

# **Integration of Building Information Modeling (BIM) into an ACCE Accredited Construction Management Curriculum**

**J. Mark Taylor, Ph.D., JD**  
**Junshan Liu, MBC and**  
**Michael F. Hein, PE**  
Auburn University  
Auburn, Alabama

Building Information Modeling (BIM) is becoming a revolution in the AEC industry. In order to introduce their students to basic concepts of BIM, faculty members in an ACCE construction management program have been experimenting with BIM in a variety of ways. This paper outlines a few methods of integrating BIM into their curriculum, their experience teaching an introductory course in BIM and feedback from students. Also, other courses in the curriculum, which are prerequisites to BIM and deliver fundamental skills on digital visualization, CAD drafting and 3D modeling, are briefly introduced by the authors. Furthermore, the future of integrating BIM into the curriculum, a new type of undergraduate capstone project utilizing BIM concepts, and curricular changes as a result of BIM will briefly be discussed.

**Keywords:** Building Information Modeling, BIM, Information Technology, Construction Education

## **Introduction**

The recent rapid evolution of BIM software and its adoption among the building disciplines suggests that BIM holds tremendous promise for the future of building. Due to its many uses and capabilities, contractors and construction associations are at the forefront of the BIM debate. The comprehensive nature of BIM suggests that it will become an integrating catalyst among AEC communities. If education is to prepare students for the coming BIM revolution, its integrative potential among the related disciplines must be explored at educational institutions. The current cross-disciplinary trend in higher education creates an environment which is ripe for such an exploration.

Certainly construction curricula should be undergoing self study to investigate how this powerful new tool can enhance student understanding of how buildings go together, and the evolving roles the various parties have in the building process. According to Mulva and Tisdell, "... BIM is indeed a new frontier for construction education" (Mulva & Tisdell, 2007). This paper outlines some ways in which an ACCE accredited university program is exploring the integration of BIM in its curriculum, and some reflections its faculty and students have about how best to move the curriculum forward with BIM. In his paper on pedagogical challenges of BIM, Woo concludes:

“A rich and rigorous learning environment could be achieved through purposeful attempt of integrating BIM into various course contents...” (Woo, 2007). Therefore the authors do not advocate a silver bullet course to add to an already packed curriculum, but rather promote the use of BIM as a means of better integrating a construction curriculum. This integration can begin with an introductory drafting course, follow through many courses in the curriculum, and end with a BIM based capstone thesis project.

### **Integration of Construction Information Technologies**

This construction management program has a long tradition of introducing its students the up-to-date technology used in the design, engineering and construction industries. Currently, two information technology skills courses are taught in the curriculum with the intention to expose students early in their academic careers to a variety of the technologies used in building construction (Liu & Hein, 2007).

The first course, which is named Construction Information Technology (CIT1) and offered to students first semester of their junior year, covers elements of digital computations utilizing MS Office Excel and Access as main topics. Other areas, such as basic IT terminology, digital media management and simple digital drafting and presentation applications are also briefly introduced in this course. The second course, which is called Digital Construction Graphics (CIT2), focuses on knowledge and applications that can enhance communication and visualization in construction. The major topics covered in this course include digital photography, editing and managing digital image files, creating and managing 2-dimensional drawings and 3-dimensional models, generating and editing simple animation and digital videos, and fundamental BIM modeling. Following is a list of software programs that have been introduced in this course:

- MS Office Picture Manager
- MS Office 2007
- Autodesk AutoCAD 2008
- MS Office Visio 2007
- Google SketchUp Pro
- Windows Moviemaker

Since their contents are similar, both of these IT courses are delivered through a lecture-lab combined delivery: each class section has two 2-hour sessions per week. To provide students sufficient practice time in this type of hands-on computer course, each class session generally consists of instructor's lecture and demonstration during the first hour, and hands-on guided instruction using exercises in the second hour.

Because of the rapid change of information technology applications, the unique demands of the construction industry and the broad scope of topics covered, there is no textbook that is sufficient for either of the IT courses addressed above. A set of customized tutorials, exercises and assignments upon each topic in the courses have been developed by the instructors. To incorporate the goals of the courses, various means of media are used in the tutorials, including text, images, animations, videos, drawings, 3d models, websites, etc. Also, contents of both

courses have been improved and upgraded continuously as new technology adopted and new construction examples emerge from practitioners.



Figure 1: A 3D rendering of a building's first floor created in Google SketchUp by a student.

