Thinking the BIM Way

Early integration of Building Information Modelling in education

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Since Building Information Modelling as a technology depends on recognizing parts of the buildings as objects that can be simulated digitally, to prepare students to grasp the BIM way of thinking, educators can start introducing the concept early in the architectural curriculum without using the real tools. The researchers monitored the students' progress over a period of time while they were using different 3 dimensional CAD tools in several situations such as design studio visualization and construction document production until eventually the same group of students have been introduced formally to a real BIM tool. The research tries to establish a relationship between the pedagogical techniques and the success of the students to grasp what BIM is about and the development of their ability to use it fruitfully. Comparisons between their performances should shed the light on the best method to use in order to prepare students for the use of BIM.

Keywords: *BIM, CAD, education, pedagogy, objects*

INTRODUCTION

In conclusion to her article in the 2006 AIA's "Report on integrated practice", Renée Cheng commented on the BIM education by saying: "Regardless of the magnitude of BIM's eventual of impact on the profession, its recent rise provides the ideal catalyst for rethinking architectural education. The level of expertise required to intelligently design with BIM is significant, and serious considerations must be given to how it can be taught" (Cheng 2006).

WHAT IS BIM?

By now, a definition of Building Information Modeling is not as necessary as it was five years ago. But for the sake of a complete literature review, it is important to define BIM. However, instead of the usual definition, it would make more sense if it is defined by comparing it to physical model making.

With physical models, objects are manipulated by tools to produce particular forms that look like real world objects. A wall is piece of wood that has dimensions proportionate to its real counterpart in a building. A slab, is another piece of wood or plastic that has dimensions that are proportionate to its real

counterpart in the proposed real building. The slab edge line is well defined by the borders of the material. In a BIM solution, a user has to think in the same terms of physical modeling.

Ironically, this creates the very first obstacle to learning the tool especially if the user has been previously trained to use a drafting CAD package or a loose modeling tool such as SketchUp, where the integrity of lines to close the loop of the slab edge is not of the same order of importance.

A BIM solution will not accept an open loop as a slab edge where a simpler CAD system would, leaving the responsibility of its integrity to the user.

This articulates the definition of BIM which can be described as a system that is smart about its knowledge of the objects it uses. In most cases, treating those objects as they would be treated in the physical world.

How different is it from CAD?

The initial application of computing in architecture has been one of substituting CAD drafting to replace hand drafting. In most offices, until recently, this has been so literal that drawing sheets and computer files have been thought of in a 1:1 relationship (Johnson 2000). It is believed that the 1:1 relationship made it very straightforward to convert to CAD platforms when it became economically viable to own a computer or more in an architectural office.

And it was also true, that training to use CAD platforms was as straight forward as learning the commands that would create a line, an arc, or a circle. The rest of the knowledge was exactly the same required to produce drawings by hand, it required the architectural knowledge to do the abstract plans, sections, elevations and details.

BIM as a way of thinking, approaching ways of thinking about BIM

BIM is not just another CAD; it is the shift from presenting information about the building to representing this information. What we used to use and call CAD is in its essence a neat replacement of the pencil, pen and the T-square on our desks. It is used for the production of drawings; in much the same way as a word processor is used for letters and reports. Its contribution to efficiency matches that of the word processor, a little, rising to quite a lot when a document has to be reissued with revisions (Richens 1994). BIM based CAD is different, it requires thinking behind what we draw in order to produce a correctly represented data about the building in either format: drawings, or database. It is a way of thinking before it is a program to run on a computer. Many architects used to think the BIM way even when using traditional CAD tools, since normally, the tool would not teach you how to think.

BIM conversely begins with the virtual construction (simulation) of the whole, which is then viewed as a series of synthetic assemblies of constituent components. BIM represents a design process that does not prioritize abstract representation or fragmented conventions of communication but instead privileges the contextual construction of a formal/spatial systemic intelligent simulation (Ambrose 2007)

TEACHING BIM

While there is general support for the idea of incorporating BIM as part of higher education curricula, agreement is lacking as to the best way to achieve this. When to introduce BIM, and how to introduce BIM are questions programs approach differently. (Becerik-Gerber and Gerber et al 2011)

Academic versus professional BIM training

There is a clear difference between professional training to use BIM platforms and academic preparation for the same purpose. While professional training is more focused on producing fast results, it heavily depends and builds on the users' learning capacity and previous knowledge of computing tools, as well as their architecture and building technology knowledge and the trainees own experience as professional architects. A fast paced training on a new platform does not usually have the learning objectives of a university course. The main goal is to adequately introduce the software and its different func-

tionalities. Challenged with specific questions, the trainer responds in most cases by showing ways of achieving the familiar desired results.

