

Application of Personal Learning Environment to Teaching BIM for Construction

Julian Kang, Ph.D. and Boong Yeol Ryoo, Ph.D.
Texas A&M University
College Station, TX

A BIM class for construction often requires hands-on practice, from which students pick up skills for project acquisition, clash detection, estimating, and constructability analysis. The BIM course presented in this paper uses an industry-sponsored class project designed to teach students how to use BIM for construction planning and acquisition. Students produce a 3D model from scratch, come up with their own construction schedule, and combine the 3D model and construction schedule to produce a 4D construction sequence model. They also produce several time-line animation clips explaining how they want to build the building. One challenge is that they need to learn how to use several BIM applications such as Autodesk Revit Architecture, Revit Structure, Revit MEP, Autodesk NavisWorks, Google SketchUp, Google Earth, and Microsoft MovieMaker in a very short amount of time in order to use them for their class project. This paper presents how the "personalized learning" concept was utilized to teach students how to use multiple computer applications in a short amount of time and get their class project finished on time with a certain level of quality.

Key Words: BIM, Personalized Learning

BIM for Construction Management

Three-Dimensional (3D) visual representation of the facilities to be built helps construction professionals better understand the designer's intention and reduce RFIs (Request For Information). It also facilities them to detect clashes between the building components before construction starts, reduce change orders, use more pre-fabricated components, and reduce waste.

Visual representation of the facility's assembling sequence in 3D enables construction managers to analyze constructability of the sequence, deal with the time-space issues, develop logical construction plans, improve communication among project participants, and speed up the approval process.

Traditionally, miniature models were mostly used to visualize the facility in 3D world. Miniature models were effective means to explain the designer's intention to the clients without asking them to be able to read 2D drawings. However, creating the miniature model took a significant amount of time. Those who were using miniature models to check the integrity of nuclear power plant design and construction, for instance, found that the process of crating the model took a significant amount of time and could be a bottleneck in issuing drawings.

When Three-Dimensional Computer Aided Design (3D CAD) was introduced in the 1980s, it was expected to speed up the process of creating or updating the 3D model of the facility. Knowing the expandability and flexibility of electronic 3D CAD data, industry professionals wanted to use it not only to present the facility in 3D, but also to integrate the 3D model with additional information such as technical specification of the components.

Professionals in the oil and gas industry took advantage of 3D CAD first. They used the 3D CAD model of the process plant to visually represent the facility and remove clashes between components before construction starts. Applications such as Plant Design System (PDS) and Plant Design and Management System (PDMS) facilitated them to create the 3D digital information model of the process plants. These systems are designed to use parameters to create the object-oriented 3D graphic and information model of the process plants, automatically detect clashes between components, and handle their technical specification information. The object-oriented 3D information model of the process plants can be used to automatically generate certain drawings such as isometric pipe spool drawings. Since 2D drawings are internally connected with 3D models, modification on the 3D model is automatically updated in 2D drawings.

In the building construction industry, the advanced use of 3D CAD models was facilitated by software packages such as AutoDesk's Revit®, Bentley Systems' Architecture®, Nemetschek's VectorWorks Architect®, and Graphisoft's ArchiCAD®. These applications are designed to integrate 2D drawings, 3D models, and additional information such as material property, cost, and construction schedule using objects defined by parameters. Architects expected that the intelligent 3D model, which is also known as Building Information Model (BIM), where 2D drawings, 3D model, and associated information are integrated interactively would speed up the drafting process, help them allocate more time on design and eventually bring higher quality into design.

For contractors, BIM is a "data-rich, object-oriented, intelligent and parametric digital representation of the facility" (AGC 2005), which can be used to make decisions and improve the process of delivering the facility. One of the low-hanging fruits that contractors gain from using BIM is the ability to detect clashes between building components before construction starts and make proactive decisions that would reduce reworks on the jobsite.

Kang et al. (2008) empirically applied BIM to commercial building construction and demonstrated its merit in clash detection between the structural components of the building and the MEP (Mechanical, Electrical, and Plumbing) system. Clash detection helped general contractors reduce change orders and facilitate the use of pre-fabricated duct components for the HVAC (Heating, Ventilation, and Air Conditioning) system installation.

