BIM – A Knowledge Repository

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This paper discusses the development of a knowledge repository for learning residential construction process through Building Information Model (BIM). Building information modeling is a process in which real world elements of a facility are represented as objects in a three dimensional (3D) digital model. In addition to modeling, it provides a framework for data rich digital model development. BIM characteristics such as easy access to the information, visualization, and simulation capabilities facilitate the development of an interactive knowledge repository, which in turn can foster a conducive learning environment. This knowledge repository allows the students to discover strengths and weaknesses of their learning practices and improve accordingly. It facilitates students to learn at their own pace by providing interactive access to the repository through 3D model. The steps involved in developing BIM as a knowledge repository include development of the 3D model with components broken down to reflect the construction process and association of the information to these components. This paper discusses the feasibility of developing a knowledge repository for residential construction using Autodesk's Revit Architecture Software.

Key Words: BIM, learning environment, 3D, knowledge repository

Introduction

Students have different learning styles. Based on learning styles they can be identified as auditory, visual, and kinesthetic learners. Auditory, visual, and kinesthetic learners learn through hearing, seeing, and doing respectively (Marvin, 1998). Teaching construction engineering and management (CEM) courses by addressing students' different learning styles is a challenging task. Traditional lecture is one of the styles which is widely used for teaching CEM courses. Sometimes, the lecture format style is complimented by including construction site visits. This teaching style provides an auditory and visual learning environment. However, inclusion of site visits within the course schedule is not always feasible due reasons such as unavailability of construction sites meeting the class needs, class schedule conflicts, and safety issues (Haque et al. 2005). Additionally, lack of laboratory and training facilities are impeding the creation of kinesthetic learning environments. Sometimes traditional lecture teaching style also falls short to serve as effective communication tool for transferring knowledge to students. Due to lack of conducive learning environment which provides hearing, seeing, and doing capabilities, currently CEM students are unable to gain the required skills to solve the real world problems. A user friendly interactive knowledge repository that provides conducive learning environment is needed to enhance students' learning capabilities. Building Information Model (BIM) facilitates development of a knowledge repository and fosters conducive learning environments. BIM is a process. It provides a framework to develop data rich product models. In this process, real world elements of a facility such as walls, doors, windows and beams are represented as objects in a three dimensional (3D) digital model. In addition to modeling, it provides a framework that fosters the integration of information from conception to decommissioning of the constructed facility.

BIM serves as an excellent tool for data management. It facilities easy and fast access to the information stored in a single centralized database or in different databases held at various locations through the 3D model. Some of the BIM characteristics such as easy access to the information, visualization, and simulation capabilities provide auditory, visual, and kinesthetic learning environments. These environments allow the students to discover strengths and weaknesses of their learning practices and improve accordingly. Any time and interactive access to the repository through 3D model creates learning environment beyond time and space boundaries and facilitates students to learn at their own pace. This knowledge repository also helps as an effective communication tool to transfer the knowledge. In this paper, the feasibility of developing a knowledge repository for learning about the residential construction process is demonstrated. This is part of a research project, which is in progress. The goal of the research project is to develop an interactive knowledge repository through BIM and use it for teaching

residential construction courses. The study will be conducted in two phases. The first phase focuses on the development of interactive knowledge repository through BIM. The second phase focuses on the use of the developed knowledge repository in teaching residential construction processes. The paper presents an overview of the steps involved in the first phase of the research. The second phase scope is not included in this paper.

