

Building Information Modeling: An Academic Perspective

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Abstract

The last decade has seen a tremendous rise in object oriented and parametric modeling technology. The rapid rise has spiked interest in the academic world and the architectural, engineering, and construction (AEC) industry. Several construction firms, realizing the potential for growth using this technology, have already started their own building information modeling divisions. The academic world has also realized the need to capture this technology to further aid and enrich the learning process and, at the same time, cater to the needs of the industry of producing quality students ready to take on this new challenge from the word “go.”

To address these needs, several departments at Purdue University have come up with their own attributes, infrastructure, and characteristics of a program designed to make students aware of the potential of building information modeling (BIM) and provide them with the tools needed to incorporate this technology in their own areas of work.

This study outlines the needs of the departments with respect to visualization and modeling software and shows how the different building information modeling software could address these issues. The paper reports on the considerations that were made in the phased integration of BIM into the academic curriculum by three different departments: Computer Graphics, Industrial Technology, and Civil Engineering, respectively. The paper also explores the methods used for implementation of BIM. Furthermore, it compares and evaluates the effectiveness of the three different approaches adopted, using feedback from the students. The study also considers the obstacles presented and the future of this technology in the academic world.

Introduction

The last decade has seen a tremendous rise in computer hardware related technologies, which has proliferated the advent of powerful software packages in the industrial world. With the ever expanding involvement of information technology in today’s industrial world, the academic world is coming under increasing pressure to produce quality students equipped with the digital expertise to face the emerging challenges of the industry. The academic world is under scrutiny to provide a balanced curriculum that could balance this need of technology with courses to provide an in-depth understanding of the field. The advent of

computer aided design (CAD) started this debate, which seems to have picked up ground in recent times with a plethora of other softwares invading the industry and the academic world at the same time. BIM further adds to the mixture of techniques now available for students of architecture, construction, computer graphics, and engineering.

The Purdue University in the state of Indiana is one of the largest providers of quality students in the Midwest region. In the spring of 2008, the College of Technology and Engineering took a leaf out of the Department of Industrial Technology book and introduced undergraduate courses in BIM in response to a growing need for specialists capable of bringing about this transition from traditional 2D CAD to building information models (which are now becoming the new standard in the AEC industry). This paper reviews this ever increasing need on part of the departments to meet those needs, in addition to the need of enriching their own academic curriculum to help students get a better understanding of the subject matter. The paper reports on the considerations that were made in the phased integration of BIM in the academic curriculum of three different departments: computer graphics, industrial technology, and civil engineering, respectively. The approach adopted for this integration is examined alongside an analysis of the process and end results of BIM implementation. Conclusions are drawn relating to the value of incorporating BIM technologies into the curriculum. The study also considers the obstacles presented and the future of this technology in the academic world.

What Is BIM?

“BIM is the process of creating an intelligent and computable 3-D data set and sharing the data among the various types of professionals within the design and construction team. The goal of this process is to improve collaboration among project participants. BIM is not defined by simply creating a 3-D data set for internal analysis which has been commonplace within the design industry for many years” (Fauerbach, 2007).

BIM in its present state is commonly used on complex projects such as high-rise buildings, bridges, arts centers, stadiums, and medical facilities. The term is most commonly applied for planning, design, construction, and management of buildings; however, its capabilities are being extended to challenging and complex civil engineering projects. 3D modeling is just one aspect of BIM that has hogged the limelight, but its real strength and power lies in the knowledge database, which can be used in conjunction with other softwares to deliver quick and reliable information in areas of sustainability, estimating, structural analysis, demolition, and reconstruction.

Development of BIM Technologies

The heightened interest on part of the academic world and the industry with regards to BIM has, over the past few years, resulted in several software packages coming out in the market, each with its own strength and weaknesses. The following section examines some of the most popular BIM packages available on the market and which ones have been adopted in various course curricula as a visualization tool.

Autodesk Revit is almost synonymous with BIM. With its ease of use, availability, and power as a modeling tool, its market share is increasing at a rapid rate. The strength of Revit's central database approach is its ability to coordinate every building element into one database, thus providing users the ability to immediately see the results of any design revisions made in the model, have them reflected in the associated views (drawings), as well as to detect any coordination issues. Revit is a proprietary data model that does not currently support Industry Foundation Classes (IFC) import/export, although future IFC support has been promised in the near future. For software developers, open database connectivity (ODBC) links provide limited access to the building model information, and a limited application programming interface has been provided in the most recent release, which is one of the major drawbacks.