In an academic setting, the recipient of the training does not usually have enough background to challenge the trainer. They do not have a benchmark to measure the productivity of the software against, and most likely are happy with what the application can produce while in the same time face difficulty understanding all of its commands.

The focus of the educator in this case should always be on the concepts rather than the specifics. A lot of high level ideas about computing and database views and queries might be necessary in order to insure the comprehension of why things are the way they are and why do they behave the way they behave.

A usual course at the undergraduate level will be delivered in a 15 weeks semester. The knowledge has to be divided into smaller digestible portions for the students to follow successfully.

Object oriented modelling "objectification"

Architectural drawings are abstract means of communications about real physical objects. It has been a long legacy of drawing creation that shaped the todays' architectural education with its abstract based means of communications. In the era of BIM, thing are being reversed a little. In fact, many concepts might need to be revisited to adjust to the new mode of production. Users depend on objects when using BIM which negates the notion of abstraction that the education is very familiar with. Producing drawings as an abstraction of the real thing with a BIM system confuses the basic training of an architecture student.

- Objectification versus Abstraction: By definition, designing is an abstract process that requires jumping between different scales and modes. It also requires expressing the thoughts of the designer in a comprehensible way to others. Working with physical models and visiting real buildings has been and still are normal everyday activities in architectural education. Students need to develop a sense of the real objects they are required to abstract in a drawing later. BIM assisted education would benefit from such a relationship. Using a BIM tool requires the user to jump between thinking in an abstract mode to objects mode and back again.
- Physical models versus digital models: Despite the face similarities, working in the digital world is different. Many CAD application have a very generic notion to the objects, for instance, a "line" is an object. This does not help the user grasp the concept of an "Object". One particular application is SketchUp where the idea of an object is clearly misleading. Students need to be instructed to use groups and components to achieve the effect of an object. BIM solutions can bridge this gap.

The happiness curve

It is important to let the students know what to expect from the ride. What has been described by Krygiel and Nies in the book Green BIM as happiness overtime curve sums up the experience of learning such a system; you cannot learn it all in one session see Figure 1.

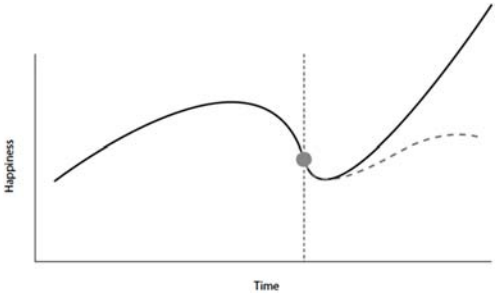


Figure 1
Krygiel and Nies happiness curve

The technology requires laying many foundations to start, then advances by adding other layers of skills which leaves the user frustrated at certain points of the learning curve. It is important to understand the nature of the steep learning curve.

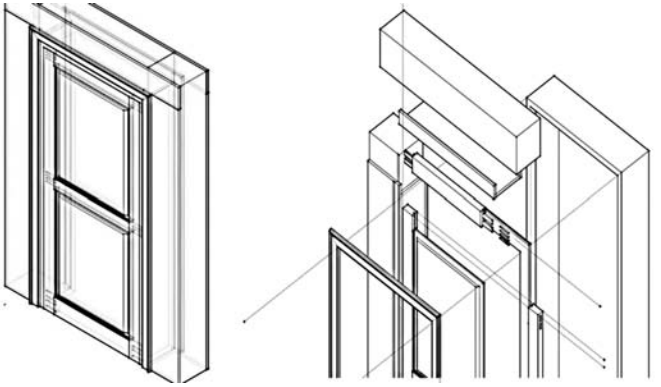


Figure 2
A door model using SketchUp, every part of the assembly is modelled as a separate object. The whole is composed of the parts.