Incorporating the skills taught in these two classes by students has steadily increased over time throughout the curriculum, especially in the areas of digital visualization. Many examples can be found in homework, projects and especially in capstone thesis projects. Examples include construction estimate quantity take-off and pricing completed with electronic spreadsheet in MS Office Excel, sketches of temporary structures such as wall bracing in MS Office Excel, business organization charts and project timelines drawn in MS Office Visio, and building structural analysis and temporary structures design demonstrated through SketchUp models. A review of the thesis projects from the graduating classes of Fall 2006 through Fall 2007 shows that 100% of the graduates have made use of digital computations and graphics in their capstone thesis project. The best measure of effectiveness of the course is evidence of graduates incorporating the material in their work as constructors. Instructors continue to receive examples from recent graduates of the ways they are introducing IT applications to their construction companies. The authors have every reason to believe that this transfer of construction IT knowledge from students to industry will continue with BIM as it is integrated into the curriculum.

### **BIM Technology**

The following BIM related software applications have been used by the authors and presented to students studying BIM. While there are other BIM software applications, these are most commonly used in the US and most accessible to students and faculty.

1. Revit (by Autodesk) – Available as Revit Architecture, Structure and MEP modules. This software is excellent for generating BIM's. Contains libraries of standard components such as wall types, windows, doors, etc., which can be easily copied and edited to create additional components. Door window and wall schedules are easily extracted to spreadsheets, databases, and other estimating and scheduling packages.
2. Constructor (by Vico Software, formerly Graphisoft) – This is a more mature modeling software, which is easy to use. It contains it's architectural, structural and MEP

components in a single program called “Constructor”. A related program “Estimator” contains all of the Constructor components and also adds database management, which enables a fairly easy to use estimating system. A third program “Control” can be utilized for the scheduling aspect of BIM. Like Revit, it contains extensive component libraries that can be used or modified to suit the needs of the modeler.

3. Navisworks (by Autodesk)\_ – is the program of choice for integrating models from a variety of sources. It features excellent conflict detection and resolution and animation capabilities.

All of the above software applications are available to students and faculty with a PC at little to no cost. Faculty and student versions typically require keys that are installed directly on the user’s computer. Institutional versions almost always employ a network key. All of the products owned by Autodesk are offered to students for free by Autodesk (Taylor & Dean, 2007). Faculty can request a “checkout” copy from the School or Department in which they work. ArchiCAD and Constructor are available free to both students and faculty members. Navisworks in the past has been free for students and faculty before the company was acquired by Autodesk, however it has not been available recently. Since Autodesk offers all of its products free to students and faculty, eventually Navisworks should again fall into this category. The hardware system requirements for this BIM software are similar among the packages, see Appendix A. No information was available from Navisworks at the time of writing. As one can see from Appendix A, the software can be run on commonly available PCs with the addition of a high-end graphics card.

## **Integration Methodologies Attempted**

### *Study Abroad Special Thesis*

BIM was first introduced into the curriculum on a test basis with a group of study abroad students. The sixteen study abroad students were grouped in pairs, each consisting of an architecture student and a construction management student. The groups were required to complete a collaborative final project utilizing a European construction site and methodologies. As a part of their final presentation the groups were required to utilize Constructor and include components of conceptual design, estimating and scheduling.

As the class did not lend itself to regular lectures, lab or studio sessions, each student was required to learn the software on their own or within their student group without the benefit of “hands on” instruction. Each student was required to have a laptop and download a copy of Constructor from the Vico Software website and obtain a copy of the self-paced tutorial also available from Vico.

The students were able to learn enough about the software with this self taught approach to make their final presentations. The faculty that observed the final presentations were quiet impressed with the students’ mastery of the software without any formal instruction. However, the students did voice some level of frustration with this method of learning and the faculty and students all

agreed that this was not the best approach. BIM software is simply too complex to pick up on your own without some guidance.

### *Prototype Class on BIM*

The next pedagogical attempt at BIM involved developing an introductory elective course in BIM. The course was attended by both architecture and construction undergraduate and graduate students. Parts of the course were audited by four construction faculty members.

In developing the BIM to meet the needs of students and to respond to the needs of industry, a number of factors were discussed and evaluated for a period of six months or more. Topics that were at the forefront of the discussion included (1) what topics were to be covered in the class, (2) how long it would take to cover the topics and (3) what our software / technology requirements would be to offer the desired elements.

