BIM AS LEARNING MEDIA FOR BUILDING CONSTRUCTION

DR. AHMED MOKHTAR
American University of Sharjah
P.O. Box 26666, Sharjah
United Arab Emirates
mokhtar@aus.edu

Abstract. A fundamental module of any recognized architecture curricula is the understanding of buildings construction. A major component of such understanding is learning how to put together a structure system for a building. The difficulty most students find is not in knowing these structure systems in their abstract form, rather in applying this knowledge while making design decisions. Selecting the appropriate system and adapting it to the difficult conditions that accompany a particular design is the more challenging aspect to grasp. Instructors use various techniques to help students overcome this challenge. These techniques range from simply showing photos to requiring students to construct a building. This paper describes a new technique experimented with by the author. It is based on using Building Information Modeling (BIM) software as a learning media to help students face the challenge. The paper discusses the technique and the details of the experiment through a case study. The paper eventually reports on what the experiment reveals regarding the advantages and disadvantages of using BIM as a learning media.

1. Background

Understanding how to construct a building and how to put its various components together is essential for professional architects. Therefore, architecture schools have on their curriculum one or more courses that focus on teaching the various stages of constructing a building from site preparation until finishing. Through this course(s), students learn the relationship between the design decisions they make and the process of constructing the building. They understand that each line they draw has construction implications that affect cost, time and constructability. Students become aware that the various building components need to work together in an integrated fashion. Hence, the design decisions should be taken accordingly.
2. Construction Learning Techniques

Various techniques and technologies are utilized by instructors of construction courses to help students learn the important concepts and to become capable of making meaningful and appropriate design decisions.

Among these techniques is the showing of photos of buildings under construction. The instructor stimulates students’ ability to analyze what they see in the photo, to extract the design decisions taken by the architect, and to relate these decisions to the construction process. They may also reflect on the level of design integration among the components of different building systems shown in a photo.

Another technique is the use of case studies where a selected building is analyzed by one or more students. In this technique, students have the opportunity to reflect on the design of one or more full building systems rather than just on components of systems. If the students are able to visit the analyzed building during its construction, they greatly benefit from seeing the reality of construction and from communicating with those involved in the construction process.

Some instructors ask students to construct a scaled physical model of an existing building. Commonly, buildings with non-traditional structures are selected. Students learn through imitation. They gradually recognize the issues of concern as they go through constructing the studied building model. However, the nature of modeling requires simplification of reality. This results in missing some important construction-related issues. The materials of modeling also present a learning limitation, due to their different structural behavior from real construction materials. Another limitation comes from the fact that joining the various structural elements in a model is typically different from reality.

The above learning techniques have the common limitation of not requiring students to make design decisions. Students only analyze what others have decided.

Constructing an actual building using real construction materials is another learning technique. This technique significantly helps students recognize the complexity of construction; particularly the issues of relating design to constructability, to managing cost and time, to deciding on the sequence of construction, and to integrating different building systems. Yet, there are serious logistical issues with this technique including how to relate course duration to that of construction, how to pay the cost, and safety considerations. The technique also tends to favor the development of skills that are essential for a technician rather than an architect. An architect ultimately needs to develop the skill of using others to construct his/her design decisions.

Developing construction drawings is also used to help students learn about construction. As students develop these two-dimensional drawings, the instructor discusses and explains construction implications of what they draw. The advantage of this technique is that students develop the skill of making construction-related design decisions using the communication language currently used in the industry. Students need to overcome the difficulty of relating two-dimensional drawings presented in a variety of plans, sections, and elevations to the physical realities of construction. This can be challenging for some students.
Using 3D digital modeling is another technique used by instructors. Students model selected components of a building using computer generated surfaces. Occasionally, details of a component or interrelated components are modeled for better understanding of their construction. This technique helps students visualize the design much easier than two dimensional drawings and reduces the instructor’s effort in pinpointing relations between design and construction. The ability to change scale, colors, rendering material, and level of details clearly help in visualizing issues of concern and in relating them to design decisions. The problem with digital modeling, however, is the absence of genuine material behavior and the lack of the fundamentals of physics. A 3D digital model will not object to having neither a non-supported beam nor an extra thin column.

Different analysis of the techniques used to strengthen students' awareness and abilities in construction is introduced by (Clayton et al 2002).

Following this quick review of various techniques to help students learn about construction, the author believes that a curriculum should provide opportunity for students to experience several of these techniques. As students learn differently and as each technique has advantages and disadvantages, diversity enriches the students’ learning environment.

