BIM- A New Teaching Tool

Pavan Meadati, Ph.D.[1] Javier Irizarry, Ph.D.[2]

Abstract – This paper discusses the development of knowledge repositories through Building Information Modeling (BIM) that facilitate a conducive learning environment for construction engineering and management (CEM) students. Based on learning styles, students can be identified as auditory, visual, and kinesthetic learners. Due to lack of conducive learning environment which provides hearing, seeing, and doing capabilities, currently CEM students struggle to gain the required skills to solve many real world problems. A user-friendly interactive learning tool that provides a conducive learning environment is needed to enhance students' learning capabilities. BIM facilitates development of a knowledge repository, which fosters conducive learning environments. BIM characteristics such as easy access to the information, visualization, and simulation capabilities facilitate the students to discover strengths and weaknesses of their learning practices and improve accordingly. It facilitates students to learn at their own pace and creates the learning environment beyond class room boundaries.

Keywords: BIM, conducive learning, CEM, 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, 8]. Teaching construction engineering and management (CEM) courses by addressing students' different learning styles is a challenging task. Traditional lecture is one of the widely used styles 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 to reasons such as unavailability of construction sites meeting the class needs, class schedule conflicts, and safety issues [Haque et al., 4]. Additionally, lack of laboratory and training facilities are impeding the creation of kinesthetic learning environments. Sometimes the traditional lecture teaching style also falls short to serve as an effective communication tool for transferring knowledge to students. Due to a lack of conducive learning environment which provides hearing, seeing, and doing capabilities, currently CEM students are struggle to gain the required skills to solve real world problems. A user-friendly and interactive knowledge repository that provides a conducive learning environment is needed to enhance students' learning capabilities. Building Information Modeling (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.

BUILDING INFORMATION MODELING

"BIM is an approach and not a technology" [Autodesk, 1]. In this approach, real world elements, such as walls, beams, doors, and windows, are represented as 3D objects to develop a 3D digital model. Attaching geometry and other information to these objects further enriches the 3D digital model. 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

[1] Assistant Professor, Construction Management Department, Southern Polytechnic State University, Room H-338 Academic Building, 1100 South Marietta Parkway Marietta, GA 30060-2896, pmeadati@spsu.edu

[2] Assistant Professor, School of Building Construction, Georgia Institute of Technology, 280 Ferst Drive, 1st Floor, Atlanta, GA 30332-0680, javier.irizarry@coa.gatech.edu

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 [Meadati and Irizarry, 10]. These environments allow the students to discover strengths and weaknesses of their learning practices and improve accordingly. Any time access to the repository creates learning environment beyond time and space boundaries. An interactive access to the repository through 3D model facilitates students to learn at their own pace. This repository also helps as an effective knowledge transfer and communication tool. Development of these environments is part of ongoing research with the goal of developing an interactive knowledge repository through BIM to be used for teaching residential construction and concrete formwork courses. In this paper, the feasibility of developing knowledge repositories for learning about the residential house construction process and concrete formwork is demonstrated.

METHODOLOGY FOR BIM KNOWLEDGE REPOSITORY

This section discusses the methodology adopted for the development of a knowledge repository through BIM (Figure 1). 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 components of the 3D model can be retrieved through parameters of the components. These establish the links between respective files and components in digital format. 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. Autodesk's Revit software was used for developing the BIM knowledge repository. The following sections describe in detail the steps used in the methodology.