At the threshold of our discussions was the question: “Do we want our students to be able to model or be able to use a model?” In a perfect world we would have answered the question by ascertaining to the best of our collective ability, how BIM is going to be used in the AEC industry in the future. Our conclusion would be that the contractor should be obtaining models from the design team – architects and engineers – and would be in charge of using these models for the purposes of construction analysis and construction efficiencies. However, in talking with a number of construction companies who are using BIM technology at the present time, it is clear that we do not live in a perfect world. Most likely, construction companies find themselves in a position of developing their own models (or hiring a third party to develop the model) if they wish to take advantages of BIM. The modeler must first develop the model by essentially tracing the drawings provided by the architect (Hedgepath, 2007).

We therefore concluded that we would teach our students not only how to use a model to meet the needs of a general contractor but also to develop the model as is required in the industry at the present time. This conclusion reinforced the thoughts of a number of our faculty that we should treat BIM as we treat estimating or scheduling. We not only want our students to be able to use the software available but to fully understand the concepts behind the technology.

The topics to be covered in the BIM class would include:

1. Developing an Architectural Model
  - a. Walls
  - b. Slabs
  - c. Roofs
  - d. Ceilings
  - e. Floor Coverings and Wall Coverings
  - f. Doors and Windows
  - g. Specialty Items
2. Developing a Structural Model
  - a. Foundations
  - b. Columns
  - c. Beams
  - d. Trusses
  - e. Roof Systems
3. Developing a MEP Model – HVAC Only
4. Developing a Site Plan
5. Developing Templates for Estimating

6. Developing the Project Schedule
7. Perform Walkthroughs / Flythrough / Animation
8. Presentation Issues / Rendering

To cover this amount of material in a one semester class would dictate that only a small sample structure could be used; i.e., a small rectangular building with little or no complexity. This brought about another question – Would the student learn and appreciate the difficulties encountered in developing a model if they concentrated only on a small, simple building? Our conclusion was that they would not; rather, students must work on a project of challenging scope and complexity in order to more fully understand the extent of developing a BIM model. Most of our curriculum focuses on developing construction management skills using as examples commercial building projects of 20,000 – 30,000 SF – projects that have complete architectural, site, and MEP drawings. It was decided that this size project would also work well for the BIM class.

The class was offered in a lecture–lab format with 2 hour class sessions with software that had to be readily available in our networked lab as well as for the students to utilize on their personal computers. This narrowed our search down to products offered by Autodesk (Revit family) and Vico Software (Constructor family) with neither product offering a clear cut advantage over the other. Our compromise was that Revit would be utilized in our Fall semester 2007 BIM class and that Constructor will be utilized in our Spring semester 2008 BIM class. After the completion of Spring semester our plan is to make a determination of which software we wish to focus on in the future.

Our conclusion to date is that we can only expose students to both products but do not have the time in the curriculum to fully utilize both programs. However, we believe that if a student is proficient in one program, they can easily pick up the other in the future. Figure 2 shows a pair of renderings of a student's BIM model created in Autodesk Revit 2008.

#### *Incorporation into CIT2 course*

BIM was introduced for the first time in Fall 2007 as a one-week tutorial at the end of the CIT2 course. Students were guided through most of the standard Revit Architecture tutorial in two class periods and required to complete the tutorial for homework. Students picked up the software quickly and responded positively to its features. Students were then required to incorporate a BIM model as part of their comprehensive final project in the course. Students continued to learn a great deal about Revit and BIM during this final project. Based on the positive experience and preference showed by students for Revit over other software in the course, faculty are extending their coverage of Revit to 2 ½ weeks Spring semester 2008. To make room for expanded BIM coverage in the CIT2 course, some topics were moved to the CIT1 course and some have been dropped.

#### *Capstone Course*

Given the all-encompassing nature of BIM it makes sense to incorporate it into a comprehensive review at the end of construction management undergraduate studies, once students have been

formally exposed to all aspects of building construction covered in the curriculum. In fact, the authors believe that BIM can be the central focus of such a capstone course. For some time, students have been taking full advantage of their skills with computational as well as graphic software tools introduced to them in the IT courses by incorporating them into their capstone.

