



Call for Papers and Case Studies

BIM Academic Symposium

**In conjunction with Building Innovation 2014
The National Institute of Building Sciences Conference & Expo**

Friday, January 10, 2014

Washington, DC

The buildingSMART alliance, a council of the National Institute of Building Sciences is sponsoring an Academic Symposium to be held on Friday, January 10 in Washington DC in conjunction with Building Innovation 2014 - The National Institute of Building Sciences Conference & Expo January 6-9. The objective of this Academic Workshop is to gather representatives of different academic programs and industry to discuss the contributions and approaches that technology-based collaboration in the AECOO through Building Information Modeling educational activities incorporated at different levels of college curriculum is making in the attainment of educational outcomes through credentialing, accreditation, or certification.

The papers will be viewed worldwide to further academic models and generate dialogue about the issues with the transformational disruption of changing the way we educate to support BIM and all the offshoot opportunities BIM is creating to improve productivity.

Researchers, academicians, and practitioners in the AECOO industry are invited to submit short papers (no more than 8 pages) and/or presentations describing best practices, experiences, and challenges incorporating BIM in creating educational opportunities. Papers are also invited to describe specific course or project experiences. Specific topics to be addressed include:

- **Learning Outcomes Assessments**
- **Pedagogical Models**
- **Interdisciplinary Approaches**
- **Research Opportunities**
- **Accreditation Issues**
- **Curriculum Integration**
- **Sample Courses & Sample Lessons**
- **Student Projects**
- **Industry Involvement**
- **Academic Business Models and ROI**

DATES:

- Interested presenters are invited to submit an abstract (300 words) by May 6, 2013 to the organizing committee at: <http://s200.bcn.ufl.edu/bimeducation/openconf>
Space is limited so submission date abstract may be a determining factor in acceptance.
- Notification of acceptance will be issued by May 20, 2013
- Full papers should be submitted by July 1, 2013
- Notification for Presentations will be issued by August 5, 2013
- Final Papers, Copyright Releases and Presentations will be due by October 7, 2013

For more information please visit our WWW at: <http://www.bcn.ufl.edu/cacim/bimeducation>

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Building Information Modeling (BIM) and its future in Undergraduate Architectural Science Capstone Projects

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Abstract

The capstone course in the Architectural Science Program at Western Kentucky University is a two semester experience; during the fall semester the students submit a proposal on the facility that they intend to design, create the program for the facility and conduct subsequent research. In the spring semester they work on design solutions and carry their projects through to construction documents. During this time the students decide on the specific platform in which to implement their designs. In the current capstone cycle the use of Building Information Modeling (BIM) has increased substantially; while some students started using BIM right from schematic design, others began using it once they had completed their design concepts using other programs. This paper discusses recent capstone projects in which BIM has played a central role and how it has become an integral part of the capstone experience.

Of the 15 students in the capstone course about two-thirds are using BIM. The students in the architectural science program have one elective course where they are introduced to and taught BIM using the REVIT platform. In the current capstone experience there is a mix of students who are self-taught, who have taken BIM in previous semesters and who are currently enrolled in BIM. Feedback regarding student experiences with using BIM for their capstone projects, how it helped them, what were the difficulties they faced and the end result will be used to study the impact of BIM in the current capstone cycle and address the potential of BIM in future capstone experiences.

Keywords: Building Information Modeling (BIM), capstone projects, Architectural Science

1. Introduction

‘Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering and construction industries.’ (Eastman et al. 2008). According to Smith (2007), the concept of Building Information Modeling is to build a building virtually before the actual construction process to identify, analyze and solve potential problems and conflicts that can arise during construction as well as through the life cycle of the structure. ‘The heart of Building Information Modeling is an authoritative building information model’ (Smith 2007). BIM creates three-dimensional models and adds fourth and fifth dimensions of scheduling and cost (Sabongi 2010). BIM facilitates accurate visualization of designs along with automatic updates when design changes are made. The model also supports generation of two-dimensional drawings during any stage of the design. BIM technology can be used to extract information for cost estimation and enables collaboration with various design disciplines. (Eastman et al. 2008)

The Architectural Science Program in the Department of Architectural and Manufacturing Sciences at Western Kentucky University has in its curriculum a two semester capstone course.

The capstone course sequence is an applied research experience through which the students are expected to demonstrate mastery and competence in architectural science (WKU Undergraduate Catalog 2012-2013). It is meant to be an active learning experience and students are expected to put in substantial effort right from proposal through to the implementation stage of the project. Students work on projects utilizing skills and knowledge acquired during courses taken in the program and are expected to apply the full range of concepts, knowledge, and skills acquired from their university experience, (WKU Undergraduate Catalog 2012-2013) to demonstrate that they are ready to graduate and be productive in the work force. The capstone course is intended to show the student how all the pieces of the puzzle fit together. (Jones et al. 2009)

The first course of the capstone experience is AMS 488, Comprehensive Design which is undertaken in the fall semester of the senior year of the student's course of study. During the semester the students identify a project and client and develop an architectural proposal for the project. The proposal is reviewed by the architectural science faculty and once accepted the students begin data gathering. The students interview their client and generate a program which defines the spatial requirements. They study similar projects, conduct site analysis, review and understand the required building codes and regulations. Towards the end of the semester they begin the schematic design for the proposed facility.

The second course which occurs in the spring semester is AMS 490, Senior Project. This forms the culmination of the capstone sequence. In this semester the students continue to develop the schematic design that was approved in the fall semester. The project is taken forward through design development resulting in presentation and construction drawings. At the end of the semester the students present their projects to the client, faculty and industry professionals.

2. 2012-2013 Capstone Sequence

Fifteen students were enrolled in the 2012- 2013 capstone courses. In order to successfully complete the capstone course students were expected to develop a three-dimensional model (either virtual or physical), presentation drawings and construction documents which included site plan, floor plans, elevations, sections and details. To this end the students began by finalizing their projects and conducted required research with the objective of developing a program, code analysis and typology research. Schematic design began towards the end of the fall semester at which point the students chose the medium by which to convey their design ideas.

Traditionally students in the Architectural Science Program have utilized AutoCAD (ACAD) and Google SketchUp to put forward their design ideas and schemes. Google SketchUp is used to generate the three dimensional model and ACAD is used to prepare accurate drawings for the construction documents phase. Students typically use Karkethya or IDEX to render the models generated through SketchUp. During the 2012-2013 academic year the use of BIM tools increased tremendously in the capstone course.

Of the fifteen students, fourteen successfully completed the capstone and ten students used BIM as the medium to generate the drawings and data for their projects while the other four students used ACAD and Google SketchUp. The students enrolled in the course had varying levels of knowledge of BIM. In the Architectural Science curriculum BIM is taught as an elective course. Of the ten students that used BIM for their capstone projects some had taken the elective course in a previous semester, some were enrolled in the BIM course simultaneously as they were working on their projects and one student was self-taught. This created an interesting mix of student success and frustration during the course of the project arising out of using a new technology to complete their work.

3. Student Perceptions

The students were asked about their experiences with using BIM for their capstone projects. A questionnaire was distributed to the students and feedback was gathered in the final week of AMS 490.

Tools used for capstone project: Students were first asked which tools were utilized for the implementation of the capstone project. Ten students used BIM tools specifically the REVIT platform for the implementation of their project. Four students used non-BIM tools (ACAD, Google SketchUp and other available software) for their project. Of the students who used BIM for the implementation of their project four students used BIM tools right from the conceptual design stage during AMS 488 and six students started using BIM tools at the start of the spring semester (AMS 490) for the implementation of their projects.

Objectives and motivation in tool selection: The four students who used BIM tools from the start of the project felt it helped them visualize their designs in a more holistic manner. The ease of generating two-dimensional drawings from the three-dimensional model was a significant factor in the decision to use BIM. The six students, who started using BIM in the spring semester, did so, primarily as they had not been exposed to the technology previously and were taking the BIM elective course during the spring semester simultaneously with the capstone. One of the primary motivators for all of the students who used BIM tools while working on their capstone projects was to improve their BIM skills as they felt it would be to their advantage when seeking employment.

Experience with BIM tools: Of the 10 students who used BIM for their capstone experience nine had either taken a class in spring 2012 or were currently enrolled in the BIM elective; one of the students was self-taught. The students felt that taking the class had given them the foundation they required to utilize BIM technology in the capstone (and other courses) and helped them realize the potential of BIM. The students also said that apart from the class they spent on an average 3-4 hours per week outside class learning how to model the more intricate aspects of their project. Most of the information and research was gained through resources available on the internet.

Recommendations to future student users: All the students who used BIM tools said they would definitely recommend the use of BIM tools to future seniors for their capstone experience. Reasons provided for this included the ability to develop a complete project, ability to generate good three-dimensional renderings and the ease of generating two-dimensional drawings from the created model.

Future advantages of using BIM tools: Students felt that working on their capstone project which involved schematic design; design development and construction drawings gave them an opportunity to utilize their skills and put into practice all that they had learnt about BIM, potentially giving them an advantage in the job market.

4. Case Studies

Three capstone course projects have been discussed in detail. The case studies presented in this paper represent the project from the student who was self-taught, the student who had taken the BIM elective in spring 2012, and the student who was simultaneously enrolled in the BIM elective while working on the capstone project.

4.1 River View at Veterans

The first case study examines the project of a self-taught student. This project is a mixed use facility designed for a site located on the river front in the city of Owensboro, KY. The lower level consists of retail and restaurant while the upper floors have a mix of one, two and three bedroom apartments. During the fall semester in AMS 488 the student worked on developing the proposal, program and code analysis for the proposed project. Towards the end of the semester work on schematic design began and the student made a decision to use BIM tools for the project from schematic design through construction documents.

The three-dimensional view of the project is visually compelling. What makes this particularly interesting from a BIM capstone perspective is revealed in the extracted construction documents. As can be seen in figure 2 & 3 the student has used the appropriate construction typology which would be to near exacting specifications expected by other professionals in the chain of construction.



Figure 1: Three-dimensional rendered exterior view of the BIM model



Figure 2: Floor Plan of the proposed project generated from the model and detailed using features of REVIT.