This paper introduces an additional technique that the author believes to be important for instructors to include with their list of options. It uses the technology of building information modeling (BIM) as a learning media. The following sections of the paper firstly introduce BIM for those unfamiliar with it. The paper then describes the new technique through an experimental case study. Finally, it provides the author’s perspective on the advantages and disadvantages of this learning media.

3. Understanding Building Information Models

A Building Information Model is defined by the National BIM Standard (NBIMS) Executive Committee of the National Institute of Building Sciences (National Institute of Building Sciences, 2006) as a “digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward.” The author usually simplifies this to students as digitally constructing a building on a computer using digital building components and with as much details as necessary for the required purpose. The details are not only geometric but extend to textual and numeric data. As such, a BIM is very different from a standard 3D digital model which only models an abstract geometry of selected building components.

Research on potential use of BIM in building construction has been around for quite some time even though the term BIM was not commonly used. (Mokhtar 1998) provides a survey of this early research work which covered aspects such as conformance with regulations, evaluating building performance, and design of building envelope. However, applying this research work proved to be difficult because software that uses the BIM approach was - and still is - not developed to a stage that enables easy use of their full capabilities. According to a statistic compiled by a joint committee
of the American Institute of Architects and the Associated General Contractors of America (J.G., 2006), 98 percent of those using BIM or 3D use it for rendering and presentation graphics related to conceptual design. Only about 34 percent are using it for intelligent modeling, or for generating information such as cost or quantity data. Consequently, little incentive exists for software developed to translate the research work built on using the BIM approach into commercial products. Nevertheless, recent versions of BIM software show promise by simplifying its use and providing more training opportunities. The author expects that soon the use of BIM will become standard in construction industry as it is now in many sectors of the manufacturing industry.

4. The New Learning Technique

BIM software provides the user with the capacity to construct a building digitally. Digital construction is indeed very different in its process from actual construction. For example, constructing an actual site cast reinforced concrete beam requires skills to build the necessary formwork, to shape and to install the reinforcement, to mix and pour concrete, and other similar skills. Using BIM, the same beam is digitally constructed using few mouse clicks and data input. Nevertheless, the process of constructing digitally helps the decision maker to investigate the appropriateness of the decisions in relation to real construction needs and concerns. This help is particularly notable when investigating the interrelationship between the different decisions. Consequently, costly errors that can occur in actual construction are minimized. In the previous example, investigating the relation between a digitally constructed beam and a digitally constructed window lintel below it may reveal that changing the window’s height or the beam’s depth increases constructability and reduce cost during actual construction. Design decisions are modified accordingly. As making decisions is what an architecture student is trained to do, using digital construction as a pedagogical tool seems attractive to explore. For this reason the author developed a case study to experiment with the use of BIM software as a learning media. The experiment is not intended to determine whether such media provides a better learning technique. Rather, the intention is to explore the advantages and disadvantages of BIM as a potential learning technique.

4.1. THE CASE STUDY

As part of a course on advanced computer-aided architectural design, students learn the basic concepts related to the BIM approach of using computers in architecture. Students develop skills in constructing and managing a BIM. Autodesk® Architectural Desktop (ADT) is used in the course as an example of BIM software. The selection of ADT is based on its availability in the school and the familiarity of the instructor (the author) with it. No comparison with other BIM software is done and hence the author does not particularly endorse the use of ADT. The general focus of the course is how to use computers in managing design information and in assisting design decisions during the detailed design stage of a project. Hence preliminary designs are always given to students to use.
As the course’s capstone project, students are asked to digitally construct a small building (sample is shown in Figure 1). Completing the project requires students to make many decisions. These include the following:

- Selection of an appropriate structural system and deciding on the location and dimensions of the structure’s various elements.
- Making appropriate selection of building elements such as walls, doors, and window types, and finishing materials.
- Managing of the digital construction process through appropriate selection of number of files, the contents in each file, and the relationship among these files. Digital construction time and ability to coordinate the design of different systems depends heavily on this management aspect.

Students in the course are all third year architecture students who took only one construction course that covers the construction process from site preparation through to the erecting of the main structural elements of the building. They have little exposure and experience in detailed design decision. They are only familiar with conceptual design process and concerns as these are emphasized in design studios.