Methodology for BIM Knowledge Repository

This section discusses the methodology adopted for the development of a knowledge repository for the residential construction process through BIM (see Figure 1). A two-story residential structure of 2800 square feet is considered for this study. The steps involved in the development process include 3D model development with components broken down to reflect the construction process and integration of information to the 3D model components. The ease of integration depends on the availability and type of parameters in the BIM software. The information associated with the component of the 3D model can be retrieved through parameters of the component. These establish the links between respective files and components in digital format. The 3D model was developed using Autodesk's Revit software (Autodesk, 2009). The information needed was collected through paper format and digital format from various sources. Since BIM needs the information in digital format, the paper-based information was converted into digital format (PDF files) by scanning. The following sections describe in detail the steps used in the methodology.
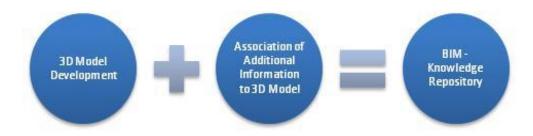

Figure 1: Methodology for BIM knowledge repository development

3D Model Development

Revit Architecture 2010 is used to develop the 3D model. Revit classifies the elements by categories, families, types and instances. A category is a group of elements that is used to model or document a building design. For example categories of the model elements include walls, columns, and beams. Families are classes of elements in a category. A family groups elements with a common set of parameters having similar graphical representation and identical use. For example families include round, square and circular columns. Revit has three kinds of families. They are system, loadable, and in-place. System families are predefined and useful to create basic building elements. System families constitute the elements, which are assembled on a construction site. Walls, floors, and roofs are some examples of system families. Loadable families are used to create both building components and annotation elements. Loadable families include the elements, which are installed in and around a building. Some examples include doors, windows and casework. Loadable families are created in external files and are loaded into a project. In-place elements are specific and unique elements that are created for the project. A specific size of a family is referred as Type. A family can have several types. For example, a door may be available in several sizes. Instances are the actual items that are placed in project and have specific locations in the building.

Typical BIM components like walls, slabs, windows, and doors are useful to represent the finished component but cannot serve to depict actual construction progress (Goedert & Meadati, 2008). For example, the different layers in the exterior wall include 3-5/8" thick brick veneer, 1" thick air membrane, 3/4" thick OSB, 3 ½" thick stud frame, and 1/2" thick gypsum board. The exterior finished wall can be represented by duplicating and modifying the Exterior – Brick on Metal Stud type wall from the system library (see Figure 2). When this wall type is used, all the different components of the wall are combined and behave as a single entity. This will not allow depiction of the actual construction sequence since it is done in stages. In addition, it would not facilitate independent selection of

the different components. To depict the actual construction sequence and to facilitate the selection of individual components, each of these were represented as independent components. The 3D model of the 2800 square feet, two story residential structure is used in the study (see Figure 3). Some of the different components of the 3D model include foundations, wood stud frame, wall sheathing, exterior brick veneer, drywall, open web wooden floor beams, floor sheathing, roof trusses, roof sheathing, asphalt shingles, plumbing pipes, HVAC ducts, doors and windows.

Association of Information to 3D Model

Information used to develop the knowledge repository can be classified as semi structured data files (HTML and XML files), unstructured data files (MS Word or plain text files), and unstructured multimedia files (photographs, audio, and video files) (Caldas & Soibelman, 2005). To facilitate interaction with the repository through the 3D model, the information is to be integrated with the 3D digital model. The steps involved in the integration of information with the 3D model include creation of new parameters and association of information to these parameters. In Revit, each element is associated with predefined parameters and these are categorized into type parameters and instance parameters. The type parameters control properties of elements of that type while the instance parameters control the instances properties. The type and instance parameters are further categorized into different groups. The data format stored in each parameter is of type: text, integer, number, length, area, volume, angle, URL, material, and yes/no. In this project, since the predefined type or instance parameters are inadequate, new parameters are added to the elements. Revit facilitates the addition of new parameter as project parameter or shared parameter (see Figure 4). Only the shared parameters are exported to databases. Other families and projects share these, whereas project parameters are not exported to the databases. Some of the newly added shared parameters include Manufacturing Process, Material Tests, Specifications, Construction Video, Code Requirements, Materials needed, Unit Price, Quantity Estimation, Typical Section and Construction Photos (see Figure 5). These parameters are made to appear under the group name 'Other' in the type parameters list. The URL data format is used for each parameter. This format is useful to establish the link between the respective files and component. The association of information to the model components is accomplished by assigning the file paths of the information to the parameters. This link between the documents through the path stored in the parameter allows easy access to the required information.
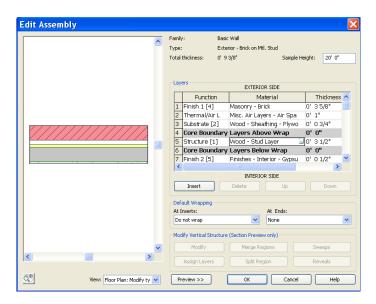