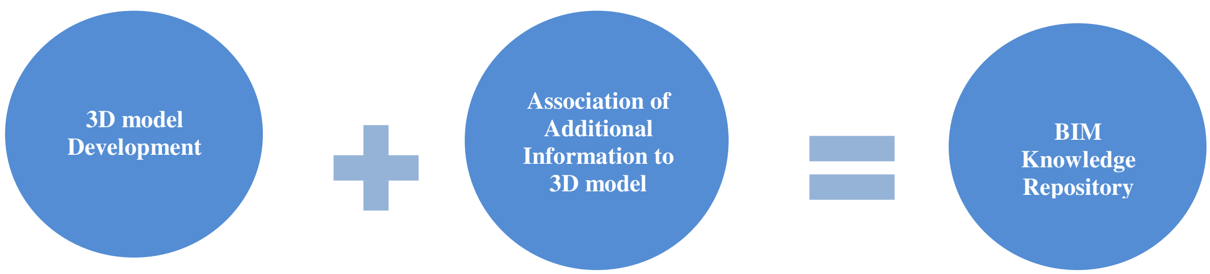

Figure 1: Methodology for BIM concrete formwork repository development

3D Model Development

Autodesk's Revit software 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 familygroups 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 a project and have specific locations in the building. The required 3D model was developed by using different families.

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 and Soibelman, 2]. 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. Only the shared parameters are exported to databases. Other families and projects share these, whereas project parameters are not exported to the databases. To associate the required information, some new parameters were created for each element.

BIM KNOWLEDGE REPOSITORIES

Using the methodology discussed above, BIM knowledge repositories were developed for teaching CEM courses. Residential house and wall formwork system knowledge repositories were developed for teaching residential house construction process and concrete formwork courses respectively. The following sections discuss the repositories.

Residential House Knowledge Repository

Revit Architecture 2010 was used to develop a two story residential house BIM knowledge repository (Figure 2). Some of the different components of the BIM components 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. Typical BIM components like walls, slabs, windows, and doors available in Revit Architecture are useful to represent the finished component but cannot serve to depict actual construction progress [Goedert and Meadati, 3]. 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. 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. 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. 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 was 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.