THE EXPERIMENT: FROM SKETCHUP TO REVIT

This paper is to document a rare opportunity that was available to the researcher. On the course of four years, a group of students were monitored while building their digital skills until they were able to successfully and effectively use a BIM platform.

The researcher has been intentionally tailoring the instructions to follow a particular method. Also, tests and exams were used to verify the success of the followed method.

It is important to note that it is difficult to follow a big group of students in architecture for four years, this is why the number started with 21 students but ended with 9. There was also the factor of luck that one instructor would get the same students for that time.

Building technology objects

In their second year, students were first faced with a serious modeling task when they were asked to model a door assembly in their second course of Building Technology. The assignment followed a series of lectures on the types and composition of several door types and a series of drafting assignments to technically draft the different types in plans, sections and elevations as well as details of wooden connections in isometric projection.

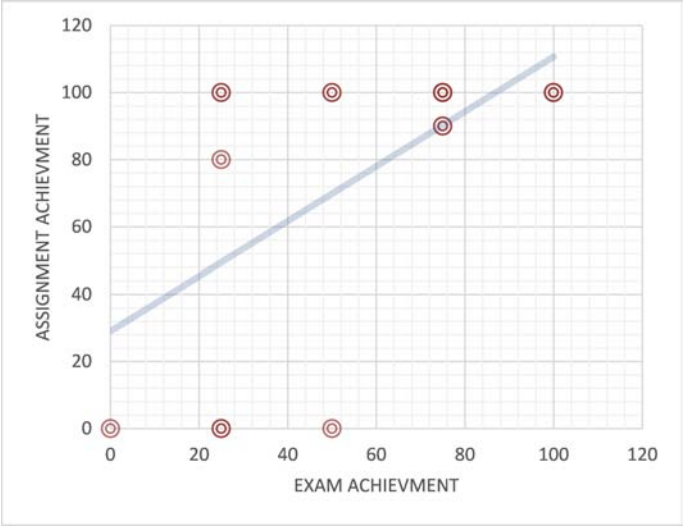
The students were then asked to use SketchUp to model a panelled door. The assignment was to model each part of the door, vertical stiles, horizontal boards, panels, door frame, and the wood connections and assemble each part to the next. They were asked to present their model as an exploded axonometric, see Figure 2. Out of 21 students, only 15 completed the model properly.

In their final exam, the whole group of students were faced with a question to measure how well they understood the connection and to measure the value of the modelling exercise. The question asked the students to locate a particular given connection in a door.

Out of the 15 students, 11 were able to get 75% of the mark of that question, a percentage of 73% where only 33% of the other group were able to achieve 75% of the marks of that question see Figure 3. Making a correlation between successfully completing the assignment and proper answering of the exam question resulted in a correlation factor = 0.597 with p value = 0.009

The results show the value of the model exercise in the overall understanding of the two dimensional drawings, which clearly indicated a better performance due to the assignment of modeling the parts. No BIM tools were introduced, but thinking about the parts to create the whole was emphasized. Thinking in terms of objects rather than just lines facilitated the understanding of the complex relationships.

Figure 3
The correlation of successfully answering the test question versus the completion of the SketchUp model



Design studio modeling of building elements

Later in their studies, the students registered for a studio class. The same approach to modelling was used. Instead of using the digital 3D model to design, the usual hand drawn sketching and physical models were used as preliminary design study tools. The students were asked to start modeling what they achieved on SketchUp in an object oriented way. Walls were expected to be three dimensional boxes with proper dimensions. Floor slabs were extruded faces and columns and structural elements were also modelled the same way, see Figure 4.

Although this seems like a straight forward approach, it has been observed that in many cases, students will focus in their digital model on achieving an outer shell of what they designed, ignoring the physical dimensions of the components. A wall can be just a face with a proper material or color and floor slabs or structural elements might be completely ignored if they do not show on the exterior. Few will model all the components but with a different intent. Their goal is usually the creation of presentation drawings, for projecting plans, cut sections and elevation from the model. This is a useful approach but misses the point of dealing with objects. Accordingly, they might sacrifice certain aspects to achieve the desired visual appeal.

In this projects, the students were required to model the glass panels, the window frames, and the shading device. One of the compelling reasons was the solar studies and shading device suitability to the location.