Some advanced contractors combine 3D model and construction schedule to visualize the construction sequence. Four-dimensional (4D) representation of the construction sequence helps to understand the potential time-space issues on the jobsite and come up with solutions in advance to avoid any conflicts between the trades on the job site. Akinci et al. (2002), Guo (2002), and Kang et al. (2007) reported the advantages of 4D construction models in time-space conflict analysis and construction planning.

The construction industry has been rapidly embracing BIM technology. The ENR Smart Market Report (Young et al. 2009) noted that the half of the construction industry were using BIM or BIM related tools in 20009, which represented a 75% increase in two years. During the same period, the number of BIM experts or advanced users increased three times. The number of contractors using BIM or BIM-related tools increased four times. As contractors started using BIM, they expected higher-education institutions to teach students how to use BIM for construction management.

Teaching BIM for Construction Management

For construction, BIM can be utilized for several objectives including marketing, material take-off, cost estimating, clash detection, construction sequence representation, constructability analysis, project control, and safety analysis. Among these objectives, marketing, clash detection, and construction sequence representation can yield high satisfaction for those who are using BIM for construction management.

Teaching students how to use BIM for marketing, clash detection, and visual representation of the construction sequence in a semester bears some challenges. Students need to understand how to create an object-based 3D model of a building and combine it with the construction schedule in order to visualize the construction sequence in 4D world. They also need to understand how to use the visual representation of the construction sequence for marketing. In order to gain necessary knowledge of using BIM for these tasks, students may need to learn how to use multiple computer applications to 1) produce the object-based 3D computer model of a building, 2) manipulate the 3D models of construction equipment such as tower crane, 3) explain the location of the project, 4) combine the 3D model and construction schedule to produce a 4D model representing the construction sequence, and 5) produce a video clip explaining the construction sequence and equipment utilization.

Students enrolled in our BIM classes learn how to use BIM for clash detection, visual representation of the construction sequence, and marketing. Our BIM classes are designed to facilitate students to pick up these competencies from getting engaged in an actual project sponsored by construction companies. Students are expected to use several computer applications including Autodesk Revit®, Goggle Sketch-Up®, Google Earth®, Autodesk NavisWorks®, and Microsoft Movie Maker® collectively to work on the class project. Autodesk Revit® is used to produce the object-based 3D computer model of a building. Google Sketch-Up® is used to manipulate the 3D models of construction equipment such as tower crane. Google Earth® is used to explain the location of the project. Autodesk NavisWorks® is used to combine the 3D model and a construction schedule, and then produce a 4D model representing the construction sequence. Microsoft Movie Maker® is used to produce a video clip explaining the construction sequence and equipment utilization. In many cases, most students enrolled in the BIM have never been exposed to these computer applications. Teaching them how to use all these applications in one semester is therefore a daunting task.

Over the years, various experiments have been tried to come up with an effective teaching method to handle this challenge. While revising the teaching pedagogy multiple times, the author found that the following three elements helped students effectively gain necessary BIM skills in a short amount of time:

- Fun and Excitement
- Motivation
- Personalized Learning

Fun and Excitement

One question students ask almost always at the beginning of each semester is whether they need to have pre-knowledge on 2D or 3D CAD applications to take the BIM class. After getting informed of all class activities and projects that include 3D modeling, 4D construction sequence modeling, and video production for marketing, most students are wondering whether they would be able to follow the class activities even if they don't have any pre-knowledge on multiple BIM applications. The first challenge that the instructor would have to deal with is to help students get confidence that they could manage all class activities. The authors managed this challenge by asking students to create the 3D model of their own house after presenting overall process of creating the Revit Architecture model. About one hour is allocated to show students the step-by-step process of creating the 3D model using Revit Architecture. Students are also informed of any on-line resources they can access to obtain additional information. Students are allowed to assume or come up with fictitious dimensions when they create the 3D model. Students are given one week for this assignment. They are also informed that some of them will get a chance to show and tell what they have created in front of their classmates. The essence of this assignment is to encourage students to put their hands on the application and have fun while they create the 3D model for the first time. Students get the full mark as long as they produce any model using Revit.