Graphisoft has developed ArchiCAD over the course of time into a fully BIM enabled software package. It has been designed to support each stage in the building process with early design iterations and fast-sketch modes, as well as detail-level design tools for offsite fabrication and coordinated digital construction sequences. In addition to ArchiCAD, Graphisoft is also working with a consortium of application partners to deploy Enterprise Performance Management (EPM) Technology's IFC-based model server as a virtual building repository, possibly the most innovative technical approach to the future of BIM.

Bentley Systems visualize BIM as an integrated project model that comprises of a family of application modules, such as Bentley Architecture, Bentley Structures, Bentley HVAC, etc. Bentley's approach is an evolutionary one that allows its Microstation users to migrate work practices that still have their origins based on using CAD. Access to project data is provided with DWG and IFC file formats, both being supported. However, the highest levels of interoperability are achieved only when the entire range of Bentley products are used during the course of the project.

Integration of BIM into the Academic Curriculum

Industrial Technology

Industrial technology is a field of study designed to prepare technical and management oriented professionals for employment in business, industry, education, and government. Although used to a limited extent, the Industrial Technology department laid the first seeds of incorporating BIM technology into the academic curriculum and, hence, need a special mention.

Revit is used as the primary design and visualization tool in the course titled, "Teaching Civil Engineering and Architecture." The purpose of this course is to prepare future high school teachers to teach a similar course. The course focuses on the design process; the roles of engineers and architects and how they interact with a client; site research and preparation; and designing a building for a particular plot. Now in its third year, this course has been greatly appreciated by the students, and the numbers of students taking interest continues to show a sharp rise.

Computer Graphics Department

The Computer Graphics department, a part of the College of Technology at Purdue University, is an emerging department that prepares visually oriented students for careers in creating and managing the production of computer graphics within a wide range of industries. Students work collaboratively in computer labs to master graphic techniques and concepts, along with management skills. Students seek specialization in a number of industrial areas, among which construction is a major attraction. With the advent of new parametric modeling and other animation softwares combined with the traditional drafting softwares like AutoCAD, most construction companies look for students in computer graphics who have knowledge of these software programs. The department, having recognized this ever increasing need, continually updates and revises the course curriculum to keep the students informed about all of the latest technologies.

To meet this industrial demand, the approach of the department with most of its courses has been application oriented, with emphasis on hands-on experience so that the students can directly fit into the system. Students looking for construction as their area of expertise are taught CAD in the first year and construction plans and measurements in the second year of their coursework, which introduces them to the architectural concepts and 2D CAD techniques still predominately used in the industry. For BIM, which requires an understanding of the different facets of building construction, it was decided to use Revit Architecture for instructional purposes in the fourth year, since by then the students have been exposed to several courses on building construction. This would allow the students to focus more on using BIM as a tool and learning its applications rather than having to spend more time on learning about different aspects of building construction.

The students in the lecture class were introduced through a series of structured lectures to the concepts of object oriented modeling and the fundamental differences between BIM and CAD. The lecture program focused on the visualization capabilities of Revit and its increasing role in the industry right from the inception of a project to the facilities management stage. Today, BIM softwares supplement the conventional plans, sections, elevations, and 3D models with ray-traced or radiosity renderings, which a few years ago were possible only with the help of specialist visualization packages. The lectures also focused on the suitability of this technology for different commercial projects and how the industry is using this technology for its benefit.

The series of lectures were supplemented by weekly lab classes, where the students for the first month learned the fundamentals of the program by working through assignments provided in the book, *Commercial Design Using Autodesk Revit Architecture*. This information was further supplemented with audio and video files to create a better understanding. Once the basic skills had been acquired, students were encouraged to apply their knowledge to develop an entire set of plans, 3D drawings, and rendered images using the traditional 2D drawings. As part of the final project, students were divided into groups to work on bigger projects, which included an office building and a black cultural center. In

addition to making the complete set of architectural drawings and 3D models of the project drawings, they were also encouraged to create mechanical, electrical, and plumbing (MEP) systems for which they were given a brief introduction to Revit MEP. Throughout the modeling process, which spanned an eight-week period, it was evident that the students were learning much more than visualization techniques. BIM encouraged students to consider the building as a whole and study the relationship between the different elements involved.