The project took 8 class sessions covering around 4 weeks of work. In each session the instructor discussed with each student or group of students a variety of issues related to the decisions they have to take. The learning of construction consideration occurred chiefly during these sessions as students raised questions and tried to collaborate in solving them.

The main outcome of the project is a digitally constructed building as shown in Figure 2. A view of the building without wall finishing and soil (Figure 3) is required to expose the relationship between structure elements, curtain wall, doors, and windows among others. Selected sectional perspectives are generated (Figure 4) to show some relationships among building elements. Some construction errors can be detected in the digital construction as revealed in both Figure 3 and Figure 4. These errors could not be detected if standard 3D digital model is used as it would appear similar to Figure 2. The students are also asked to separate the structure system of the building to study its integrity. Figures 5 and 6 show how two students decided on the structure of the same building differently. Several plans, sections, and elevations are also generated by the software and appropriately presented by the students.

Analyzing this case study reveals several advantages and disadvantages for using ADT as a learning media. The following two sections discuss them from the author’s experience and perspective.
Figure 1. Sample design used in the capstone project.

Figure 2. A view of the digitally constructed building.

Figure 3. A view without external finishing of walls and without soil.

Figure 4. A sectional perspective showing the relationship between internal building elements.

Figure 5. Structure system components without slabs are shown independently.

Figure 6. Structure system components without slabs are shown independently (another student).
4.2. ADVANTAGES

Constructing digitally using BIM results in a rich learning environment. It provides an environment with plenty of opportunity for the instructor to discuss construction-related design decisions. Students themselves start to ask relevant questions as they have no choice but to make design decisions. The ability of the software to make live sections and to easily manipulate dimensions and materials makes the comparison of different design decisions easier to demonstrate to the students.

In comparing digital construction technique with another learning technique such as 3D digital modeling, the former provides a much better sense of reality. Students deal with construction objects (e.g., windows) that have understandable property (e.g., head height) and not just standard modeling objects (e.g., box) that have generic property (e.g., z-value). By making design decisions for a “head height” rather than for a “z-value”, students are automatically put in a construction-aware set of mind.

When evaluated against the technique of constructing an actual building using real construction materials, digital construction allows a much higher percentage of instruction time for the learning of making design decisions rather than learning the skills needed for construction technicians. The aspects of time commitment, cost, and size of the project favor digital construction as well.

The learning technique of digital construction using BIM enables students to make more details than physical model making technique. The ability to view materials that appear more like actual construction material also favors digital construction.

From another aspect, getting architecture students to learn through BIM provides important value to the profession. Students become familiar with the BIM approach and become able to utilize it as assistant in decision making. This helps the drive towards having BIM as the standard rather than the exceptional CAD approach in consulting offices.

4.3. DISADVANTAGES

While having the above mentioned advantages, there are indeed obstacles that need to be overcome in order for the digital construction technique to achieve better results. Probably the most important obstacle is the complexity of using BIM software in comparison with other traditional 3D modeling software. The author found that students get into curves of learning. As each new BIM concept or capability is introduced – using the ADT as the tool – students complain about its complexity. However, after using the capability for a period of time, they start to feel more comfortable and delighted with the results, until another concept or capability is introduced. The instructor did not face such learning patterns while teaching standard CAD software such as AutoCAD.

Fortunately, the course in which this case study is conducted is about advanced computer aided architectural design. Therefore, students have enough time to grasp the important BIM concepts and capabilities before starting the digital construction. Such time will not be available if the course
focus is building construction and the instructor wants to use digital construction and BIM as a learning media.

BIM also has the drawback of traditional 3D digital modeling, which is the lack of feeling the material and its weight and behavior. As a result, a student may miss the difference in behavior between a lumber beam and a concrete one. BIM-based software may soon be able to detect logical errors in construction but at present the software will not reject having a structural beam flying in the air without vertical support elements. This will not occur if a student is making a scaled physical model or an actual construction.

5. Conclusion

Through a case study, the author experimented with the use of BIM-based software (ADT is used as an example) as a media for architecture students to learn about building construction. Several advantages are found in comparison with other learning techniques. Some disadvantages are identified as well. The author believes that using BIM can be an important addition to the learning techniques used by instructors, particularly as the use of the software become simplified. The author also believes that a variety of learning techniques should be used in an architectural curriculum to cope with the fact that students learn differently.

References

J.G.: 2006, To architects - building information modeling is still primarily a visualization tool, Architectural Record, 194(7), pg. 158