Knowing that they have freedom for the assignment and there is no risk for their being creative, most students try to create something unique and worth to get attention from their peers. One week later, the instructor simply asks students who wants to present what they have created. There have been always some students who were dying to show and tell what they have created, and instructor gives them a chance to do so. Not all students were getting excited at the beginning. However, after seeing what their friends have created, many of them started getting confidence that they also could produce the similar model. Figure 1 shows the snapshot of the Autodesk Revit model created by a student within a week after learning how to use it.

Figure 1: 3D model created by a student in one week

Motivation

Being able to create a fictitious model of their dream house in Revit does not necessarily mean that one can use BIM to enhance visual-based communication in construction. Students need to get engaged in more practical issues in terms of creating object-based 3D model, producing 4D construction sequence model, and produce a video clip presenting the construction plan. This is not an easy process and a short excitement may not be able to help students keep working on it. We get students motivated by getting them engaged in the real project, for which we invite the industry sponsors to develop the class project together. The class project is asking students to produce a short video clip explaining the logic of the construction sequence of the sponsor's ongoing project, for which they need to read 2D drawings provided by the sponsor, create the Revit model, come up with the construction sequence, combine the Revit model and construction schedule in NavisWorks to produce a 4D construction sequence model. The objective of the class project is to help students gain proficiency in terms of using BIM to enhance communication for construction management.

The industry-driven class project got most students actively engaged in class activities. They were excited about having the opportunity to work on the sponsor's real projects. The class project helped them understand what was really going on in practice. They were willing to take additional workloads once they understood what was required in the construction industry. The sponsors were also excited about the opportunity to get engaged with our BIM classes. They were impressed by the video clips student produced. Many sponsors offer students jobs when the semester was over. One sponsor arranged a special interview session for those who took the BIM class, and hired three students immediately. The sponsors had a chance to monitor the entire progress of the class project through out the semester, and they knew whom they want to hire at the end of the semester. The experiences of these students helped other students to get more engaged with the sponsor's class project hoping that they too would get similar opportunities. When students are fully motivated, they begin to teach themselves and an instructor does not have to teach how to use BIM applications in detail.

Personalized Learning

Learning multiple BIM applications, creating the Revit model from scratch, developing the construction schedule, creating the 4D construction sequence model, and producing a short video clip in three months is still a daunting task. Students need to know how to use various BIM applications in detail in order to produce the video clip on time. Not all students can pick up these skills at the same time. Some students simply need more time to gain necessary skills for the BIM applications. Many educators discussed this individual learning issue, and they found that the new pedagogy called as personalized learning helps students gain knowledge more effectively. Personalized learning is the tailoring of the curriculum and learning environments to meet the needs of individual learners, often with extensive use of technology in the process. This term was used by David Miliband (2006), Minister of State for School Standards for the United Kingdom (U.K.), who stated that "personalized learning is the way in which our best schools tailor education to ensure that every pupil achieves the highest standard possible". Personalized learning can be explained by the following elements (Wolf 2010):

1. Flexible, Anytime/Everywhere Learning
2. Project-Based, Authentic Learning
3. Student Driven Learning Path

In order to provide the personalized learning environment, our BIM class encourages students to use the online tutorials, YouTube® videos, and Facebook® to pick up detail skills needed for the class project. Autodesk provides various online tutorials and students use them whenever they want to learn specific functions of BIM applications. They also use the YouTube videos posted by many industry professionals explaining how to use BIM applications. For example, students can find more than 10 videos specifically explaining how to place the stair railing by putting the proper keyword in the YouTube search field as shown in Figure 2.