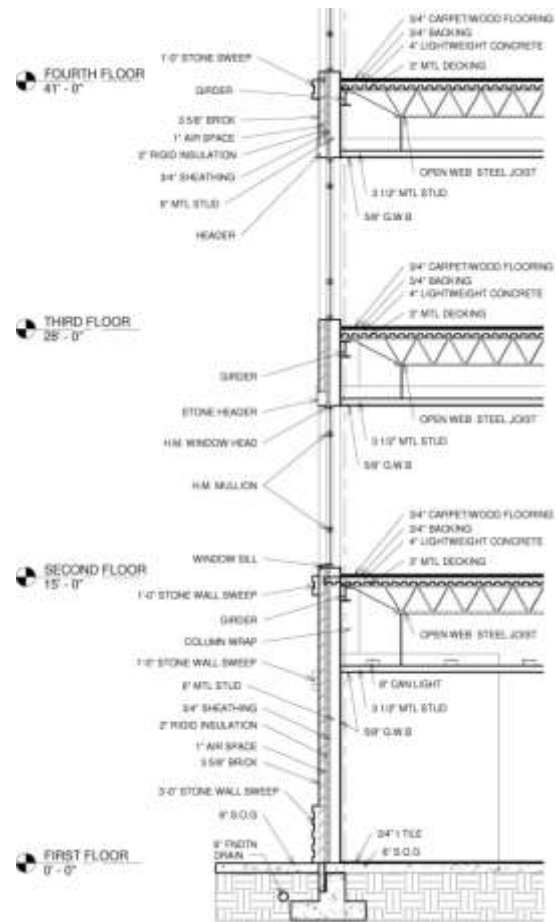


Figure 3: Wall section extracted from the BIM model demonstrating appropriate construction typology

Three main reasons were cited for using BIM;

- Easier three-dimensional design visualization as the model was being developed.
- Gradual learning curve and shorter rendering time by using the native renderer. (figure 1)
- The ease of generating two-dimensional construction drawings. (figure 2)

Main problems encountered while creating the BIM model included;

- Difficulty in editing families and creating custom objects. As seen in the rendered image of the project (figure 1) the student used window families that were available in the REVIT library as creating custom window designs became complicated for the level of understanding that the student had of the program.
- The program slowed down due to the large amount of data (model size 110MB).

The student had started learning BIM in the fall of 2011 and had worked on simple projects in BIM; as a result of this the student spent approximately three hours a week outside of class researching and learning the more complicated aspects of the tool. Not having taken a course in BIM the student had to spend a considerable time viewing various resources on the internet. The lack of formal training also affected in certain situations, the student's ability to decide between using three-dimensional objects or two-dimensional objects in the model.

4.2 Sigma Phi Epsilon Fraternity House

In this case study we discuss the design of the Sigma Phi Epsilon Fraternity House by a student who had taken the BIM elective during spring 2012. The design included living, recreation spaces, and bedrooms for the chapter members. Since the project was on a smaller scale than the other projects being undertaken for the capstone experience the student was instructed to work on developing the interiors as well as details for the structure.



Figure 4: Three-dimensional rendered BIM model of the Fraternity House



Figure 5: Floor Plan of the proposed project generated from the model and detailed using features of REVIT.

The three-dimensional view of the project as seen in figure 4 demonstrates the level of the student's skills. Having taken the BIM elective class previously the student was very comfortable using REVIT to develop the project. Initially the student felt that the design was being driven by the software as there were roof elements that were harder to develop than anticipated. A considerable amount of time was spent researching appropriate modeling techniques so that obstacles could be overcome and the envisioned design modeled. A significant amount of effort was also spent in developing interior details and renderings in the BIM model.

For this project too, BIM technology (REVIT) was used from the schematic design stage. The reasons cited for using BIM included;

- A higher comfort level using BIM software (REVIT) compared to ACAD.

- Constant visualization of the three-dimensional model through the development of the project.
- Help in improving REVIT skills which would be an asset while seeking employment.



Figure 6: Interior rendering of the Fraternity House

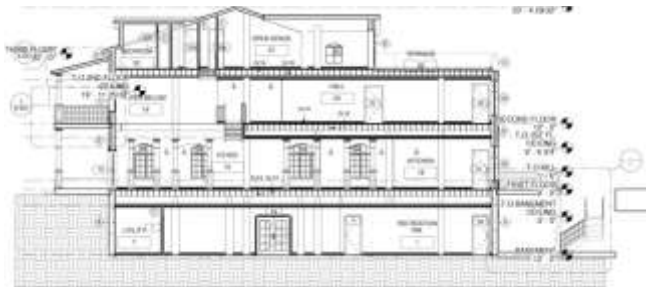


Figure 7: Detail section developed in the BIM model

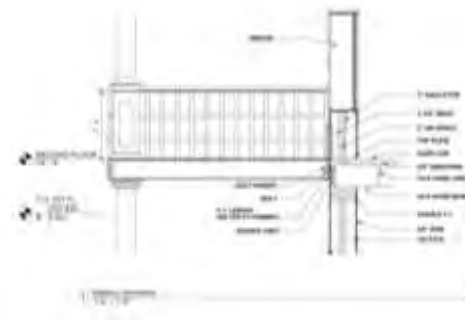


Figure 8: Details of front porch of Fraternity House

Main problems encountered while creating the BIM model included;

- Lack of knowledge of certain aspects of the technology, initially giving the impression that the design was being driven by the software.
- Difficulty in modeling roof elements.

Due to prior training in BIM the student had the foundation required to be successful in using BIM for the capstone project. Despite this, the student spent considerable time outside class understanding the more complex aspects of modeling. The student spent about 5 hours a week of additional research effort to improve BIM skills.

4.3 Owensboro City Center

This case study examines the project of a student who was enrolled in the BIM elective class during spring 2013 while simultaneously working on the capstone. The project was located on the river front in the city of Owensboro, KY. The project was a mixed use facility with retail, restaurant, offices, boutique hotel and apartments on various levels. During the conceptual design stage the student worked on the project using ACAD and Google SketchUp. After a few weeks of exposure to BIM in the spring semester the student decided to switch over and complete the capstone project using the REVIT platform.

The three-dimensional REVIT model developed (Figure 9) incorporates all the elements that the student had envisioned when the project was being developed using SketchUp. To develop the model ACAD drawings were linked to the REVIT file and used as a base to start modeling. Extensive work was done to create the exterior elements but due to time and

knowledge constraints the interior of the model was not developed to the extent as highlighted in the previous case studies. REVIT was used to generate the construction drawings but as seen in figure 10 & 12 these drawings were not developed to the level of detail as required of students at the capstone level.



Figure 9: Exterior rendered view of the mixed-use facility

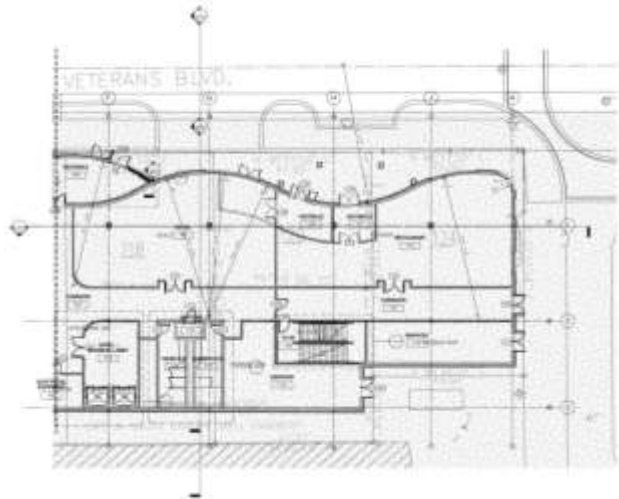


Figure 10: Construction drawing of floor plan



Figure 11: Exterior rendered BIM view of the roof top garden for the mixed-use facility

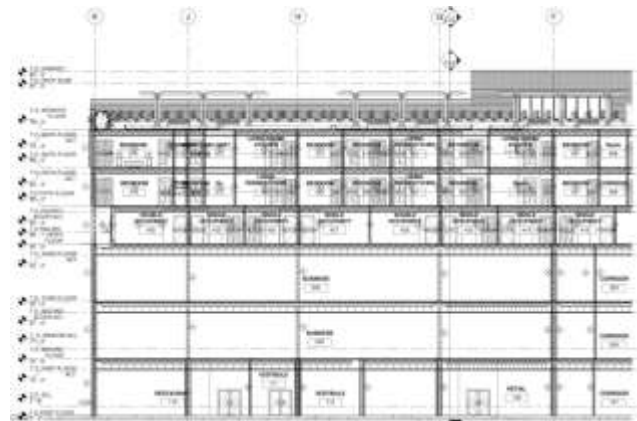


Figure 12: Construction Drawing of Section

The reasons for switching over to using BIM tools were:

- Modeling exterior elements of the structure was easier.
- Easier rendering using the inbuilt renderer of REVIT

Some of the problems encountered included:

- Embedding doors into the curved wall surfaces
- Time constraints due to switching over to the BIM platform later in the semester.

In developing the capstone project using BIM the student faced the additional challenge of taking the BIM elective while simultaneously working on the capstone. The student spent about 5-6 hours outside class learning some of the more complicated modeling aspects of the program.

5. Discussion & Conclusion

Design is an integral part of architecture programs. Modern architecture design solutions incorporate a huge amount of information that is used by other disciplines from structural and MEP consultants to construction and interior design professionals. BIM enables a student (the future design practitioner) to focus on the core design solution using a tool that manages the huge information complexity that a comprehensive design solution demands. BIM also demands a very good understanding of how buildings come together (Eastman et al. 2008), as a result when Architectural Science students use BIM tools they not only create a three-dimensional view but are also able to see and understand the nuts and bolts of what goes into the structure (information model).

According to Eastman et al. (2008), with changing roles and activities in the architecture and engineering workplace junior architects will be expected to demonstrate proficiency with BIM as a condition of employment. Student feedback indicates that a significant driver of interest in BIM was that it is seen as an important requirement of the job market.

While the case studies discussed have emphasized how BIM is an innovative approach to three-dimensional design and two-dimensional drawing generation, a huge facilitator in enhancing future capstone experiences would be to, (i) position the elective BIM course prior to the start of the capstone to enable students to take advantage of BIM from schematic design stage rather than have a steep learning curve for BIM during the capstone experience; (ii) Augment BIM course content from beyond foundational to addressing similar complex modeling problems encountered by students in the current capstone cycle.

While the current capstone cycle has been successful in the use of BIM for the three-dimensional creation of the model and two-dimensional generation of documents, the fourth and fifth dimensional aspects of creating schedules and estimating have not been explored. It would hence seem a logical road map to move towards integrating these aspects of BIM in future capstone experiences. It is also envisioned that collaboration with the Construction Management Program in the department can lead students to explore the limits to which BIM can be utilized in achieving an ideal architecture solution for future capstone projects.