Civil Engineering Department

The Civil Engineering department in the College of Engineering is a well established department that has been providing quality civil engineers to Midwestern states like Indiana, Illinois, and Kentucky for the past 57 years. The department's collaborative efforts with industry giants in the field of construction has, over the years, resulted in a curriculum that provides the right blend of practical and theoretical knowledge to the students. The coursework is geared towards the needs of the industry and, at the same time, encourages students to explore new areas of their own. The collaboration has, over the years, provided the industry with many solutions to many emerging technology problems—BIM comes as no exception. Although, BIM has been primarily touted as visualization tool, its capabilities are far reaching. The industry giants have realized its applications in areas of planning, design, construction, and asset management of civil engineering projects. They want this technology to be incorporated in their areas of work but face a stiff challenge in finding employees capable to handle it.

Being one of the premiere civil engineering schools who take pride in the quality of their students, they took a more radical approach towards BIM. The idea behind the course was to go a step beyond using BIM software's as an application tool for visualization purposes. The aim was to foster an environment where the students could understand what goes on behind the tools to create new tools and libraries of products suited to their own projects. Students should not be limited to what the software provides but be capable of molding it according to their needs and take it a step forward. The potential of including BIM tools for estimating and analysis design was also given due consideration to help students in other areas of work.

The course started with a series of video demonstrations to highlight the capabilities and limits of BIM as a technology. From the second week onward, the lectures were supplemented with lab work and assignments to delve further in a specified area. The first software introduced was Microsoft Visio, which enabled the students to create advanced diagrams and layouts, as well as to create unique functionality to link their diagrams to a number of data sources and display the information graphically. The idea behind starting with relatively simple software was to help students get a grip of the BIM technology and working with easier projects. Also, for many civil engineers tasks, a 2D representation/visualization is sufficient and time saving. The students were then introduced to more powerful software in the form of ArchiCAD. In addition to providing the application side of the software, the lab work also revolved around creating new and more detailed library elements particular to the projects on which they were working. With new and challenging civil and architectural projects on the horizon, the conventional libraries often

fail to provide the range of solutions required. The students worked on Visual Basic applications to create coding for those elements.

The regular modeling and products library development process culminated in a final assignment where students were asked to work on a manufacturing plant project. Their task involved developing libraries specific to the manufacturing house not included in the ArchiCAD software; then, creating the entire model for the project. The last phase included the estimation of the cost of the manufacturing house using the data from ArchiCAD.

Results

The students in the Computer Graphics department were able to produce quality work in a relatively short period of time. The set of drawings produced were much more detailed and coherent as compared to their past work on 2D CAD applications. The students were also able to produce impressive rendered images (Figure 1) of their projects. Revit provided the students with the flexibility to manage all of their work, while working on a single central file. This helped them save time and maintain focus towards quality of work. One of the key factors for the success of their final project was the collaborative nature of work facilitated by the BIM technology, whereby the group members created one central file and several local files to work on the project simultaneously.



Figure 1: Ashley Oaks Office Complex

With easy to follow tutorials supplemented by excellent demos, students were able to gain insight into the mechanical, electrical, and plumbing systems of the building. The product libraries and auto complete feature of Revit helped them to create MEP drawings of the buildings, even with their limited fundamental knowledge of the systems.

While the students in the Computer Graphics department were able to develop expertise in using Revit as an application tool, the students in the Civil Engineering department were able to master the analytical skills needed to take BIM technology to the next level. They opened

their minds to new possibilities and learned skills necessary to adapt to the ever changing and evolving nature of BIM software. From neat 2D pictorial representations to complex 3D-built forms (Figure 2), the students were able to express their competence on multiple fronts.

Students were not only able to produce excellent visual images of their projects but also able to link the project data they entered into ArchiCAD software with other estimating softwares to calculate the cost of their projects. They also created several library elements in ArchiCAD by writing programming codes on Visual Basic applications to exploit the software's capabilities to its maximum potential.



