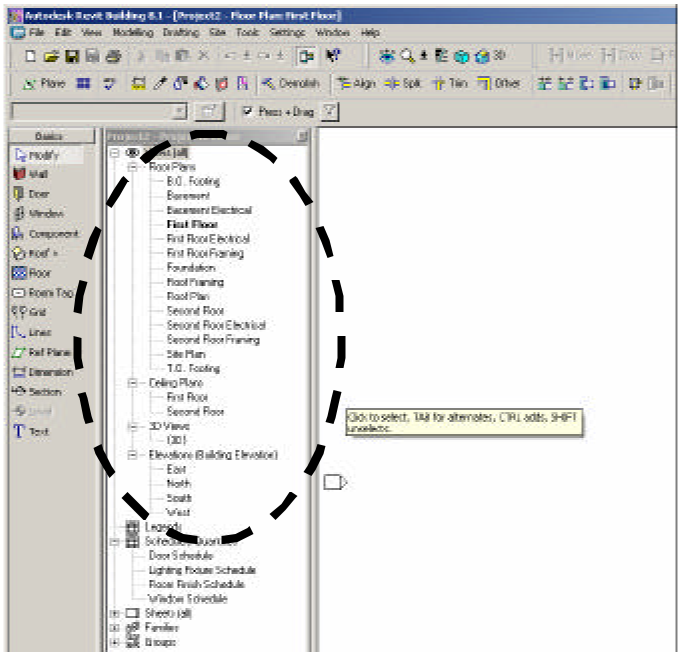
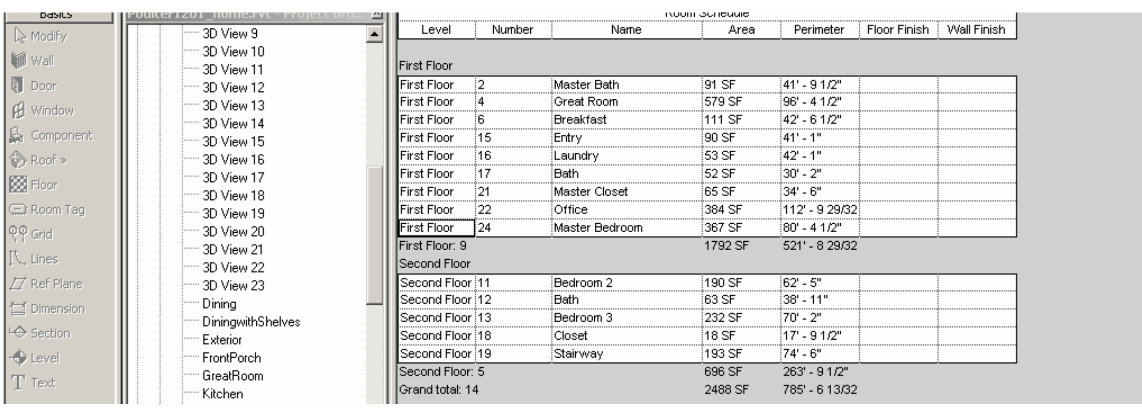


Figure 7: Project drawing browser.

One of the most tedious tasks in the architectural design process is compiling schedules. The developers of Revit understood this fact when they developed Revit (Fox and Balding, 2005). For example, all walls should be counted, categorized, and organized to compile a wall schedule to be used for quantity takeoff (Figure 7). As such, Revit automatically produces various schedules for walls, doors, windows, and room finishes upon placement of certain building components thereby reducing the chance of scheduling errors. The Students really enjoyed this function when they prepared their presentation boards.



Level	Number	Name	Area	Perimeter	Floor Finish	Wall Finish
First Floor						
First Floor	2	Master Bath	91 SF	41' - 9 1/2"		
First Floor	4	Great Room	579 SF	96' - 4 1/2"		
First Floor	6	Breakfast	111 SF	42' - 6 1/2"		
First Floor	15	Entry	90 SF	41' - 1"		
First Floor	16	Laundry	53 SF	42' - 1"		
First Floor	17	Bath	52 SF	30' - 2"		
First Floor	21	Master Closet	65 SF	34' - 6"		
First Floor	22	Office	384 SF	112' - 9 29/32		
First Floor	24	Master Bedroom	367 SF	80' - 4 1/2"		
First Floor: 9			1792 SF	521' - 8 29/32		
Second Floor						
Second Floor	11	Bedroom 2	190 SF	62' - 5"		
Second Floor	12	Bath	63 SF	38' - 11"		
Second Floor	13	Bedroom 3	232 SF	70' - 2"		
Second Floor	18	Closet	18 SF	17' - 9 1/2"		
Second Floor	19	Stairway	193 SF	74' - 6"		
Second Floor: 5			696 SF	263' - 9 1/2"		
Grand total: 14			2488 SF	785' - 6 13/32		

Figure 8: Wall Schedule.

Students were interested in Revit's intelligent error message function which recognizes when there is a conflict among building components. This messaging system can eliminate unknown errors that cause time-consuming changes after project construction has begun.

Revit also has the capability to create interior or exterior 3D perspective views and rending models of the building. Students were happy with the fact that they can create rendered perspectives without any additional training. The rendering process of Revit is much simpler than other rendering software. Although the graphic quality is not sufficient for sophisticated commercial renderings, it is suitable to create renderings for client feedback.