References

- Eastman Chuck, Teicholz Paul, Sacks Rafael, Liston Kathleen (2008) "BIM HANDBOOK- A Guide to Building Information Modeling for Owners, managers, Designers, Engineers, and Contractors". *John Wiley & Sons, Inc.* NJ. 17, 153, 315, 393
- Jones James, Mezo Mike, Warner John (2009) "Team Teaching the Capstone Construction Management Course: How and Why". *Proceedings of the 2009 ASC International Conference*, Gainesville, Florida
- Sabongi Farid J. (2009) "The Integration of BIM in the Undergraduate Curriculum: An Analysis of Undergraduate Courses". *Proceedings of the 2009 ASC International Conference*. Gainesville, Florida
- Smith Deke (2007) "An Introduction to Building Information Modeling (BIM)". *Journal of Building Information Modeling*. Washington D.C. 12
- WKU Undergraduate Catalog (2012-2013)
(http://www.wku.edu/undergradcatalog/documents/12_13_catalog_files/wku_ugrad_catalog_12_13.pdf)

INTEGRATED AEC STUDIO: ITERATION BETWEEN ANALYSIS AND DESIGN FOR INTERDISCIPLINARY LEARNING

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ABSTRACT

In this paper we present an iterative pedagogical model for interdisciplinary studio that has been refined over a five-year period. The authors of this paper teach an integrated AEC studio at the University of Washington where students from architecture and construction management as well as allied fields work in a collaborative workspaces to develop and deliver design proposals using an iterative process modeled on the practice of Integrated Project Delivery (IPD). IPD is a design approach that integrates people, systems, business structures and practices for harnessing the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication and construction. In the studio setting, professionals from the design and construction industry will work regularly with student teams to provide instruction and advice, and to critique their work. The contribution this paper makes to the team-based studio learning environment is the concept of iterative cycles between analysis and design. Students learn and practice many team decision-making techniques such as multi-attribute selection criteria and in the process learn about each other's disciplines as well as applying their own.

Keywords: Education, iteration, collaboration, integration, integrated project delivery, structures, design, construction management

1. BACKGROUND

In this current era, energy consumption has taken center stage. For buildings, this means a shift from considering buildings as shelter to acknowledging that buildings are systems with interrelated and, often, conflicting performance criteria and outcomes. What must be acknowledged is that, like many modern technologies, no single individual can accumulate the knowledge of the entire process: the design, fabrication and construction of a high performance building. It takes a team of experts – no one more important than another – to accomplish the task.

This paradigm shift favors synthesis over singular vision. This requires then close collaboration between many specialists such as lighting and interior designers; mechanical, structure, and electrical engineers; project architects; general contractors; specialty contractors and suppliers; owners, developers and end users. The professions of architecture, engineering and construction to be both specialists in their own disciplines, while being open to and interested in learning about how their discipline intersects with others. Successful architects, engineers and contractors then are able to organize, integrate, and orchestrate synthesis across teams of artistic and technical experts simultaneously setting a vision while creating social mechanisms for teams to reconcile tensions between competing and at time conflicting building requirements. This challenges academic programs to respond to a changing professional

paradigm and there is a need to develop collaboration skills that go beyond the cooperative practices of the past.

2. COLLABORATION VERSUS COOPERATION

While collaborate and cooperate are often thought of and used as synonyms, we can make an important distinction between them that is very useful when thinking about how interdisciplinary teams work together on a building construction project. The Oxford English Dictionary tells us that the word cooperation has negative roots in wartime “traitorous cooperation with the enemy.” However, in common practice today the word means both positive as well as negative work: “collaboration”: 1. united labour, co-operation, esp in literary, artistic, or scientific work.” In contrast “coordination” is defined as “1. to make co-ordinate; to place or class in the same order, rank, or division.... 2. To place or arrange (things) in proper position relatively to each other and to the system of which the form parts; to bring into proper combined order as parts of a whole. While “cooperation” has a softer definition “1. the action of cooperating, i.e., of working together towards the same end, purpose, or effect; joint operation.”

Team work has been shown to improve both learning outcomes and retention in engineering programs (Carlson & Sullivan 1999; Springer et al. 1999). However, the focus in most engineering curricula has been on cooperative—not collaborative—approaches to team learning, in which students in small groups learn from each other under carefully structured situations of accountability (Smith et al. 2005). Collaborative learning, on the other hand, is characterized by relatively unstructured processes through which participants negotiate goals, define problems, develop procedures, and produce socially constructed knowledge in small groups (Goldsmith & Johnson 1990, Dorsey et al. 1999). Collaborative learning is important because the amount of time in these learning situations offer greater opportunities for student engagement and learning, and is correlated with higher retention in STEM fields (Springer et al. 1999). It also models the type of interdisciplinary project team learning that is required for complex engineering problems (Dossick & Neff 2011). We seek to go beyond cooperative learning, the more common student team experience in engineering, to design technological-enhanced engineering studio experiences with potential for deep, collaborative, interdisciplinary, student engagement.

From the students’ perspective, the challenge with team-based learning is often that the easiest way to “get the assignment done”—a common goal for students as well as professionals—is to cooperate on the assignment, to divide and concur. If given a set of math problems, for example, a group of students could each take a page, do them individually, then staple them together and turn in the completed assignment. However, each student would only learn about the math problems that they did, and they would not gain any knowledge or understanding from the other pages completed by their teammates. They miss completely the objective of the assignment, which is to interact with each other around the problems, learn through this interaction and improve the final answers meanwhile. This is analogous to how architectural design practice has developed over the years. While inside a firm, inside a studio, the team may function very collaboratively—interacting with each other, talking about design ideas, collectively developing the project—interaction with consultants is often cooperative. Architects publish a set of architectural backgrounds to the engineers, who then work in their own offices on the engineering analysis and plans. This is made explicit in the drawing set and specification. There are the architectural drawings (‘A’) authored by the architect, the structural drawings (‘S’) authored by the structural engineer, the civil drawings (‘C’) authored by the civil engineer, and so forth. Each discipline getting their own set of pages to “turn in”. This system of a set of drawings does not encourage or engender collaboration. In fact, low design fees reinforce a “get it done” system where the path of least resistance, divide and concur, prevails. Architects and engineers are supposed to coordinate their drawings, putting them in proper interaction¹, but the coordinated system of drawings actually work against the team’s efforts and does not support or even suggest deeper collaboration.

¹ Webster’s 21st Century Dictionary definition of Coordinate ...4) put in proper interaction.

Team-based curriculum in general and in labs (engineering) and studios (architecture) specifically is one approach for interdisciplinary learning by providing projects that require interdisciplinary teams where students practice integrating their domain knowledge thereby supporting team-based collaborative learning particularly (McCuen and Fithian 2010). In AEC programs, interdisciplinary studio design courses—problem-based laboratory courses where students are given design parameters and a team develops a design solution together—are growing in popularity because they reflect professional work environments and support team-based collaborative interdisciplinary learning (McCuen & Fithian 2010; Dossick & Pena 2010; Holland et al. 2010; Dib & Koch 2010; Gardzelewski et al. 2010; Salazar et al. 2010). Conceptually, these interactions allow students to cross boundaries between disciplines, explore approaches and processes for design, and broaden their perspectives. However, in our experience, student and industry teams alike, do not always achieve collaborative norms of interaction and learning (Dossick and Pena, 2010, Dossick and Neff 2010).

We are challenged then to build a curriculum that encourages and rewards collaboration. Collaboration, as opposed to cooperation, is socially constructed knowledge. Ingram and Hathorn (2004) define collaboration as having three essential elements: participation, interaction, and synthesis (creation of new knowledge). Collaboration requires that individuals create a shared mental model through dialog (Orr 2006, Dossick & Neff 2011). That dialog can entail conversation, as well as other forms of expression – drawing, writing, movement, and gesture. How can a shared mental model be supported when the individual work is distributed across individual sheets? Individual designers must put these drawings together in their mind’s eye, flipping back and forth between pages to get a “complete picture”. Or, teams historically have put overlay drawings together “super plots”, which superimpose multiple drawings together on top of one another. Here we often see a noodled image of multiple disciplines all intersecting in some meaningful and some non-meaningful ways on the page.

3. BUILDING INFORMATION MODELING

Into these collaborative and cooperative systems steps Building Information Modeling (BIM). Three-dimensional computer software that introduces the idea of a central co-developed model. What many people do not recognize right away is that the models alone do not contain enough information to support collaborative work. As one architect noted:

In some respects the modeling forces communication. You can say it enhances, but I like to say forces, because you might think, ‘Oh, I’m going to have to tell so-and-so I moved this column,’ and walk over there and tell them, but if so-and-so is sitting over there and all of a sudden they see in the model they’re working on that the column has moved. . . it’s right there in front of them, they see it. And it will prompt them to ask you, ‘Hey, you moved the column?’ So there’s a level of just managing all this information internally. (Interview with Architect)

Working with the models cooperatively, “I’ll add my stuff then you add your stuff and we should be coordinated”, falls far short of the needs of complex design problems. Collaboration requires dialog between experts. It is this dialog that engenders effective interdisciplinary design. In another example, at an AIA industry workshop, the architect, contractor and owner discussed the Federal Center South project. They observed that "No matter how much modeling we did, we still needed people looking at the models." "You got to know what you are looking at when you are looking at the models. When we got out into the field, we still had sprinkler pipe running under the light fixtures." (AIA Project Delivery Forum December 2012)

Shared virtual models in some ways support this dialog and in other ways does not. Mixed media practices develop where experts use a variety of tools in their work together – pen and paper, marker and whiteboard, mouse and screen. In her work, *On line and On Paper*, Henderson (1999) calls this mixed-use practice:

"Creative people use the new tool to meet their needs and the needs of the company by employing mixed practices that work rather than letter marketing promotions dictate how the tool should be used. The smart managers who let designers do so should witness a new visual culture that capitalizes on mixed-use practices, multi-visual competencies and the meta-indexical quality of visual representations that resourceful users are sharing with one another." (Henderson 1999, pg 207)

4. EDUCATION

Turning our attention to educating AEC professionals then, we see clearly emerging a need for skills that include the breadth of practices, from drawing to modeling, from individual analysis to deep collaborative problem solving. The professionals to emerge from our programs need “multivisual competencies” and collaboration fluency. They will not only model or only collaborate, but those activities are added to the already full repertoire of architecture, engineering and construction skills.

As integration becomes a growing trend in architectural practice, architectural educators seek new ways of teaching collaboration. In this paper we present examples of studio teaching integrating architecture, construction management and engineering disciplines at three different institutions over the past 5 years. These examples complement research into methods to teach collaborative and integrated project development (Simonen, et. al. 2012; Schaffer, et. al. 2008; Carlson and Sullivan 1999, Kuhn 2001).

While each of these studios has grappled with the logistics of time and workspace organization, in this paper we focus on cycles between analysis and design as a way to support and reward collaboration across disciplinary boundaries. We seek to answer what successes has each studio found in their attempts to overcome student team learning challenges. Human beings are messy, and bringing students together for any team exercise is challenging. We are asking our student to go beyond the usual norms of divide and concur, we want to encourage them to synthesize their knowledge and co-create designs. This is challenging for experienced professionals let alone students who are just learning their disciplines. Next, we present an example of a collaboration studios know as the Integrated AEC Studio, which is an undergraduate architecture/construction management studio.