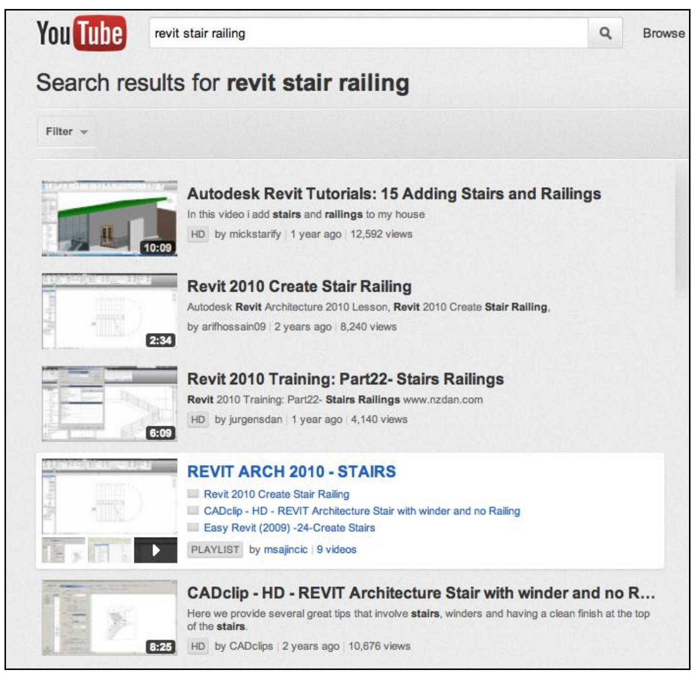

Figure 2: Screen shot of the Facebook page presenting how students exchanged tips

Most videos posted on the YouTube show the computer screen while the presenter demonstrates the step-by-step procedures of using BIM applications. These videos are particularly working well for students as they can easily follow the instruction and they can watch them multiple times whenever they want. When they find any interesting YouTube videos that they think help them understand how to use the BIM applications, they post the link of the video on Facebook group so that their friends in class can take advantage of it as well. Facebook group is also used to exchange tips and information for class projects with the industry professionals. While industry professionals invited to this Facebook group respond to questions posted by some students, other students gain knowledge simply from monitoring the correspondences between industry professionals and students. Figure 3 is the screen shot of the Facebook group page presenting how students used the Facebook group for exchanging information.

Figure 3: Screen shot of the Facebook page presenting how students exchanged tips

Class Project

For the class project, students read the plans provided by the class project sponsor, and create the Revit model. Most students spend more time reading the plans to understand the configuration of the building than creating the 3D model of it. Therefore, students should be informed how much time they need to allocate for reading plans or creating the 3D model. In order to help students better understand the class project, the architects who were hired for the sponsor's project were invited to visit the class and present their design intent. Upon producing multiple Revit models for architecture, structure, and MEP system of the class project, students import them into Autodesk NavisWorks and combine them together to create one integrated 3D model.

For 4D modeling, students come up with construction activities for the project, identify the logical relationship between the activities, and develop the sequence of these activities in the network. They identify the critical paths in the network and calculate the start dates and end dates of the activities using scheduling applications such as Microsoft Project® or Primavera 6®. The number of scheduling activities is limited to 50 for the entire project in order to guide students to work on the class project with a reasonable level of detail.

Although most students taking our BIM classes are seniors who already took a scheduling class and understand how to use scheduling applications such as Microsoft Project, many of them are not familiar with the real construction activities. For them, getting to know how long a certain activity needs to be executed in real projects therefore would be a challenging task. The class project sponsor is then again invited to visit the class and inform students of the durations of major activities of the class project.

As the start date and end date of the activities identified are brought into Autodesk NavisWorks, students divide the 3D model into smaller pieces accordingly and assign them to associated activities to produce a 4D construction sequence model in the NavisWorks. NavisWorks then shows the construction sequence through timeline animation, as shown in Figure 4.

For the video creation process, students learn how to tell a story in a 3-minute video clip. They watch movie trailers in class and discuss the camera movements and the script used in order to understand how movie directors tell their stories in a short amount of time. Students also watch video clips produced by students enrolled in the BIM in the previous semesters. They watch the best video clips and worst video clips chosen by the instructor, and discuss about the ideas that they want to pick up or avoid. Most students strive to produce better video clips than those produced in previous semesters.