The jump to a real BIM tool

The next step was a formal introduction to BIM. By their fourth year of the five years program in architecture, students are very well familiar with digital modelling tools, as well as a strong background of technical building technology knowledge. They were also introduced to working drawings and produced two dimensional CAD set of construction documents of a small building that made them very familiar with proper drafting techniques, line types, pen assignments, annotations and dimensions.

The course was carefully structured to benefit

Figure 4
Presentation Perspective generated from the object model

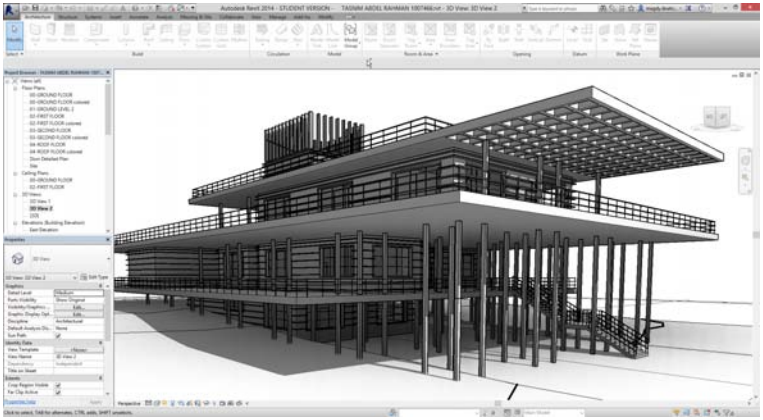


Figure 5
The same building modeled on Revit

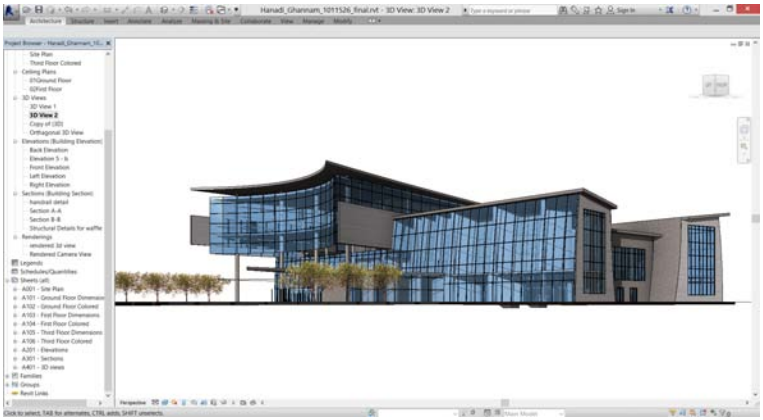


Figure 6
Another example showing a sophisticated design created in Revit

from the students previous knowledge in technical architecture. Few meetings were spent familiarizing the students with the interface and theory, which proved very important in their long term understanding of the technology. Then the students were asked to model their previous studio project on the BIM platform, see Figure 5.

It was obvious that thinking in the object mode, was easy to achieve at this stage. In the beginning, the students struggled mainly with the interface of the application. They knew what they wanted to do, and their questions were always about finding the proper tool.

Looking at the application from the standpoint of analogy to real world objects was easily achieved among this group of students. They were ready for the technology, see Figure 6.

Working drawings course

Finally, the students moved on to their second Working Drawings Course in their curriculum. The instructor never mentioned any particular expectation of a particular CAD tool usage. Even drafting by hand was accepted as long as it adhered to the expected level of presentation. There were no recommendations on how to use any system. The class only discussed the technical issues related to a complex building. Choice of materials, joints and connections, structural systems, water proofing and the like discussions were the only topics as expected in such a highly technical course. There was no computer related instructions.

Almost 90% percent of the students started their projects on a BIM platform. Their argument was; it will keep them focused on the technical part.

The projects were far more complicated than the students' ability to finish what they started solely on BIM, but most of the verifications of validity of spaces by cutting sections in the critical points, were achieved through the BIM model, see Figure 7.

By themselves, the students started criticizing their designs, pointing out the unrealistic geometries that might get overlooked in a design studio, but would proof very difficult to document as a construction drawing.