5. INTEGRATED STUDIO – ITERATING BETWEEN ANALYSIS AND DESIGN

In the design of the integrated studio curriculum at the University of Washington, we leverage iteration as a way to organize the teamwork around design and analysis problems. This Integrated Studio is a project-based construction management/architecture design studio where students from the two disciplines and allied fields work in a collaborative environment to develop and deliver design proposals using a working process modeled on the practice of Integrated Project Delivery (IPD). IPD is a design approach that integrates people, systems, business structures and practices for harnessing the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication and construction (AIA 2012). Professionals from the design and construction industry work regularly with student teams to provide instruction and advice, and to critique their work.

Building Information Modeling (BIM) and other computational tools are applied to the analysis, design, project management and communication of design intentions. Students apply skills acquired in previous coursework and as a team they work through collaboration exercises. In addition to a fully developed architectural design proposal, each team develops a conceptual cost estimate, a construction plan and a schedule.

This course is aimed at developing the skills required to work effectively and productively in a rapidly evolving world of design and project delivery. The design and construction proposals developed in collaborative teams achieve a relatively high degree of resolution for undergraduate studios including

the development of major assemblies, selection of materials, development of the building envelope, integration of structural and environmental systems, preliminary cost estimates and construction schedules through the analysis of alternatives for massing, structure, exterior systems and interior finishes. Design proposals aim to achieve high performance building criteria, evaluating and improving environmental impacts of building operation and construction.

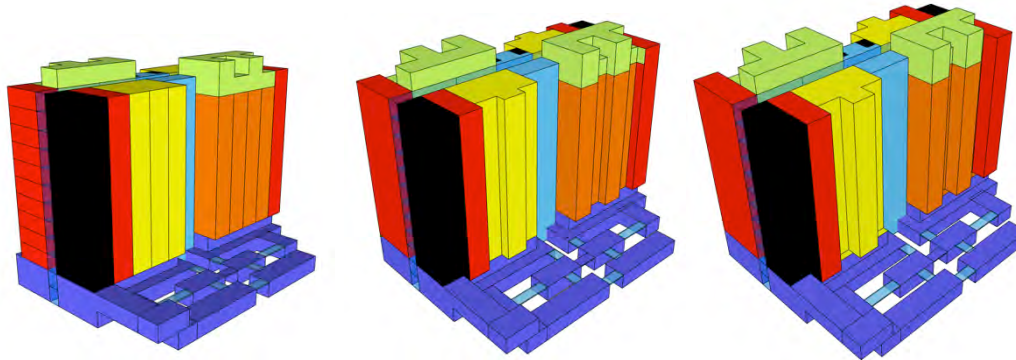
5.1 Objectives

A primary learning goal of this studio is for the students to apply their new found disciplinary knowledge in the context of a team projects, to develop a deep appreciation for the allied AEC disciplines and demonstrate the strengths of integrating analysis and design. The goal of the iterative cycles is to formalize the process of refining options sufficiently to permit analysis and make design decisions that integrate aesthetics with multiple performance criteria such as construction, cost and sustainability.

5.2 Description

Over the ten-week studio, we first produced a 1-week charrette, where the students broke the ice on a joint problem and get to understand their teammates, the expectations of studio work and culture, and dive into the design problem. The studio term were divided into three cycles of design and analysis. The first week focused on analysis after which the students then incorporated this analysis into the design in terms of building performance, cost and construction logistics in the second week. In each subsequent cycle, the student teams were asked to analyze two (or more) alternatives, diving into and laying out the pros and cons for each and then recommending direction for future work. At the final review, the students compile a comprehensive report that covered the design, building performance, cost and schedule for the project that included a building information model and a 4D model of their final design.

The students were given a program, and were required to create a design that took into consideration building performance, costs as well as construction logistics. With a cohort of students from different disciplines, the faculty has been challenged to coach and guide each of these dimensions. The iteration design of the cycle (week 1 analysis, week 2 design) provided an opportunity for the faculty to focus their conversations in desk critique and allow for milestones in the design process where analysis can take place and impact design. We also encouraged subsequent design responded to the analysis, and that the analysis answer questions posed by the design, so that each step of the iterative process informs the next.



NO OFFSET

6FT OFFSET

10FT OFFSET



Figure 2: Massing cycle comparing design and cost for varying façade offsets (by: Michelle Deng, Jason Duckowitz, Chen-Ann Fu, Cory Hartwigsen, Marc Kinsman Alan Montufar and Cameron Wu, 2013.)



Figure 3: Design iterations over the term. (by Michelle Deng, Jason Duckowitz, Chen-Ann Fu, Cory Hartwigsen, Marc Kinsman Alan Montufar and Cameron Wu, 2013)

Over the past few years of this studio, the design problem has varied in scope and complexity. We have found that a mid-rise to high-rise building in an urban setting is a good building type with interesting issues for design, engineering and construction students to engage in. However, we also found a mixed-use historical preservation project and a modular prefabrication to be very interesting as well in that both set up a close interrelationship between design and constructability.

The cycles then helped guide the students through a conceptual design process that got them deep enough into the problem for a fairly detailed construction estimate and schedule in the final. An example of the cycle schedule for one of the studios is as follows: Cycle 1: Massing and Siting. Cycle 2: Structure and Systems. Cycle 3: Exterior Systems. See figure 2 and 3 for examples of design and analysis results throughout the cycles. We found that a cycle of analysis first, followed by design allowed the teams to do a specific analytical task, and then integrated these findings into design decisions. When they did the

design first and analyzed the design, the analysis often was not synthesized into the next iteration of design. This was an important lesson learned in the most recent 2013 studio.

For the daily studio experience, we set up a rhythm to the studio. On Mondays the students presented based on the prior week's work; this both encouraged work over the weekend and kicks-off the next set of design or analysis. On Wednesday and Friday the faculty met with the student teams in desk critique sessions during the first half of studio time. In the second half of studio, we conducted breakout sessions for specific topics. These topics included design, structure, sustainability, project management, cost, schedule, and building information modeling. While the desk critiques allow the faculty to engage with the teams as a whole, the breakout sessions give us a chance to meet with the students on more of an individual and disciplinary specific basis.

5.3 Evolution

In the first years of offering this studio we did not formalize the iterative process. Architecture students entered the studio with an understanding that their design would evolve over time but little experience in designing with a group and incorporating analysis. Construction management and engineering students saw design as a linear process (e.g. design a beam for a particular loading) and were often frustrated when the design changed leading them to want to wait until the design was 'finalized' to perform the analysis.

The formalization of the iteration process came out of successful team coaching we experienced in 2011. We asked teams to develop multiple design options to be analyzed, which provided flexibility to design teams interested in exploring different personal ideas while at the same time gave clear meaning to the early stage analysis as it informed and shaped the design. We formalized the idea of analysis and subsequent design synthesis into the cycles reported above. The repetitive analysis enables students to track progress over the term in terms of meeting team design goals including building performance, cost and constructability.

6. CONCLUSION

In this paper we argue that due to changing AEC industry practices, namely a shift from cooperative to collaborative work, there is a need for pedagogical models that help students acquire collaborative skills in the AEC disciplines. We present one model for project-based team learning where by students are challenged to work across their disciplines to design and analyze a building project. The iterative cycle of the studio class allows the faculty and student teams to focus on specific disciplines (design week one, construction week two), and thereby understand how to apply their own disciplines to the problem as well as understand how the other disciplines also contribute to the problem. The iterative cycle allows us to organize the rhythm of the studio work as well as accomplish the complex and multifaceted learning goals. In our future work we seek to compare similar and related pedagogic strategies from across universities as we continue to refine the iterative model. We also seek to balance the competing demands on faculty and student time in the studio which include the various disciplinary dimensions of architectural design, structure, systems, energy, cost, constructability with the need for the students to also learn, practice and reflect on their collaborative experiences.

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REFERENCES

- AIA, AIA Minnesota, and University of Minnesota (2012) "Integrated Project Delivery: 2012 Case Studies, March
- Carlson, L. E. and Sullivan, J. F. (1999). "Hands-on Engineering: Learning by Doing in the Integrated Teaching and Learning Program." *International Journal of Engineering Education*, 15:1, pp. 20–31.
- Dib, H. and D. Koch (2010). "Integration of curriculum between computer graphics technology (CGT) and Building construction management (BCM)." *Ecobuild America BIM-Related Academic Workshop*. G. Salazar and R. Issa. Washington DC.
- Dorsey, D. W., Campbell, G. E., Foster L. L., & Miles, D. E. (1999). "Assessing knowledge structures: relations with experience and post-training performance". *Human Performance*, 12, 31–57.
- Dossick, Carrie Sturts and Gina Neff (2011) "Messy Talk and Clean Technology: Communication, problem solving, and collaboration using Building Information Modeling" *Engineering Project Organizations Journal*, 1(2): 83–93.
- Dossick, Carrie Sturts and Gina Neff (2010) "Organizational Divisions in BIM-Enabled Commercial Construction", *Journal of Construction Engineering and Management*, 136(4):459-467.
- Dossick, Carrie Sturts and Rob B. Pena (2010) "Bringing Together 'A', 'E' and 'C' in a Problem-based Collaborative Studio", Paper presented at the 2010 National Institute of Building Sciences Annual Meeting, Ecobuild America, Washington D.C., December 6–10.
- Gardzelewski, J. A., Tan G., and Denzer, A. (2010). "Integrated Design Studio Utilizing a Multi-disciplinary Design Team." *Ecobuild America BIM-Related Academic Workshop*. Washington DC.
- Goldsmith, T. E., & Johnson, P. J. (1990). "A structural assessment of classroom learning." In R. W. Schvaneveldt (Ed.), *Pathfinder associative networks: Studies in knowledge organization* (pp. 241–254). Norwood, NJ: Ablex.
- Henderson, K. 1999. *On Line and on Paper: Visual Representations, Visual Culture, and Computer Graphics in Design Engineering*. Cambridge, MA: MIT Press.
- Holland, R., Messner, J., Parfitt, K., Poerschke, U., Pilak, M., and Solnosky, R. (2010) "Integrated Design Courses Using BIM as the Technology Platform". *Proceedings of the BIM-Related Academic Workshop*, Ecobuild America 2010, December 7–9, Washington, DC.
- Ingram, A. L., and Hathorn, L. G. (2004). "Chapter X. Methods for Analyzing Collaboration in Online Communications." *Online Collaborative Learning: Theory and Practice* by Tim S. Roberts, Information Science Publishing.
- Kuhn, S. (2001) "Learning from the Architecture Studio: Implications for Project Based Pedagogy," *International Journal of Engineering Education*, 17(3&4), 349-352 (2001).
- McCuen, T. and L. Fithian (2010). "Team Processes and Dynamics Demonstrated in Interdisciplinary BIM Teams." *Ecobuild America BIM-Related Academic Workshop*. G. S. R. Issa. Washington DC.
- Orr, D. (2006) *Design on the Edge, The Making of a High Performance Building*, Cambridge Massachusetts: MIT Press.
- Salazar, G. F., Vadney T.J., and Eccleston, D. (2010). "Collaborative Term Project between Worcester Polytechnic Institute & Boston Architectural College." *Ecobuild America BIM-Related Academic Workshop*. G. Salazar and R. Issa. Washington DC.
- Schaffer, S. P., Lei K., and Paulino L. R. (2008). "A Framework for Cross-Disciplinary Team Learning and Performance." *Performance Improvement Quarterly* 21(3): 7–21.
- Simonen, K., Dossick, C.S., and Pena, R., (2012) "Reaching for Sustainability Using Technology and Teamwork: Testing Integrated Project Delivery in Multi-Disciplinary Studio Teaching". *Proceedings of the Association of Collegiate Schools of Architecture Conference*, March, Boston, MA.
- Smith, K. A., S.D. Shepard, D. W. Johnson, and R. T. Johnson. (2005). "Pedagogies of Engagement: Classroom-Based Practices." *Journal of Engineering Education* 94(1): 87–101.
- Springer, L., Stanne, M. E., and Donovan, S. S. (1999). *Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis*. *Review of Educational Research* 69(1): 21–51.