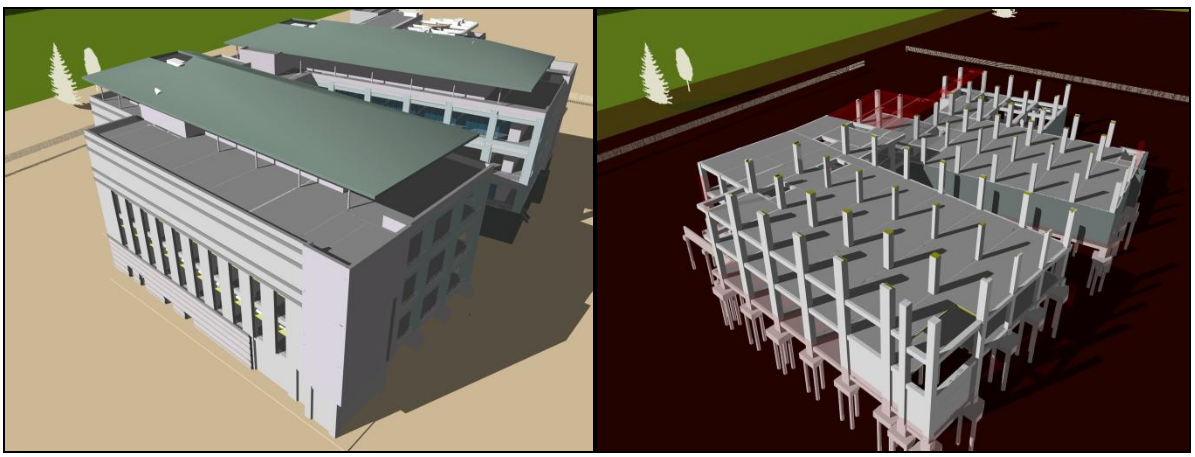

Figure 4: 3D and 4D Models created for the class project

Conclusion

This paper presents how the "personalized learning" concept was utilized to teach college students how to use BIM for construction in a short amount of time. The construction industry is using BIM for several practices including project acquisition, clash detection, constructability analysis, and 4D construction planning, and they expect the higher education institutes to these topics. However, in most cases, teaching college students BIM for construction in one semester is considered as a challenging task because of the number of topics to be covered.

The BIM class presented in the paper works with the industry sponsor and teaches college students how to create the Revit model of the sponsor's project, detect clashes in the model, come up with the logical construction sequences, develop a 4D construction sequence model in NavisWorks, and produce a short video clip explaining how they want to build the building. Students learn how to use all these computer applications, and work on the class project creating models and producing a short video clip in one semester.

What makes it possible to teach college students all these computer applications in a very short amount of time is the personalized learning environment. While the instructor covers the basic information of the BIM applications used for the class project, YouTube videos and Facebook group facilitate our students to teach themselves how to use detail functions of these BIM applications as they work on the class project. Students get helped from the instructor, industry professionals, and their peers outside classroom through Facebook group. Questions and answers posted on the Facebook group are available for all students to follow. No one needs to ask or answer the same questions.

Although some students dropped in the middle of semester because of heavy workloads they had to handle outside class, most students successfully went through the course activities and learned how to use BIM for construction. Those who successfully pass our BIM class have been well received by the construction industry. General contractors who hired them were pleased with their knowledge on BIM. Seeing how happy the construction industry is with BIM class, it is reasonable to suppose that our experiment with the "personalized learning" concept has been working. It helps our students learn multiple BIM applications whenever they want and more importantly in a very short amount of time.

References

Associated General Contractors of America (2005). "The contractor's guide to BIM", 1st ed. *AGC Research Foundation*, Las Vegas, NV.

Akinci, B., Fischer, M., and Kunz, J. (2002). "Automated generation of work spaces required by construction activities", *Journal of Construction Engineering and Management*, American Society of Civil Engineers, Vol. 128, No. 4, pp. 306-315.

Guo, S.J., (2002). "Identification and resolution of work space conflicts in building construction", *Journal of Construction Engineering and Management*, American Society of Civil Engineers, Vol. 128, No. 4, pp. 287-295.

Miliband, D. (2006) "Choice and voice in personalized learning", *Personalizing Education*, OECD/CERI, pp. 21-30.

Kang, J., Anderson, S., and Clayton, M. (2007) "Empirical study on the merit of web-based 4D visualization in collaborative construction planning and scheduling", *Journal of Construction Engineering and Management*, American Society of Civil engineers, Vol. 133, No. 6, pp. 447-461.

Kang, J., Smith, J., Kale, A., and Jayaraman, N. (2008) "Empirical application of Building Information Modeling to commercial construction", *Technical Report*, Associate General Contractors in America.

Young, N. W., Jones, S. A., Bernstein, H. M., and Gudgel, J. E. (2009). "The business value of BIM", *McGraw Hill Construction SmartMarket Report*, McGraw Hill.

Wolf, M.A. (2010). "*Innovate to educate: System [Re]design for personalized learning", Software & Information Industry Association*, p.7.