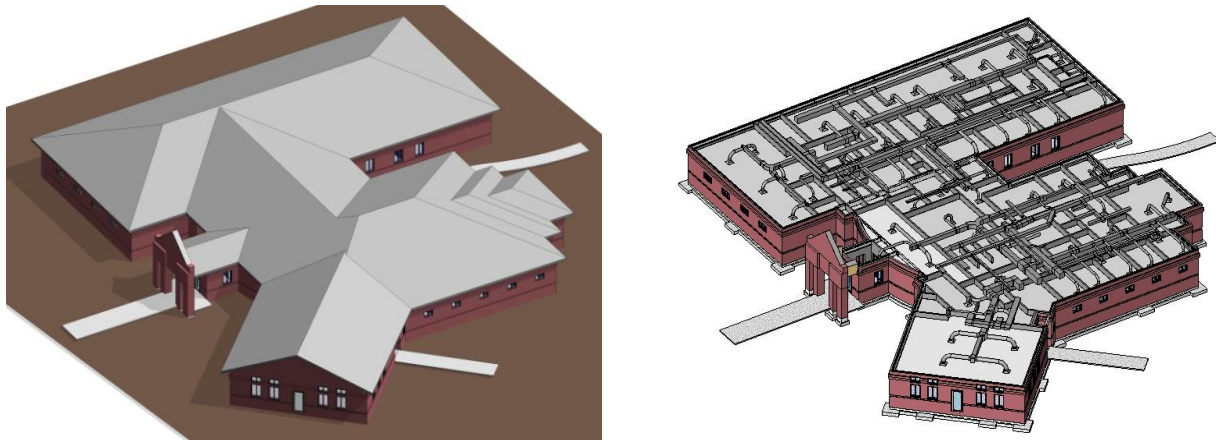


Figure 2: A BIM model created in Autodesk Revit by a student.

As the final piece of the integration of BIM into its curriculum a proposal was made to program faculty at the beginning of Fall 2007 semester to be considered for adoption Spring semester 2008. The proposal outlined BIM as an alternate vehicle for undergraduate capstone thesis project. Two exemplary seniors were invited to participate in a BIM special thesis submittal in Spring. These students showed excellent work beyond what was expected of them in both IT courses. They were eager to participate in the exercise and the authors were interested in guiding them through the process.

The program involved the following:

- Invite exemplary students to apply for participation in Special BIM Thesis.
- Have selected students enroll in Fall semester BIM elective course.
- Conduct fall and spring (bi-weekly) meetings with students and interested faculty to discuss and develop BIM thesis requirements and select an appropriate thesis project.
- Launch Spring BIM Thesis project by mid Fall semester.
- Advise students during the BIM Spring Thesis process, monitoring progress and results.
- Students present BIM Thesis projects to at large faculty jury at end of spring.
- Faculty jury discusses results and suggests improvements.
- Lead faculty proposes more permanent BIM Thesis project for adoption.
- Faculty develop a publication reporting on the results of the experiment.

The proposal was unanimously approved by the faculty and the process of selecting and training students began in Fall 2007. The two students selected excelled in the introductory BIM training course offered Fall 2007. Both students began incorporated their knowledge of Revit

immediately; each of them has voluntarily created BIM's for projects in their other courses. One of the students has given a presentation in his MEP class using a BIM model and has also given two lectures to the CIT2 class. These lectures were the first formal integration of BIM into an existing course in the current curriculum. Students of these lectures were able to incorporate their new skill with Revit into their final projects in the course. Provided the results are well received by the larger faculty, the next step will be to rewrite the capstone thesis requirements to include a BIM requirement.

### **Integration Methodologies Considered for the Future**

Based on our faculty discussions and feedback from students recently graduated or having taken the BIM class, it is our initial thought that a 3rd technology class could be offered and that BIM needs to be integrated throughout the curriculum in industry specific classes. Some of the basic BIM topics would be introduced in the first and second technology courses thereby giving the student an introduction as early in their academic careers as possible and then offering a third class encompassing much of the subject matter in the prototype class discussed above.

As one student stated: "I think BIM would be an excellent teaching aid in Work Drawings and Specs. A professor could get a model in three dimensions and show the section, elevations, and plans from it. This would help students visualize exactly how 2 dimensional plans translate into a three dimensional structure" (Hand, 2007).

All involved with the introduction of BIM have been amazed at how the students are eager to use the technology in a variety of ways. As another student stated: "I have also used BIM in some of my other course work in Building Science. Many of the professors have been very interested in somehow incorporating BIM in the curriculum. I have used BIM during a collaborative project with the Architecture department, in which I was paired with an architecture student. I used Revit and made a preliminary model from the schematic drawings I was given. The architecture student could then easily decide on the type and size of the structure and the height of the building and could provide input as the MEP systems were modeled. As soon as the design was finished, the estimate was just pricing after that. The use of BIM dramatically affected the ease of which this project was completed" (Hardie, 2007).