The Challenges of Advancing BIM in the Curriculum while Addressing Current Accreditation Standards for Construction

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ABSTRACT

Accreditation of postsecondary education programs for construction provides a means of ensuring that standards and criteria are met through a rigorous objective evaluation. The American Council for Construction Education [ACCE] is one accrediting body for construction programs in the United States. The ACCE standards and criteria are prescriptive with five categories and specify the minimum contact hours required in each category. The five categories are 1) general education, 2) mathematics and science, 3) business and management, 4) construction science, and 5) construction. Accreditation from ACCE requires that a program of study produce evidence through student work that demonstrates students' knowledge and abilities necessary of a professional in the construction industry. As the demand from industry increases for graduates from accredited programs with BIM skills and knowledge, postsecondary education is challenged to integrate BIM into programs of study that must meet traditional accreditation evaluation. The purpose of this paper is to discuss the alignment and misalignment of BIM needs with current criteria, possible strategies for how BIM can be considered in future standards, and the challenges faced by educators who must balance accreditation standards and industry demands.

Keywords: BIM, accreditation, educational standards

1. INTRODUCTION

Results from a recent survey indicated that 71% of the 582 respondents have adopted building information modeling (BIM) for the design, construction, and operations of facilities in the United States (Jones & Bernstein, 2012). The contractors' rate of response to the survey was the largest with 208 or 35.7% of the total respondents. Spatial coordination was the BIM activity reported as adding the most value to preconstruction activities and as the BIM tool used most frequently. In addition to spatial coordination, contractors reported that they frequently use BIM for constructability and job site planning/logistics activities (Jones & Bernstein, 2012). With the rate of BIM adoption by contractors increasing it seems likely that the rate of organizations expecting to hire construction education program graduates with BIM skills and knowledge will also increase. The lack of adequately trained BIM personnel to fill positions in industry presents a challenge for organizations with either plans to adopt BIM or in the process of BIM implementation (Becerik-Gerber, Gerber, & Ku, 2011).

If construction education is to meet industry's need for personnel with BIM skills and knowledge then it needs to be integrated into the curriculum. Construction programs are often challenged to meet this need based on the available resources and the current accreditation standards. Limited research has been completed to date in this area, however based on the current data a disparity exists between the integration rate of BIM in the curricula and the adoption rate of BIM in industry. This paper discusses the standards and criteria in detail and identifies the challenges programs face with balancing resources, accreditation, and integrating BIM.

2. CURRENT INDUSTRY DEMAND

A recent study was completed investigating the experiences and expectations constructors have when hiring graduates from construction programs. Thirty-one companies located primarily in the Mid-Atlantic states responded to an online survey (Ku & Taiebet, 2011). Due to the sample size and limited geographic location the results are not generalizable however the results provide a benchmark for future research and reflect indicators about industry's immediate and future needs. This section highlights the results from the study that are particularly relevant to the discussion about standards and accreditation.

The BIM experience of companies participating in the Ku & Taiebet (2011) study was evenly distributed with 26% reporting less than 1 year of experience; 26% between 1 and 3 years of experience; 26% between 3 and 5 years; and 22% with more than 5 years of experience. Results from the study revealed that the participating companies' preferences are for graduates that have both conceptual knowledge and software skills. Participants also reported that there is a growing need for project personnel with general BIM capabilities, in addition to BIM specialists. When asked to prioritize the expected BIM knowledge and competencies of construction graduates by immediate, near future, and far future needs the number one response for the immediate needs category was visualization. The companies ranked constructability as the second category of immediate needs for construction. In terms of near future needs the companies ranked model based estimating and cost controls at the top of the list (Ku & Taiebet, 2011).

As industry needs for BIM continue to evolve it is important to ensure that the future needs for BIM knowledge and competencies are communicated to construction educators. Industry involvement with construction programs is very important to American Council for Construction Education [ACCE]. In fact, the ACCE standards and criteria document includes a section dedicated to assessing a program's relations with industry.

Additionally programs are required to have an advisory committee comprised of representatives from the construction industry actively involved in the construction program. As a practice-oriented profession it is important that educators understand the changing knowledge and competencies graduates will need in the future. ACCE requires that members of the advisory committee be representative of potential employers of the program's graduates. It is with this criterion that ACCE ensures construction programs are preparing students with the appropriate skills and knowledge needed by the industry upon graduation.

3. CURRENT STATE OF BIM IN CONSTRUCTION PROGRAMS

Evidence from the research discussed in the previous section indicates that industry has immediate and future needs for graduates with specific BIM knowledge and competencies. The discussion in this section focuses on the results from recent research by Becerik-Gerber et al. (2011) investigating the integration of innovation in the curricula of accredited architecture, engineering, and construction programs. Included in the study was an investigation into the level of BIM integration in construction education. This section focuses specifically on the results about construction programs.

Participants were twenty six deans, department chairs, or program directors from accredited construction programs in the U.S. that responded to an online survey. Participants reported BIM as either very important or important to the future of AEC. They also reported that BIM is integrated into the curriculum in three different ways: 1) part of existing technology courses, 2) part of other construction courses, or 3) as a stand-alone course. The majority of BIM courses in

the participating programs are offered at the junior and senior level and they are offered as an elective. Only 36% of programs reported BIM as a required undergraduate course. Unique to construction programs, in comparison to architecture and engineering programs, was the finding that that construction programs with BIM courses actually teach students how to use BIM software on projects in class and students are not expected to learn those BIM skills by themselves. Construction programs reported offering 3.1 BIM courses on average in their undergraduate curriculum. Courses taught include constructability, 4D scheduling, model based estimating, design, visualization, and cost control (Becerik-Gerber et al., 2011).

Included in the survey were questions about limitations to integrating BIM in the curriculum. Forty-five percent responded that they lack the resources and 27% see the lack of accreditation specificity for BIM as a barrier to its integration in the construction curriculum. The following section provides a detailed discussion about the accreditation standards and criteria used to assess construction programs in the United States.

4. STANDARDS AND CRITERIA FOR ACCREDITATION

The American Council for Construction Education (ACCE) and the Accreditation Board for Engineering and Technology (ABET) are the two accrediting bodies for post-secondary engineering and construction programs in the United States. This paper focuses solely on the ACCE standards and criteria and the alignment, and misalignment, of BIM needs in relationship to the current criteria.

The ACCE mission is “...to be a leading advocate of quality construction education...” (<http://acce-hq.org/mission.htm>). As an accrediting body ACCE assesses the quality of construction programs using its standards and criteria. The ACCE acts as a conduit between post-secondary education and the construction community with standards and criteria intended to prepare graduates for a career as a professional constructor. As a conduit ACCE ensures that students receive a quality professional education and it recognizes the significant responsibility that the construction industry has to the general public in ensuring the quality of construction projects. Below are just two examples of how ACCE accreditation seeks to enhance the quality of construction by (American Council for Construction Education, 2013):

- Accrediting programs that meet the standards of competence as required by the criteria and therefore warranting public and professional confidence
- Encouraging construction education programs to maintain academic curricula, instruction and learning experiences, and research relevant to the needs of the construction profession and general public through an interchange of ideas

The general goal is to assess construction education programs based on standards and criteria written to ensure graduates have the skills and knowledge needed to contribute to the construction industry and meet the industry demand for graduates prepared to work in the ever changing industry. The fact that construction is an ever changing industry presents a challenge for construction programs to provide a curriculum that meets the immediate and future needs of the construction industry. The ACCE standards and criteria for accreditation are set forth in Document 103 (<http://acce-hq.org/documents/Document103053113.pdf>), which is the guiding document by which Construction programs seeking ACCE accreditation or re-accreditation are assessed. Document 103 includes assessment criteria in the areas of: 1) organization and administration, 2) curriculum, 3) faculty and staff, 4) students, 5) facilities and services, 6) relations with industry, 7) relations with the general public, 8) program quality and outcome assessment, and 9) quality improvement plan.

This section focuses on the current criteria to assess the curriculum for a baccalaureate degree program. Recommendations and strategies for BIM integration into construction education are included in the discussion to provide context about the current accreditation criteria. The ACCE curriculum criteria require a minimum of 120 semester (180 quarter) credit hours where 1 semester hour equals 15 instructional hours and 1 quarter hour equals 10 instructional hours. The criteria are organized into 5 categories of core subject matter with the number of required credit hours prescribed for each category, totaling 98 semester (146 quarter) hours. There is also a sixth category with 22 semester (34 quarter) hours assigned to it. The sixth category is an open category that gives individual programs the opportunity to identify courses at their discretion to meet the total hours required for accreditation. Due to the prescriptive nature of the ACCE accreditation the assessment of a construction program counts the number of hours dedicated to teaching topics by the core subject matter in each of the five curriculum categories. Therefore if a topic in one of the core subject matter areas has a 2 semester hour requirement then there must be evidence that the students' education included 30 instructional hours specific to the topic. The five curriculum categories are 1) general education, 2) mathematics and science, 3) business and management, 4) construction science, and 5) construction. As indicated in the list of categories three of the five categories are outside of the construction discipline. The 3 non-construction categories account for 48, or approximately 40%, of the 120 required semester hours for ACCE accreditation. The sections below discuss each of the five categories and the core subject matter in each category.