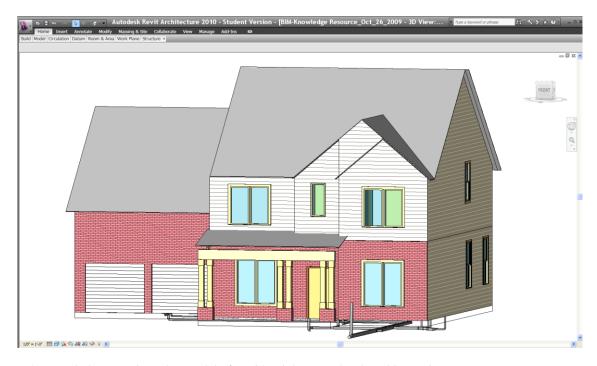*Figure 2:* Edit assembly window for wall type component in Revit

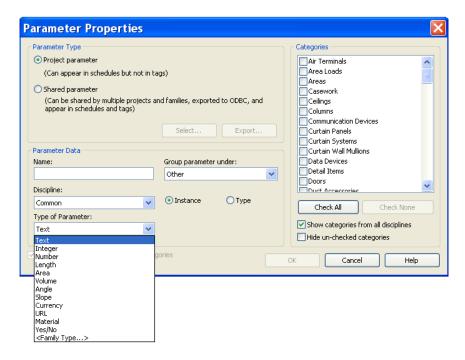*Figure 3:* Knowledge repository 3D model of Residential House developed in Revit
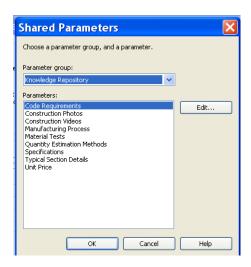

Figure 4: Addition of new parameters window in Revit

Figure 5: Knowledge Repository shared parameters added to the project

BIM as a Learning Tool

The characteristics, which help BIM to serve as a better learning and teaching tool, are accessibility and visualization. BIM reduces the element accessibility time since it facilitates easy visual correlation with real world elements through a 3D model. The information retrieval time can be reduced since BIM facilitates access to the information on a mouse click. The new parameters added and populated as explained above will facilitate retrieval of the information. For example, to learn about the manufacturing process and quantity take off guidelines of asphalt shingles the user needs to select the roof component and click the file path assigned to the 'Manufacturing Process' and 'Quantity Estimation Methods' parameters respectively, which in turn displays the asphalt shingles manufacturing video and estimation guidelines associated to these parameters (see Figure 6). The 3D model can further be utilized to learn about the construction process. Traditionally the construction sequence is taught by using two dimensional (2D) drawings and critical path method (CPM) bar charts. Students need to develop 3D models about the construction sequence in their minds to correlate the relationships between different components and schedule activities. Lack of 3D model visualization skills limits the students' ability to comprehend the construction sequence (Messner et al. 2003). The short comings of these traditional methods can be addressed by using four dimensional (4D) modeling (Koo & Fisher, 2000; Kang et al. 2004). BIM facilitates integration of 3D with schedule for 4D modeling. This can be accomplished by using the phase feature available in Revit. This feature is useful for creating a visual simulation based on the project schedule and helps to develop a feasible schedule instead of using 2D drawings. This simulation helps to explain and communicate the construction process better than 2D drawings and CPM bar charts.