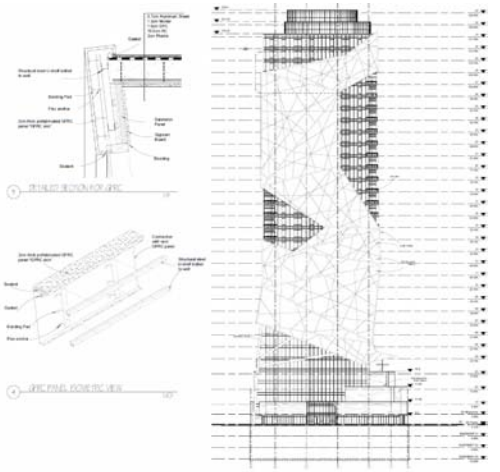


Figure 7
Example of the drawings produced in the working drawing course

Although, the final production was made mostly on two-dimensional CAD, most of the basis of the files were generated from the BIM model.

Most notable issues

- As useful as this experiment is, it is still a limited study. To the researcher, the privilege to work with a group of students on an extended time of their undergraduate years is an exception that might never occur again. In itself, the study sheds a light on certain aspects of the pedagogical process, however it is clear that more investigation is required.
- Also, it is understood that not all instructors can be as digitally savvy to guide their students through such a journey.
- It is very important for the students to understand that different CAD tools are for different jobs, and the fact that they might be used interchangeably does not undermine the purpose for each system that is expected to fulfil.
- Design rationalization should start rather early in the process of a project design. With

the new tools, there is no excuse to postpone thinking about the components of the project in a more comprehensive way.

- Introducing BIM thinking in technology courses not design courses: BIM tools are not design tools. The fact that some users would be fluent enough to use the platform to design does not change the fact that the main role of BIM tools is the documentation of a worked design. Therefore, the proper introduction of the tool to students should be through technical courses such as building technology and not design studios.

- Moving between an object and its abstraction is critical. Students in architecture are taught to abstract objects, but BIM tools works the opposite way. Clarity about understanding the object and its abstraction is important to establish early enough in the education process.

- It is not expected anymore to question how a plan was drafted on CAD, it just has been drafted, no further explanation. Accordingly, modeling on a BIM platform should be treated the same way. And regardless of the platform, even if it is a simple modeler, the fact that the student is thinking about the parts as objects is the most important value. They do not have to worry about drafting them, but should focus instead on getting them to work in the real world.

- Parametric modeling has not been tested in this research. Working with a parametric model is another layer of investigation that should be sought.

DISCUSSION AND CONCLUSION

In the late 80's of the twentieth century, while studying architecture, CAD was treated as a sin from some professors who did not grasp what it was really about. Five years later, using CAD got streamlined in academia and very quickly became a necessity that can/should not be avoided. Few years later, most architectural programs had a course teaching CAD. In essence, CAD replaced the conventional production methods, and became an essential technical knowledge. Referring to it as it was when it first emerged with the suspicious eyes of the professors at the time, establishes a status that does not and should not exist anymore. BIM should be treated in the same manner. It should get incorporated as a way of thinking at all levels.

Despite the clear penetration and solid implementation of the Building Information Modelling technology in the AEC industry worldwide, and despite the fact that schools of architecture around the world are recognizing Building Information Modeling as the technology to prepare their students for in order to satisfy the market demand, there is no clear path on how to introduce the technology.

Many CAD tools have already implemented the "dynamic" components/block technology for making smarter than usual components/blocks. As useful as this is, it does not really help the students grasp the concept of objectifying elements of the building in order to produce a model. A precursor to this should be thinking of the "parts" or the objects that constitute the whole. Rather than being overwhelmed by the inherent complexity of a full-fledged BIM solution, simple and easy to use modelling packages should be used to help introduce students to such concept of smart objects.

In this research, the researcher monitored the students' progress over a period of time while they were using different 3-dimensional CAD tools in several situations such as design studio visualization and construction document production until eventually the same group of students have been introduced formally to a real BIM tool.

The research tries to establish a relationship between the pedagogical techniques and the success of the students to grasp what BIM is about and the development of their ability to use it fruitfully. Compar-

isons between their performances should shed the light on the best method to use in order to prepare students for the technology.

Finally, this research effort does not claim a particular success of a method over another, it rather documents a certain approach to the problem while recognizing the viability of other approaches.

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