The first category is general education and the requirement is for 15 semester (22 quarter) hours in courses such as communications, human relations, psychology, sociology, literature, history, philosophy, language, and art. Two of the core subjects in this category are oral communication and written communication. Of the 15 semester hours required, 8 hours in this category must be dedicated strictly to stand-alone oral and written communication courses. According to Document 103, construction is concerned with people and their relationships, graduates must be able to communicate and understand human behavior to be a successful constructor, thus the requirement for these courses. Additionally oral and written communication must be integrated into at least 33% of the total number of construction and construction science courses.

Mathematics and science courses outside of construction are in the next category required for accreditation. The curriculum must include 15 semester (22 quarter) hours in the core subjects of physical or environmental science and statistics and mathematics. Examples of courses in this category are analytic geometry, physics, calculus, statistics, and geology. The third category is business and management with a requirement of 18 semester (27 quarter) hours taught within the academic business unit at the institution to ensure the instruction focuses on the fundamental concepts of business. Fundamental courses in this category include economics, principles of management, organizational behavior, financial accounting, managerial accounting, business law, finance, marketing, and labor relations. As previously mentioned the three categories discussed above total 48 semester (71 quarter) hours leaving only 72 semester (109 quarter) hours in which BIM may be integrated into the curriculum.

The next three categories are construction science, construction, and 'other' courses as needed to meet the required credit hours. The core subject matter areas included in the construction science category are 1) design theory, 2) analysis and design of construction systems, 3) construction methods and materials, 4) construction graphics, 5) construction surveying, and 6) ethics. The construction science category requires 20 semester (30 quarter)

hours of instruction in the curriculum. Table 1 below shows the minimum academic credit required in each core subject matter.

Core Subject Matter	Minimum Academic Credit
Design theory	3 semester (4 quarter) hours
Analysis and design of construction systems	6 semester (9 quarter) hours
Construction methods and materials	6 semester (9 quarter) hours
Construction graphics	1 semester (1.5 quarter) hour(s)
Ethics	1 semester (1.5 quarter) hour(s)

Table 1 Construction Science requirements

Examples of content that should be included in courses selected for this category are structural mechanics, soil mechanics, electricity, thermodynamics, structural systems, HVAC, plumbing, mechanical, temporary facilities, foundations, surveying, construction graphics, materials, equipment, feasibility studies, value analysis, site planning, and building codes. Obvious from the list of example courses most are courses in areas where BIM is often used by professionals in industry, therefore it may seem like each of the courses listed are opportunities to integrate BIM. However the fact is that in addition to teaching BIM concepts and tools, there are fundamental subject matter concepts, principles, and procedures that students must first learn in each area to appropriately use BIM as a means for problem solving or completing tasks.

Document 103 states that the construction science course requirement purpose is to introduce students to the design disciplines' processes and how to communicate with design professionals. The document also states that the intent of the analysis and design of construction systems requirement is to ensure that graduates have some exposure to all the basic systems that may be incorporated into a building project. The overall requirement for this category is for courses on topics about construction sciences and architectural or engineering design that focus on communicating with design disciplines to solve practical construction problems. Ultimately the construction students should be capable of participating during the planning phase of design-build projects therefore emphasis in this category is on preparing to work with design disciplines. If construction programs were integrated with design programs and students shared common courses then perhaps it may be easier to integrate BIM however multi-disciplinary courses complicate students learning about the technical content that is required of each discipline, and it may also be limited by the accreditation standards for design disciplines.

The construction curriculum category requires courses that focus on effective management of personnel, materials, equipment, costs, and time in the context of office and field activities. In particular the topics should address the constructor as a member of a multi-disciplinary team, the assessment of project risk, and the alternate project delivery methods. A minimum of 20 semester (30 quarter) hours are required in the construction category. Table 2 shows the core subject matter and credit hour requirement for each subject.

Core Subject Matter	Minimum Academic Credit
Estimating	3 semester (4 quarter) hours
Planning and scheduling	3 semester (4 quarter) hours
Construction accounting and finance	1 semester (1.5 quarter) hour(s)
Construction law	1 semester (1.5 quarter) hour(s)
Safety	1 semester (1.5 quarter) hour(s)
Project management	3 semester (4 quarter) hours

Table 2 Construction requirements

Examples of content that should be included in courses selected for the construction category include drawings and specifications, contract documents, quantity surveying, pricing, bidding strategy, work analysis, quality control and assurance, job supervision, scheduling, cash flow, and safety. In addition to the content requirement the presentation of the content in courses should encourage problem definition and solution, creativity, communication, evaluation, and continuous learning. As shown in Table 2 the core subjects in construction are the discipline specific courses that provide instructors with the opportunity to integrate construction specific BIM tools into the classroom. The integration of BIM into the curriculum however has its challenges. The primary challenges and opportunities are discussed in detail in the next section.

Based on this review of ACCE's discipline specific categories points do exist in the curriculum to integrate BIM such that it aligns with the criteria however there other areas in the criteria that do not align as readily and create a challenge for construction education. Specific challenges and opportunities are discussed below, along with possible strategies for integrating BIM into construction curricula.

5. DISCUSSION

5.1 OPPORTUNITIES, CHALLENGES, AND DISCUSSIONS

In particular the construction science category requirements offer the greatest opportunity to introduce BIM as an element in the content for courses. The most obvious subject for integrating BIM in this category is in the construction graphics requirement for 1 semester (1.5 quarter) hour(s). The challenge however is that construction graphics are often taught as stand-alone lower level course dedicated to developing skills only. Courses in this category focus primarily on teaching the nomenclature of graphics and how to use specific graphical tools. As a result the opportunity is limited to and instructional strategy emphasizing BIM tools with an introduction to levels of development and model elements at a conceptual level.

The construction science category also includes a requirement for six credit hours that must be dedicated to the analysis and design of construction systems. Integrating BIM into these courses aligns with industry's immediate needs for graduates with the skills and knowledge for analyzing the constructability of a project using BIM (Ku & Taiebet, 2011). Courses in this category provide programs with opportunities to introduce a variety of BIM concepts and tools to students. One of the primary responsibilities of constructors on projects is to analyze the design of systems for planning and constructability purposes. Courses in this category are often taught at the junior and senior level due to the prerequisite knowledge needed about construction materials and methods as a foundation for analysis and design. A possible strategy for integrating BIM is to supplement or replace the existing analysis tools with BIM tools to analyze the structural systems and design construction systems such as formwork. Integrating BIM into these courses however would require that the instructors have some level of knowledge about BIM and its application for analysis. It would also require additional time in the sequence of instruction dedicated to discussions about BIM for analysis. Faculty with the necessary knowledge and skills along with time in the classroom are two resources cited as limitations to the integration of BIM in construction programs (Becerik-Gerber et al., 2011).

Another opportunity in the construction science category is the opportunity to integrate BIM concepts and tools from a multi-disciplinary perspective in a multi-disciplinary environment. In

doing so construction programs would prepare graduates with a holistic understanding of BIM concepts and tools and it would align post-secondary curricula with the needs of industry (Ku & Taiebet, 2011) and the fundamental purpose of using BIM for building projects (Smith & Tardif, 2009). This type of instruction however would require coordination between faculty and programs across disciplines to accommodate collaborative experiences and provide for the necessary resources such as time and tools. As previously discussed the challenges to accomplishing this are the resource constraints and the lack of criteria within the design and construction accreditation standards specific to multi-disciplinary knowledge and skills (Becerik-Gerber et al., 2011). As shown in Table 1 there is no requirement for a multi-disciplinary collaborative experience, however according to Document 103 construction students should be capable of working with design disciplines during the planning phase of design-build projects (ACCE, 2013). This overarching intent for the construction science category does not align with the criteria specified for the category. As a consequence the resources necessary to meet accreditation criteria of multi-disciplinary collaborative experiences in the curriculum may not be included in construction curriculum as a standard practice.

In addition to the opportunities available for the integration of BIM in the construction science category are core subjects in the construction category. In particular the three semester hours of estimating; three semester hours of planning and scheduling; one semester hour of safety, and one semester hour of project management are all opportunities for BIM instruction. As a matter of practice a variety of discipline specific tools are taught in the technical subjects of construction science. The opportunity for construction programs is to replace the traditional tools taught such as the quantity takeoff (QTO) tools that use digital on-screen images, text based scheduling, and image based planning. Instead construction programs should implement BIM technology and include model based tools for each of the core technical tasks. For example, automatic generation of a QTO is a standard feature of intelligent modeling tools. In addition to teaching students how to utilize the QTO feature teaching students how to validate the QTO for completeness and accuracy would provide students with a much needed skill. Visual based planning and scheduling are also standard features in many construction BIM tools. Once again faculty with the necessary knowledge and skills, along with time in the classroom, are the limitations cited for the lack of BIM integration (Becerik-Gerber et al., 2011).

5.2 FUTURE STANDARDS AND CRITERIA

In 2012 ACCE proposed a new standard for accreditation that will assess programs based on a set of learning outcomes criteria. Bloom's taxonomy for learning is the framework used to guide development of the new criteria. The framework specifies the categories for learning as: 1) knowledge, 2) comprehension, 3) application, 4) analysis, 5) synthesis, and 6) evaluation (Smith & Ragan, 2005). To demonstrate learning the proposed revisions to the ACCE criteria will replace the existing six prescriptive credit hours based categories and the subsequent requirements for instruction with approximately 19 outcomes' criteria. The new criteria will guide ACCE in their future assessment of student work to determine the level of student learning. Each of the 19 proposed criteria represent categories of learning according to Bloom. The future of the proposed revisions is uncertain at this time however ACCE accredited programs have been presented with the possible changes the opportunity to provide input about the criteria.

6. CONCLUSION

Integrating BIM in existing construction curriculum presents programs with challenges at both the program level and at the accreditation level. Specific at the program level are constraints due to the limited resources. First, there is a limited supply of time available for instruction about the core concepts, principles, and procedures about construction. In any course of study students must first have a basic understanding of the relevant terminology and context for the subject matter. When students enter an undergraduate construction program they enter as novices to the discipline and must first receive instruction about the fundamentals of construction. As a result the time spent developing a foundation of understanding reduces the time available for learning discipline specific tools, such as BIM, and how to apply those tools. The second limited resource is faculty with the ability to teach BIM tools instead of the traditional discipline specific tools. The likelihood of replacing current tools, such as CAD, exclusively with BIM tools in the industry is limited at this time (Butler, 2013) thus requiring continued instruction about traditional tools in construction programs. As a result of the industry's current use of both set of tools (Ku & Taibet, 2011) construction faculty are faced with finding time in courses for instruction about the required technical content, traditional tools, and BIM tools if they are to prepare students to enter industry.