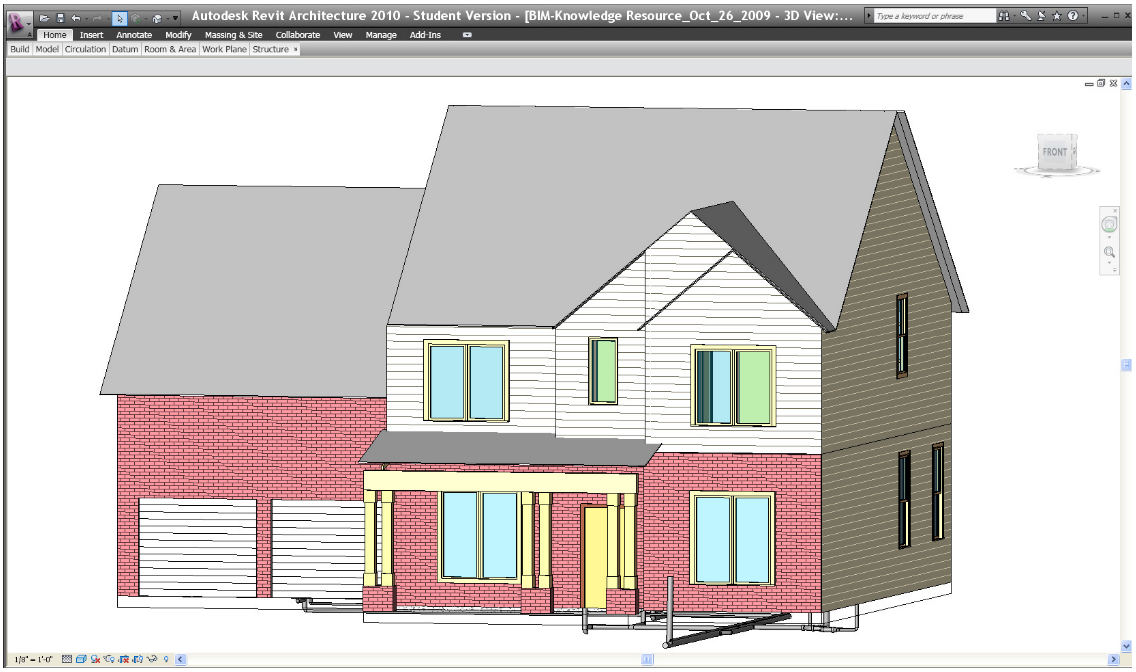

Figure 2: Knowledge repository 3D model of Residential House developed in Revit

Wall Formwork Knowledge Repository

Revit Structure 2010 was used to develop wall formwork BIM knowledge repository for a concrete wall (Figure 3). In general, the formwork system for a concrete wall consists of sheathing to retain concrete and supporting members necessary to hold the sheathing firmly in place. Members which support sheathing directly are referred to as studs in vertical formwork. The cross members which support studs are usually refereed as wales. The wales in turn are supported by ties. The different components of the formwork system were represented by using various Revit Families. To facilitate the depiction of actual construction sequence, sheathing, studs, wales components were sized to represent the actual available dimensions of material. For example, the plywood used for sheathing was cut into 8'x4' sections to reflect the actual 8'x4' plywood. 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. Some of the newly added parameters include Design Assumptions, Unit Price, Specifications, Construction Video, Quantity Estimation Steps, Typical Section and Construction Photos. 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 for establishing the link between the respective files and components. The association of information to the model components was 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. 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.

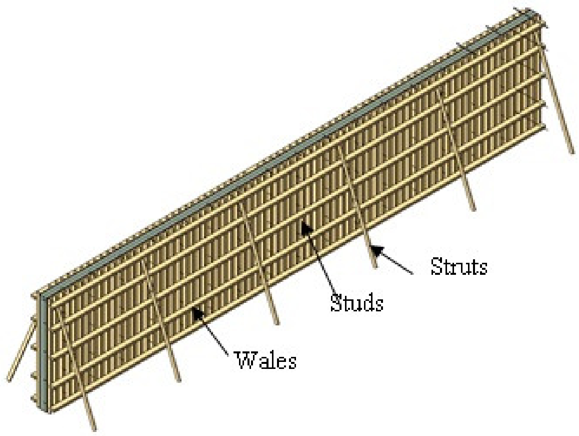

Figure 3: Knowledge repository 3D model of wall formwork system

BIM AS A LEARNING TOOL

The characteristics that help BIM to serve as a better learning and teaching tool are accessibility to information and visualization enhancement. 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 (Figure 4). 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., 11]. The short comings of these traditional methods can be addressed by using four dimensional (4D) modeling [Koo and Fisher, 7; Kang et al., 8]. BIM facilitates integration of 3D with scheduling 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 (Figure 5).

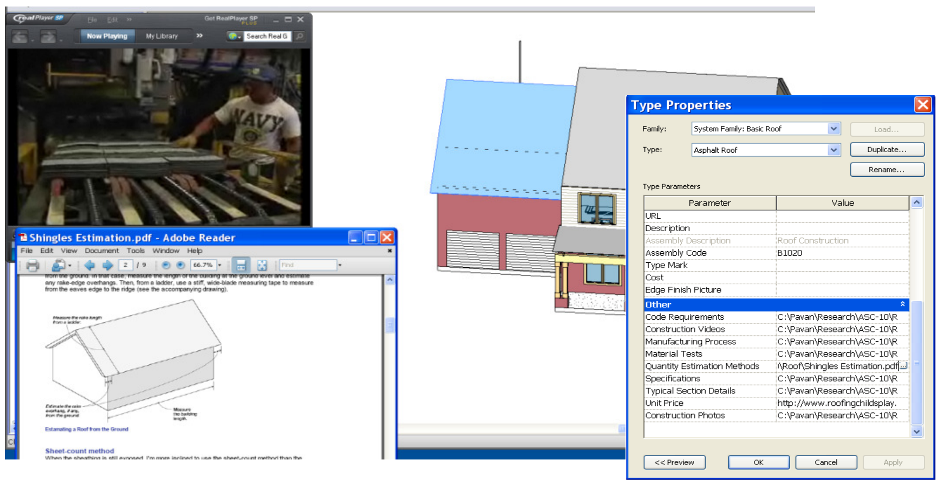

Figure 4: Retrieved manufacturing video and estimation guidelines for Asphalt Shingles roof component