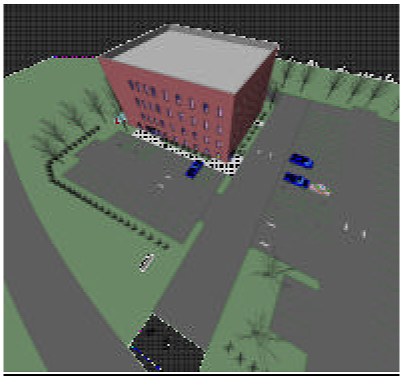


Figure 9: An Example of Bird-Eye View.

Figure10: An Example of Rendered Interior View.

Pedagogical Challenges

The analysis of student comments from open-ended questions revealed improvements that can be made in the software for better functionality.

Level of Knowledge Required to use Revit

One thing that the students did not enjoy was that it was difficult to learn many of the Revit functions as a beginner. From the start of the semester, it was complicated for the students to learn the tools of Revit, such as Properties, Stairs, Floor openings, Footings, and Foundations because these tools associate with many parameters that require expert construction knowledge and are not easily understood by the students.

Several students pointed out that Revit should develop an easier user interface or self-explanatory mechanism for the Properties windows for beginners. The students feared changing some of the parameters by opening "Edit Assembly" windows because the windows reveal so many technical details that are confusing for the students lacking technical expertise. For example, even though it is easy to draw using Revit, the students who did not have prior construction experience had trouble with the foundation walls and footings.

Vandezande (2004), CAD manager of Skidmore, Owings & Merrill, said "the senior team members with less computer experience, but greater knowledge of design and constructability seem to fare better with these tools than some of the younger designers." This is because Revit produces a model that contains a lot of technical knowledge that is typically acquired from practical experience. Architects may face with challenges in making clearer decisions about all the building components during the earlier stage of design phase in order to reduce rework and to get full benefits of using BIM.

Lack of Reference Materials

Students disappointed in the fact that there are not enough textbooks and reference materials available for them. Even though Autodesk provides several online materials and online discussion boards, the students wanted to obtain more knowledge from written materials when immediate help was needed.

Mimic Construction Sequences

Students did not like that the walls must be drawn before the footings and foundation are in place. They prefer to fully mimic construction sequences. The students also expected Revit to employ more structural systems, such as rafters, beams, and trusses.

Intelligent Error Detection and Correction

Revit partially embeds design rules in the model for intelligent error detection. Recognizing that Revit is rapidly expanding its capabilities, students would like a version of Revit that would detect their mistakes and propose solutions to correct them. The problem is the possibility of unrealistic design solutions. In fact, students feared that Revit allowed them to draw something that could not be built in the real world. For instance, Revit should not allow a load bearing wall without supports because it is not possible in the real world. As an example, Revit lets students draw a slab with a hundred foot span without proper beam support. It would be great if Revit displayed a message to let them know what the load factor is and provided some suggestions for proper beam locations necessary to build the structure. This is important information that the builder needs to check on the plans. Another example is the garage. Revit allows the design of a garage that is not large enough for a normal car. Furthermore, students expect the more intelligent functions to provide in-depth technical support. This would help students learn how to build a properly constructed building.

Limited Component Database

The answers from the survey indicate that students felt Revit is too limited by the databases. Although there is an abundance of materials and components that can be used in Revit, students still believe there should be more options to build a "virtual construction model." Ibrahim and Krawczyk (2003) also pointed out that we need to wait until new components are available on the market if a new building is to employ creative and innovative design solutions. It is possible that certain brands of materials and components are not available when you want to use them according to project specifications. There are many new styles of construction being developed today, and Revit should fully represent all of them.

Conclusion

As the end of the semester is approaching, students have realized how Revit enabled them to finish their final project before the due date by keeping all of the building information coordinated, reducing repetitive drafting tasks and keeping the entire project drawings organized. All of the students thought that the basic concept of BIM is sound and the direction in which the AEC industry needs to move. Students also pointed out that supporting technology should continuously be improved to resolve current shortcomings. After introducing BIM, students were eager to learn seriously because they wanted to master the latest technology before a competitive situation. BIM tutorials were one of the most exciting components of the courses. The author realizes that students are very good at learning new software if they really want to learn for their future career.

The courses have allowed the author to become familiar with many pedagogical challenges of implementing BIM and encouraged the author to participate in endeavors to meet those challenges. The courses also gave invaluable insights about teaching BIM in a construction educational environment. One of the main pedagogical goals is that BIM is not merely sophisticated CAD software or a new drafting technique; rather, it provides important and inter-related models of construction, such as design, construction technology and facility management. Therefore, teaching and learning BIM requires higher construction expertise based upon practical experience.

Properly structured BIM courses would provide industry-required knowledge to prepare students for successful careers in the AEC and AEC-related industries. To accomplish this goal, faculty members should place more emphasis on the use of BIM through the reconfiguration of current courses to deliver the working knowledge necessary to properly teach BIM. A consequent issue is how to set up a new course based on the concept of BIM. It might be a challenge for the faculty member to fit all course contents into one. The faculty should deliver working knowledge on BIM software, architectural drafting and construction technologies. A rich and rigorous learning environment could be achieved through purposeful attempt of integrating BIM into various course contents such as residential design, commercial design, construction estimating, construction project management or construction scheduling.

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