Given that construction programs dedicate time to teach students how to actually use BIM tools (Becerik-Gerber et al., 2011) highlights the misalignment between construction program resources, ACCE accreditation criteria, and the industry need for graduates with BIM knowledge and skills. Construction education is complex and must be coordinated and balanced to meet the needs of programs, accrediting bodies, and industry. To do so will require a coordinated effort that clearly communicates the methods and resources necessary to prepare graduates to enter the profession ready to participate in an industry where advances in technology and evolving business processes are impacting the constructors' role on building projects.

REFERENCES

- American Council for Construction Education, (2013). Document 103: Standards and Criteria for Accreditation of Postsecondary Construction Education Programs. Retrieved from <http://acce-hq.org/index.htm>.
- Becerik-Gerber, B., Gerber, J., & Ku, K., (2011). The pace of technological innovation in architecture, engineering, and construction education: Integrating recent trends into the curricula. *Journal of International Technology in Construction*, vol. 16, 411-432.
- Butler, M. (2013). Message from the United States national CAD standard project committee. *Journal of the National Institute of Building Sciences, JBIM Edition*.
- Jones, S., & Bernstein, H., (2012). *The Business Value of BIM in North America* (SmartMarket Report). New York, NY: McGraw-Hill Construction.
- Ku, K. and Taibet, M., (2011). BIM experiences and expectations: The constructors' perspective. *International Journal of Construction and Research*, 7(3), 175-197.
- Smith, D. and Tardif, M. (2009). *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*. Hoboken, NJ: John Wiley & Sons, Inc.
- Smith, P.L. and Ragan, T.J., (2005). *Instructional Design*, John Wiley & Sons, Hoboken, New Jersey.

UNIVERSAL DESIGN FOR LEARNING (UDL) WITHIN AN INTERDISCIPLINARY COURSE FOR BUILDING INFORMATION MODELING (BIM)

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ABSTRACT

As the benefits to Building Information Modeling (BIM) continue to be endorsed by the Architecture, Engineering, Construction (AEC) industry, higher education is trying to keep up with the demands to provide graduates proficient in these technologies. The quickly paced BIM revolution represents a particular challenge for higher education, with the development of new curricula.

This paper will focus on the successful introductory teaching of BIM within an interdisciplinary undergraduate course, while using Universal Design for Learning (UDL) curriculum strategies. The author presents sample course lessons and exercises from a sophomore-level Architectural Technology course that is required for students enrolled in the Bachelor of Science in Construction, the Bachelor of Science in Engineering Technology, and the Bachelor of Science in Technology Education at the University of Wisconsin-Stout. The paper will relay the author's approach to introducing and incorporating BIM through intentional UDL teaching strategies that address the varying learning styles and academic disciplines of the course participants, while fostering future industry professionals that can adapt to the continuing evolution of BIM.

Keywords: BIM, UDL, Architectural Technology

INTRODUCTION

At the University of Wisconsin-Stout (UW-Stout), BIM is introduced in a sophomore-level undergraduate course titled “AEC-237 Architectural Technology” to students enrolled in the Bachelor of Science (BS) Construction, the BS Engineering Technology facilities concentration, and the construction emphasis of the BS Technology Education. The course is housed within the Department of Construction. The BS Construction program is accredited by the American Council for Construction Education (ACCE) and the Engineering Technology Program is currently under review for Accreditation Board for Engineering and Technology (ABET) certification.

An introductory architectural drafting course is the requisite to AEC-237. The AEC-237 course description is as follows: Space programming and planning, working drawings for commercial and industrial buildings; Building codes, energy requirements, construction contract documents, structural materials and systems, building materials and systems. AEC-237 is the prerequisite to courses in estimating, scheduling and mechanical/electrical/plumbing (MEP) systems.

Upon completion of the AEC-237 Architectural Technology course, the student should be proficient in the following areas related to the architectural effectuation process:

1. Manual and computer-aided architectural drawing & scaling
2. Organizing a set of architectural drawings
3. Oral and written presentation skills relevant to the construction industry
4. Commercial building space design and applicable building codes
5. Knowledge related to energy and structural requirements of commercial building design and construction

AEC-237 serves approximately 25-30 students in each section, each term. The course is three credits and meets twice a week in a two-hour lecture/laboratory format. The students and faculty at UW-Stout benefit from what is termed the “eStout Program”- the campus digital learning environment (Learning and Information Technology, 2013). The program ensures that students and faculty have a standard set of tools - both hardware and software - that meet a majority of their wireless computing needs, thus producing a wireless laptop campus environment. The eStout Program is included in the undergraduate student tuition so that UW-Stout students are provided with the tools that they will need to be technology literate. For this course, the benefits include a laptop computer and software, wireless and wired connectivity on campus, a course management system (CMS), service and support, network storage, e-mail, and a multimedia classroom. As a “laptop campus” the University has both the ability to and expectation to provide current and high quality software platforms. Annual updates are made available to both students and faculty to upgrade the software on the laptops, fostering currency with the AEC industry.

The knowledge, regarding architectural technology, varies greatly amongst the entering AEC-237 student, as does the chosen career paths of the students upon graduation. UW-Stout Construction graduates tend to seek a variety of construction project management roles, including estimating and safety; Engineering Technology graduates seek facility management roles, including maintenance and operations supervision, and Technology Education graduates can pursue certification as instructors of primary and secondary education with specializations including architectural drafting.

The current instructor of AEC-237 is a licensed architect and has been teaching at UW-Stout since the fall 2005. She has earned teaching recognitions and began incorporating the BIM platform within AEC-237 in the fall of 2007. For AEC-237 Architectural Technology, the software programs used are Autodesk AutoCAD and REVIT Architecture, and Microsoft Office. The instructor fosters completion of the course objectives with the prioritization that the curricula will prepare the students, regardless of major, for the responsibilities associated with being a professional in the AEC industry: management skills. Through intentional design of the course structure- courses assignments, assessments and out-of-classroom course assistance opportunities- the instructor emphasizes the importance of professional communication and documentation. For example, attention is paid to communicate directions and deadlines for each assignment, along with assignment grading rubrics, in advance and to foster professional written communications between instructor & student. This practice includes emails and online course management system (CMS) discussion postings.

By formalizing the professionalism of the learning environment, the students experience the importance and benefits of clear communications. This quote by Dykstra (2011) is shared with the students, “Thorough record-keeping and effective communication and documentation are important for several reasons. Good documentation reduces misunderstandings and provides the

contractor [*or AEC professional*] with management tools, which enable him [*or her*] to maintain control over the progress of the work and the performance of subcontractors [*consultants*]. Written records support the contractor [*or AEC professional*] if there are problems or delays...” (p. 247-248).

In the fall of 2011, to further enhance her teaching strategies, the instructor was part of a UDL cohort and developed a particular interest to address multiple learning styles through the course delivery. Coined in the United States in 1972, universal design is a term known within the built environment as “the design of our environment to be usable by all people, to the greatest extent possible, without the need for adaptations or specialized design” (The RL Mace, 2013). UDL transfers this concept to a pedagogical framework. UDL is a “scientifically valid framework for guiding educational practice that (A) provides flexibility in the ways information is presented, in the ways students respond or demonstrate knowledge and skills, and in the ways students are engaged; and (B) reduces barriers in instruction, provides appropriate accommodations, supports, and challenges, and maintains high achievement expectations for all students, including students with disabilities and students who are limited English proficient” (“Higher Education Opportunity Act,” 2008).

Recognizing that the way individuals learn can be unique, the UDL framework was first defined by the Center for Applied Special Technology (CAST) in the 1990s, and calls for creating curriculum from the outset that provides the following three principles:

- Principle I: Provide Multiple Means of Representation (the “what” of learning)
- Principle II: Provide Multiple Means of Action and Expression (the “how” of learning)
- Principle III: Provide Multiple Means of Engagement (the “why” of learning)

(CAST, 2012)

Multiple means of representation gives learners various ways of obtaining information and understanding; multiple means of expression provides learners alternatives for demonstrating what they know; multiple means of engagement acknowledges that learners’ interests are sparked in a variety of ways, so the instructor is charged with finding ways to motivate and optimally challenge learning (CAST, 2011).

To address UDL Principle I, the course outline, course lectures notes and presentations are posted on the content management system (CMS) with online links to all references and the list of text references. Assignment descriptions and deadlines are posted and explained verbally in-class. In addition to in-class demonstrations, narrated “on-screen captured” tutorials are created and posted for the BIM assignments. Prior to assignment assessments, detailed grading rubrics are provided for each assignment explaining how assignment points can be earned. Multiple opportunities for assignment feedback, from the instructor and/or peers during lab time and prior to final submittals are provided. Outside-of class, office hours are held weekly to meet with students, including flexibility of date/time that can be arranged with instructor.

To address UDL Principle II, a portion of student assignments allow for choice of topic to be researched as well as the format of the submittal. See appendix A for an example.

To address UDL Principle III, course content is delivered through a combination of instructor lecture, online readings, Power Point presentations, guest presentations and video tutorials. Course format prioritizes engagement through in-class dialogue, collaborative team assignments, online discussion boards, and reflection exercises demanding critical-thinking.

Through the UDL strategies implemented, students are provided a variety of ways to learn the course content, as well as demonstrate their proficiency. The strategies address different paces and learning styles. Through assessment scores, daily class dialogue and an end-of-course

formal evaluation, the instructor also surveys the students on the effectiveness of the strategies implemented and makes adjustments accordingly.

DISCUSSION

To introduce BIM, the instructor provides industry examples of the use of BIM, in addition to video presentations that explain and demonstrate the capability of BIM platforms. Numerous free online videos are shown via the internet. Some video literature is posted by product vendors so students are advised to set aside the marketing language and focus on the capabilities of the platforms as demonstrated in the materials. The instructor asks the students to reflect on two-dimensional (2D) drafted construction drawings previously completed in the pre-requisite course and then takes the conversation from 2D to 5D, clash detection, and animated BIM “phasing” of projects synchronized with construction documentation photos. This initial session sets the stage for the impressive efficiencies generated through the use of BIM with a critical warning: a BIM model is only as good as the accuracy of its creation- “Garbage in= Garbage out”.

Upon entry, many of the AEC-237 students are developing proficiencies in the basics of construction traditional means and methods. A quickly generated 3D model, through the REVIT program defaults, is visually appealing and empowering to the drafter. However, the instructor consistently reminds the students of the dedication to detail that is needed to assure the parametric information is drawn correctly from the onset. The instructor often asks, “It may look good, but is the model right?”