Some of the factors which govern BIM repository development process include BIM software, means of information association to the model, and information format (Meadati, 2007). Lack of some features in BIM software can increase the 3D model development time. For example, lack of features that facilitates disintegrating the composite behavior of wall in BIM software influences the 3D model development time. The steps involved in the association of information include parameter creation and linking. These steps had to be repeated for each component of the 3D model. Depending on the amount of information to be associated, this becomes a time consuming process. Developing some means of automating this process can reduce this effort. Depending upon information format, inclusion of some additional steps affects the repository development process. For example, scanning process has to be included as an additional step for converting the paper format information into digital format.

Regarding the use of this digital repository in teaching, it will be distributed to the students enrolled in the residential construction course. The basic skills required for using this repository will be taught in a few lectures. Assignments will be designed to provide an auditory, visual, and kinesthetic learning environment. In one of the assignments, students will virtually construct a small residential structure using BIM software. A 3D building model

will be provided so students can identify and assign the different components of the house to their respective construction activities. For example, work related to foundations of the house will be completed during the construction of foundation. To represent this, all the footings will be selected and assigned to the footing construction activity. The final construction schedule developed by the student will be depicted through simulation (see Figure 7). The visual simulation of the proposed construction sequence will help the students to learn about the construction sequence process.
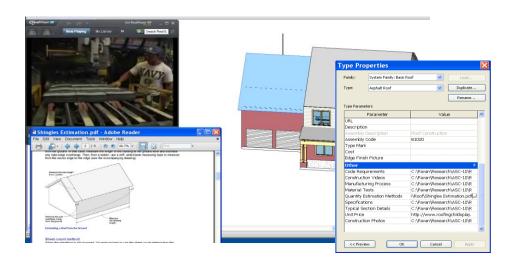

Figure 6: Retrieved manufacturing video and estimation guidelines for Asphalt Shingles roof component

Many other applications of BIM as a teaching and learning tool can be explored. Visualization of construction processes can be integrated with safety standards, operation procedures, and material or product data sheets. The continuous evolution of computing hardware allows such applications to be used even in mobile platforms. This facilitates any-time access to knowledge repository and creates a learning environment beyond time and space boundaries. For example, tablet computer can be used to explain workers on site about installation procedures based on BIM software (see Figure 8).

It is also important to consider human computer interaction (HCI) with such teaching and learning applications. Irizarry and Meadati (2009) compared the performance of students when using a standard desktop computer display versus a large format interactive display (SMARTBoard). The results of the experiment showed improved performance when the large format interactive display was used, as compared to desktop display unit. This indicates the potential of the technology to enhance the educational experience of construction management students through not only enhanced visualization but enhanced HCI.
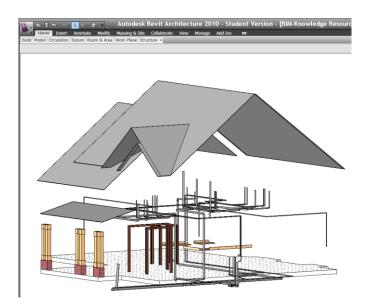
Figure 7: Visual simulation of proposed construction schedule

Figure 8: Using tablet computer for BIM knowledge repository access

Conclusion

BIM facilities easy and fast access to the information stored in a single centralized database or in different databases held at various locations through the 3D model. It provides any time access to the information through the parameters associated with 3D components. Integration of semi structured data files (HTML and XML files), unstructured data files (MS Word or plain text files), unstructured graphic files (drawings), and unstructured multimedia files (photographs audio and video files) with 3D components facilitate the use of BIM as knowledge repository for construction process learning. The ease of integration depends on the BIM software product and the availability of information in digital format. Autodesk' Revit Architecture BIM software product needs to be tailored by addition of new types or instance parameters in order to develop the knowledge repository. The methodology discussed in this paper serves as an initial step to develop a knowledge repository for residential construction process teaching and learning applications.

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