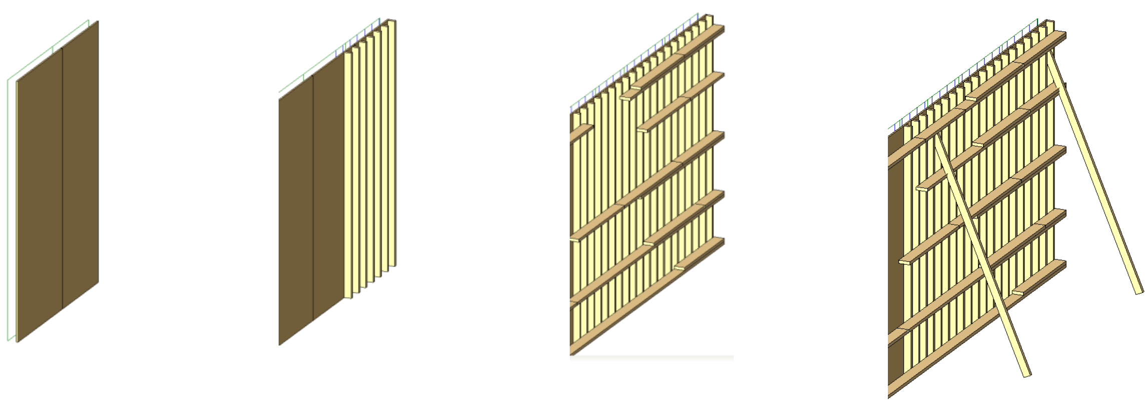

Figure 5: Erection sequence of wall formwork system

Regarding the use of the digital repository in teaching it will be distributed to the students enrolled in the course. The basic skills required for using this repository will be taught over several 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 (Figure 6). The visual simulation of the proposed construction sequence will help the students to learn about the construction sequence process.

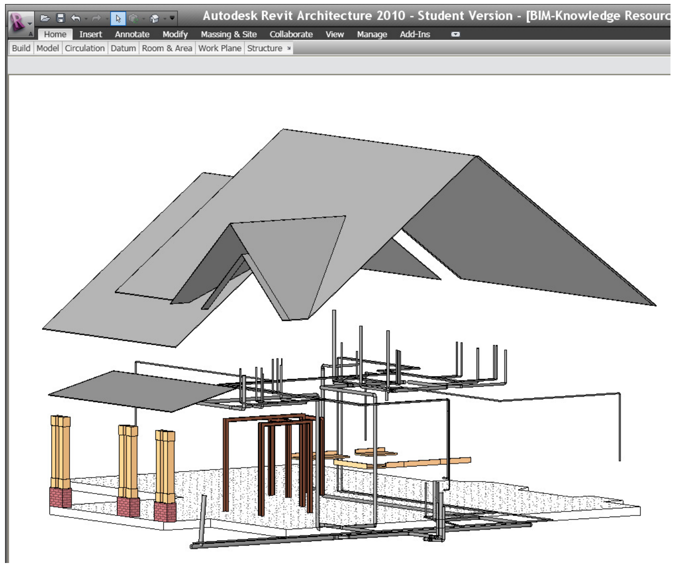

Figure 6: Visual simulation of proposed construction schedule

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 [Irizarry and Meadati, 5] (Figure 7).

Figure 7: Using tablet computer for BIM knowledge repository access

CONCLUSION

This paper presents the ongoing research efforts at the Virtual Construction Instructional Laboratory of Construction Management department at Southern Polytechnic State University to use building information models to teach students several aspects of construction operations. The BIM knowledge repositories provide faculty with a tool that can facilitate teaching of construction concepts in a more visual and interactive way. Factors such as BIM software, means of information association to the model, and information format affect BIM repository development [Meadati, 9]. Lack of some features in BIM software can increase 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 an automated process can reduce this effort. Depending upon information format, inclusion of some additional steps affects the repository development process. For example, a document scanning process has to be included as an additional step for converting paper format information into digital format. The knowledge repositories being developed by using Building Information Modeling (BIM) fosters conducive learning environments beyond classroom boundaries and has the potential to greatly enhance the educational experience of students.