One of the students interviewed after having been introduced to BIM, stated : ".....the main benefit is also the main challenge in BIM. To build a model accurately I need the knowledge of all parties involved in the construction process. As I build the model, I force myself to learn the parts of all parties involved in the construction process. I have to read building plans very effectively to create the model. In a regular estimate, I only need to know how long a wall is and what makes up the wall. In Revit, I need to know the same thing as the estimate plus how the trusses attach to it, how it attaches to other walls, how it ties to the footing etc. By the time I have finished modeling a building, I know it very well. I know it much better than a building I took off using On Screen Take Off" (Hand, 2007). This student has obviously benefited greatly from his acquired skill with BIM.



## Conclusion

BIM holds promise not only as a means of integrating the AEC disciplines in achieving the common goal of better buildings, but also a means of integrating those same disciplines in educational institutions. BIM can be an integrative force within a construction curriculum, a vehicle for delivering all aspects of its educational objectives. Perhaps most important of all is the integration of knowledge about building that it provides within the mind of each construction student. The process of attempting to integrate BIM into the curriculum of an ACCE accredited construction program has revealed to the authors that BIM does not neatly fit into the package of a single new course, but rather holds the potential to find its way into all corners of the program. After introducing BIM software to students early in the curriculum, the authors are convinced they will find ways to use it throughout their study of construction. Our students have demonstrated that they possess a strong aptitude for the tools of information technology. This coupled with a natural curiosity, and eagerness to learn can bring them and us to a better understanding of buildings using BIM.

Any curriculum-wide change to a traditional course of study requires acceptance by the entire faculty. Beyond acceptance in the program is acceptance by accrediting bodies. This may be the biggest obstacle standing in the way of widespread adoption of a new BIM paradigm in construction education. An appropriate follow-up study to our work would be an investigation of BIM usage in ACCE accredited schools across the country. With the encouraging example being set by industry, perhaps educators will feel empowered to take the leap into twenty first century construction education.

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## Appendix A

### Hardware System Requirements for Two of the BIM Software Programs

	<b>Revit Structure, MEP, &amp; Architecture:</b>	<b>ArchiCAD 11 &amp; Constructor</b>
<b>CPU</b>	* Intel® Pentium® 4, 1.4 GHz, or equivalent AMD Athlon® processor. ** Intel Core™ 2 Duo 2.40 GHz, or equivalent AMD Athlon processor	Intel® Pentium 4 2GHz, or compatible processors with equal or higher performance Macintosh® PowerPC G4 series with 1GHz processor; G5 series Macintosh® with any Intel® processor
<b>Operating System</b>	* Microsoft® Windows® XP SP1 or later (Professional, Home, Tablet PC Edition) or Windows® 2000 SP4, Microsoft® Windows Vista™ (Enterprise, Business, Premium, Ultimate Edition) ** Windows XP Professional (SP2 or later)	Microsoft® Windows® XP Professional and x64 Edition, Windows® Vista Ultimate, Business and Enterprise Edition Macintosh® OS X 10.4
<b>RAM</b>	* 1 GB RAM ** 4 GB RAM	1 GB of RAM , 2 GB or more is recommended for complex BIMs
<b>Disk Storage</b>	* 3 GB free hard disk space ** 5 GB free disk space	1 GB free hard disk space. Additional 2 GB required for work with complex projects and 3D visualization UNIX formatted HDs are not supported
<b>Display Resolution</b>	1280x1024 monitor and display adapter capable of 24-bit color	1280x1024 or higher
<b>Miscellaneous</b>	Internet connection for license registration Microsoft® Internet Explorer® 6.0 or later * MS-Mouse compliant ** Two-button mouse with scroll wheel	Note for Windows users: QuickTime 7 or later and Java 6 or later are required to run ArchiCAD.
<b>Video Card</b>	** Dedicated video card with hardware support for OpenGL® spec 1.3 or later	Open GL and DirectX 9 compatible graphic card with 64 MB on-board video memory. Mac: Open GL compatible graphic card with 64 MB on-board video memory. On-board video memory of 128 MB or more is recommended.
Note: * represents MS Windows (SP1) OS; **represents Windows XP Professional (SP2)		