Figure 2: Manufacturing Plant

Student Feedback

Written feedback was collected at the end of the semester from the students of the Computer Graphics department to get quantitative and qualitative data on the strategy of introducing BIM into the curriculum. Due to time constraints, the authors were unable to get feedback from the civil engineering students to reflect the efforts made in that department.

From a total of 16 students in the class, each student felt that the learning outcomes of the computer aided visualization and 3D modeling module had been met. Eighty-seven percent felt confident using BIM for visualization. Ninety-four percent of students were appreciative of the fact that the coursework reflected the current practices. All of the students felt that their analytical skills and the understanding of the building architecture had developed as they explored their project in detail to develop a complete model of their project.

Students were also asked to reflect on their experiences of using Revit as a software for creating sets of drawings and rendered views of the building. The majority of the students highlighted the user friendliness and the advantages associated with using a technology build specially for creating buildings and MEP systems for the project. Many students also

reflected upon the collaboration made possible using the Revit software. The group work was made a lot easier with the concept of a central file and several local files. The technology allowed them to work individually and, at the same time, keep the group informed about the latest developments. Comments most often cited were:

“Improved speed of rendering of the 3D models for the project, although with less detail than that possible in 3Ds Max models.”

“Having the ability to switch back and forth between the set of plans and the 3D view ultimately led to a better product overall.”

“Creating objects in 3D helped create a better spatial understanding.”

“Working with a software like Revit kept all of us honest, as there is no room of ‘fudging’ a design. With clash detection and automatic warnings, errors could be easily identified.”

“Helped save a lot of time. Having done several projects in past using other drafting software, Revit was a welcome change.”

“The software needs to be developed further, as it suits creation of conventional types of buildings. Creating curved surfaces is a big challenge.”

“Revit offers a limited library of objects to be used in projects. Creating new objects is time taking, and with the present tools, it’s difficult to play around with shapes.”

Even though the students met with some problems during the course of the semester, they were appreciative of being provided the opportunity of getting hands-on experience on this new technology. They realized the importance and the potential of this technology in the times to come; and they were positive that with this kind of background, they would be able to explore newer job markets. They encouraged continuation of this integration with more emphasis on software usage for detailed and more complex projects and linking it further with software such as Navisworks, etc., to reap further benefits of using a database approach of creating models.

Conclusions and Future Work

The impact of using BIM in the academic curriculum of different departments has resulted in:

- Production of high quality set of drawings and rendered images.
- Opening of a new avenue for employment for most of the students in the Computer Graphics department. BIM divisions of all the major construction companies looking for skilled students in this area handed them immediate training and job offers.

- Increased speed of production of a set of drawings and renderings.
- More creative and innovative solutions to engineering problems on the part of civil engineering students.
- Creation of new and project specific library elements to quicken the process of modeling and simulation.
- Discussions between students and staff on the potential for further integration of BIM into other areas, like structural analysis, estimating, sustainability, green building design, demolition, and reconstruction of the curriculum that heavily depend on 3D models or building database information for their work.

After an entire semester of observation and important student feedback towards the end, several potential problem areas have been identified that need rethinking on the part of departments to make BIM in the academic environment a true success. The biggest challenge in their way is the selection of the software to be used for class work. With an ever changing and evolving set of BIM standards, depending on one particular platform for the learning process can soon render the skill sets acquired by the students useless. How can academia formulate a curriculum to prepare students in BIM so that their knowledge continues to serve them in such an environment? The other area that needs to be addressed is how to make the transition between traditional 2D CAD application and BIM application smoother. BIM requires more in-depth understanding of the subject matter and large datasets about the project in the early stages, making it a real challenge for students to get involved with BIM in the early academic stages. Another challenge facing the present BIM coursework is how to break the prescriptive nature of some of the assignments. On the surface, these assignments gave the impression that the students had performed really well, but how much of it is translated into real learning that is still to be learned?

As we look forward to the future and learn from the experimental nature of the coursework this semester, the departments realize that they will have to respond and adapt to these challenges. The standards created here will affect how we see architecture, engineering, and construction education in the times to come.

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Biography

CLARK CORY is currently an Associate Professor in the Department of Computer Graphics Technology at Purdue University in West Lafayette, Indiana. Professor Cory's publications include topics on the improvement of cognitive visualization in construction using 3D models, the impact of new technology on construction jobsites, and smart house technology.

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