REFERENCES

[1] Autodesk, "Building Information Modeling in Practice," 2003, Retrieved July 25, 2006 from http://usa.autodesk.com/adsk/servlet/item?siteID=123112&id=8127972.

[2] Caldas, C. H., & Soibelman, L., "Methodology for integration of project documents in model based information systems," 2005, *Journal of Civil Engineering,* 19(1)*,* pg 25-33.

[3] Goedert, J. D., & Meadati, P., "Integration of construction process documentation into Building Information Modeling," 2008, *Journal of Construction Engineering and Management*, 134(7), pg 509-516.

[4] Haque, M.E., "n-D Virtual Environment in Construction Education," 2007, The 2nd International conference on Virtual Learning, ICVL 2007, Retrieved November 12, 2010 from http://www.cniv.ro/2007/disc2/icvl/documente/pdf/met/2.pdf.

[5] Irizarry, J., and Meadati, P. Use of interactive Display Technology for Construction Education Applications, 2009, *American Society for Engineering Education Southeastern Section Annual Conference*, April 5-7, 2009, Marietta, GA (in CD-ROM).

[6] Kang, H. J., Lho, B., & Kim, J. (2004). Development of web-based interactive 4D block tower model for construction planning and scheduling education," 2004, *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition,* Retrieved November 12, 2010 from http://architectural.asee.org/2004_papers/2004-1080_Final.pdf

[7] Koo, B. and M. Fischer, "Feasibility Study of 4D CAD in Commercial Construction," 2000, *Journal of Construction Engineering and Management*, 126(4), pg 251-260.

[8] Marvin, B. R. (1998). "Different learning styles: visual vs. non-visual learners mean raw scores in the vocabulary, comprehension, mathematical computation, and mathematical concepts." 1998, Retrieved November 11, 2008 from http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/17/95/48.pdf

[9] Meadati, P. (2007). *Integration of construction process documents into BIM.* Doctoral dissertation, University of Nebraska, Lincoln.

[10] Meadati, P., & Irizarry, J. (2010). BIM – A knowledge Repository. *Proceedings of the 46th Annual International Conference of the Associated Schools of Construction,* Retrieved November 12, 2010 from http://ascpro0.ascweb.org/archives/cd/2010/paper/CERT177002010.pdf

[11] Messner, J. I., S. C. M. Yerrapathruni, V. E.Whisker, and A. J. Baratta, "Using Virtual Reality to Improve Construction Engineering Education." *2003 ASEE Annual Conference*, Nashville, TN, 2003, Retrieved November 11, 2010 from http://www.engr.psu.edu/ae/cic/publications/Conference/Messner_2003_Using_Virtual_Reality.pdf.

Pavan Meadati, Ph.D., LEED AP

Dr. Meadati holds a BS in Civil Engineering, a Masters in Construction Engineering and Management from India and a PhD in Civil Engineering from University of Nebraska. Dr. Meadati works as Assistant Professor in Construction Management at Southern Polytechnic State University and serves as director for Virtual Construction Instructional Laboratory. His research areas include building information modeling and application of information technologies in construction.

Javier Irizarry, Ph.D., P.E.

Dr. Irizarry has experience in the planning and construction of multiple types of infrastructure facilities and has conducted research in the areas of construction safety, constructability of transportation infrastructure, information technology applications for construction operations and education. As faculty member in the School of Building Construction at the Georgia Institute of Technology, he directs the CONECTech Laboratory. He holds a BS in Civil Engineering from the University of Puerto Rico, a Masters in Engineering Management from the Polytechnic University of Puerto Rico and a PhD in Civil Engineering from Purdue University.