The BIM assignments begin by lessons on the drafting differences between the Autodesk REVIT Architecture platform and 2D AutoCAD. Although the course is dedicated to commercial/industrial building types, the initial drawing assignment consists of drafting a wood-framed building shell totaling 800 square feet (74.32 m²) in AutoCAD and then replicating it in REVIT. The assignment is included as Appendix B and C. The instructor finds benefits to beginning BIM with a building-type that is known by the audience. At the sophomore level, the majority of AEC-237 students have experienced building a wood-framed structure first-hand. As a result, class instruction focuses on the intersection of planes captured in 3-dimensions, scaled annotations, the learning of tool commands, and keystrokes within REVIT. An additional benefit to starting with the somewhat “known” is that it leads to strengthening the student’s confidence to draw the construction “unknowns”. For many students at this point in their academic careers, commercial-building construction methods are unfamiliar.

One class period is focused on navigating the REVIT drawing screen and understanding how the assemblies are initially drafted, including each connection point to each intersecting spatial plane. Though somewhat intuitive for some, spatial intersections as a concept can be initially challenging for students. At first, it is also not natural for the students to toggle between the varying model views that are being created. Over the course of a two-hour laboratory session, a student begins to confidently examine the additional views and schedules that are being generated automatically, as they make drafting decisions in a single view.

Upon completion of the first BIM assignment, students have created a wood-framed single-level floor in REVIT. The student learning outcomes include proficiency in setting wall bottom and top constraints, inserting default program components (doors, windows, furnishings, etc.), making slight size manipulations of a default component (simplifying a wall type, making windows wider), providing necessary annotations (dimensions, north arrow and general notes), formatting simple schedules (door and window), inserting section tags that reference a section sheet, and printing a scaled drawing sheet.

The assignment rubric (Appendix E) is provided at the time of the assignment, with learning outcomes noted, to allow students to review how points will be awarded. The instructor reviews points earned per assignment, and per learning outcome, to determine areas for additional review. For program quality assessment, the goal is for the class median score to be 73% or higher. To foster student learning, the instructor incorporates a variety of resources for the students with each BIM exercise. This includes in-class communications, handouts and on-screen tutorials that are posted on the CMS. The instructor has successfully implemented the use of Jing, a free screen capture and short video (< 5 minutes) narration tool. Select any window or region that you would like to record on your screen, and Jing captures everything that happens in that area (Techsmith, 2013). Jing records mouse movements to fully narrated tutorials. The videos are limited to five minutes and as soon as you are done with your screen capture or screen recording, it is ready to upload to the CMS. Appendix D provides a screen shot of the tutorial, as viewed from the CMS.

The use of on-screen tutorials has become an efficient way to address the students' content questions and provide an outside-of-class resource. The CMS discussion board also provides a venue to post additional questions and updated Jing tutorials. Permission settings within the CMS can allow the instructor to monitor how frequently students access each tutorial. For continuous quality improvement, the instructor evaluates the number and type of student-generated questions, scores earned on the assignments specific learning outcomes and frequency of visits to the tutorials. Informally, a dialogue also takes place regarding additional resources found through student self-initiation. Students are accustomed to the web as a repository for resources and they find REVIT resources in a variety of formats including Autodesk tutorials, user-based forums and blogs, and other online learning services such as Lynda.com.

Once an 800 square feet (74.32 m²) building shell is accurately drawn, the students explore additional benefits to the BIM platform, including the quantity take-offs, phasing and scheduling features of REVIT. At the sophomore-level, the course instruction is still focused on what these items are, in addition to how the BIM platform efficiently creates them from the three-dimensional (3D) model being drawn. Having to manually update each individual change across multiple construction drawing sheets in prior 2D AutoCAD exercises versus the automatic updates accomplished in REVIT unanimously produces the same response across each class: the students are impressed with the efficiencies gained through the use of BIM.

For the second BIM exercise in AEC-237, the students are asked to replicate a 2,880 square feet (267.6 m²) commercial building shell. The drawings provided to the students include a floor plan, building section and axonometric. The exercise is intended to test the student's attention to detail and proficiency regarding presentation of necessary information. The instructor asks the students to reflect on questions such as, how much information is needed on each drawing? How do you dimension this masonry building differently than the first wood-framed building? What is the purpose of a building grid on a building plan and/or section? This second BIM model becomes the basis for the remainder of the term concepts including the learning of building codes, the American with Disabilities Act (ADA) legislation, the design of light-steel framing and the design of concrete foundations. The students continue adding applicable content features to the commercial building model as each topic area is covered.

From the middle of the term until its completion, the BIM model and class content work hand-in-hand. For example, once the learning module in schematic structural calculations is covered and the students have determined the framing elements, they proceed with inserting the light-steel framing structural members into the BIM model and simultaneously generate a

framing schedule. When the site planning module is covered, the students proceed with inserting terrain in the BIM model and adjusting the benchmark elevations (levels) accordingly. The model provides a “hands-on” experience for the students and the variety of supplemental resources provided (text descriptions, video tutorials, class lectures, CMS resources, outside of class office hours) promote student learning.

By the end of a 15-week term, a final project tests the students’ ability to navigate the REVIT platform for a variety of simple tasks and synthesize the learned course content. To further increase student engagement, the instructor secures a non-profit client for the final project, and through service-learning, the students work in teams to provide a variety of schematic design services including preliminary space planning proposals, schematic building designs, with rough estimates of quantities and material costs, using the BIM platform.

CONCLUSIONS AND FUTURE WORK

This paper addressed the instructor’s approach to introduce BIM to interdisciplinary sophomore-level undergraduate students. The instructor emphasizes the use of clear and professional communication techniques and provides multiple resources for student learning, in alignment with the principles of UDL, to help students learn. For a sophomore-level introductory BIM exercise, the author recommends starting with a building or space that is known to the students in order to focus the learning on the capabilities of a particular BIM platform.

Just as the industry is challenged to keep up with continuing technological advances, faculty are charged with staying current and dialogue is critical within the industry and academic sector. UW-Stout Construction department faculty maintain strong ties to industry through the Construction Program Industry Advisory Board. At a minimum, the Construction department faculty are in consultation with the advisory board members once a term on current industry needs and the established program curricula.

For students enrolled in the BS Construction, BS Engineering Technology facilities concentration and the construction emphasis of the BS Technology Education, the importance of understanding the capabilities of BIM, the evolving roles of AEC players due to BIM, and the blurring that is occurring between traditional AEC roles due to BIM, emphasizes the importance of communication and documentation across each discipline.

With the goal of continuous improvement, the instructor evaluates both quantitative and qualitative data from student assessments which include points earned on individual and team assignments, end-of-term course evaluations, and informal class dialogue. Positive comments regarding currency of learning content, availability of tutorials, clarity of instructions and timeliness of rubrics are overall themes found within student evaluations.

A future curriculum goal is to assure that the courses that follow AEC-237 Architectural Technology continue to build on the sophomore-level BIM skills. A possibility is for the more specialized AEC courses to begin with the AEC-237 commercial building file and add to it. Using additional BIM platforms- such as structural, MEP, estimating, and clash detection programs- the students could continue to manipulate the model and further understand its benefits. This collaborative approach among courses and instructors would mimic the collaborative nature of the AEC industry.

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REFERENCES

- Center for Applied Special Technology, CAST (2011). Universal Design for Learning Guidelines version 2.0. Wakefield, MA: Author. Retrieved from: http://www.udlresource.com/uploads/1/2/1/2/12126894/udl_guidelines_version_2.0_final_3.pdf
- Center for Applied Special Technology, CAST (2012). *The Three Principles*. Retrieved from: <http://www.udlcenter.org/aboutudl/whatisudl/3principles>
- Dykstra, A. (2011) *Construction project management: A complete introduction*. Kirshner Publishing Company Inc. Santa Rosa, CA.
- Higher Education Opportunity Act (2008). *Sec. 103. Additional Definitions- Universal Design for Learning*. Retrieved from: <http://www.gpo.gov/fdsys/pkg/PLAW-110publ315/pdf/PLAW-110publ315.pdf>
- Learning and Information Technology Department, University of Wisconsin-Stout (2013). *About the eStout program*. Retrieved from: <http://www.uwstout.edu/lit/es/index.cfm>
- The RL Mace Universal Design Institute (2013). *What is universal design?* Retrieved from <http://udinstitute.org/whatisud.php>
- Rose, D.H., & Meyer, A. (2002) *Teaching every student in the digital age: Universal design for learning*. Alexandria, VA: ASCD.
- Techsmith (2013) *Jing*. Retrieved from: <http://www.techsmith.com/jing.html>

APPENDICES

Appendix A: Sample final project assignment with choices on research topic

Appendix B: Introductory AutoCAD exercise

Appendix C: Introductory REVIT exercise, text description

Appendix D: Introductory REVIT exercise, on-screen video tutorial

Appendix E: Introductory REVIT exercise, assignment grading rubric

Appendix F: Part 2- Introductory REVIT exercise, text description

*Team Member Names:

Project Selected:

Date:

Class Session	Teams/Research Assignments									
	Building Certifications		Energy Efficiency		Low-Cost Remodeling Options		New Construction Options			New Real Estate Options
	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8	Team 9	Team 10
4/3	Project Assignments/ Initial Teams Determined. Delegation of tasks and schedule of deliverables									
4/5										
4/10										
4/12										
4/17										
4/19										
4/24										
4/26										
5/1	In-Class Presentation/ Practice for Showcase Event									
5/2	Thursday, Showcase-Time/Location TBD- Has been in the evening in the past, at a local business location (conference room).									

<p>1. LEED New Construction vs. LEED Existing Buildings</p> <ul style="list-style-type: none"> What are the differences between these (2) types of certifications? What are categories of points to be awarded? Review examples found of LEED (NC & E) certified projects and what are actual things done to achieve the points that can apply to our project? Find costs associated with each <p>2. Energy Star Participating Contractor</p> <ul style="list-style-type: none"> What are the benefits to the client, to work with an Energy Star Participating Contractor for the remodel or new construction? What does it take to become an Energy Star Participation Contractor? What are examples of things that are done to achieve the Energy Star rating for the project? Find costs associated with each <p>3. IRS Tax Credits for Energy Efficient Practices</p> <ul style="list-style-type: none"> Review the DSIRE resource- what is it, etc.? What IRS credits are available for our client for energy efficiency measures taken? How does the process work? Find costs associated with each <p>4. Remote Wall Construction Building Techniques</p> <ul style="list-style-type: none"> Review Resources- What is remote wall construction? What are the pros & cons of this type of construction? Find construction details associated with this construction Find costs associated with this construction 	<p>5-6. Low-Cost Remodeling Option</p> <ul style="list-style-type: none"> Using the paper copies, begin by sketching low-cost remodeling options for the client After instructor approval, transfer the information to either the AutoCAD or REVIT file Find estimated quantities and costs associated with the proposal(s) <p>7-9. New Construction Option</p> <ul style="list-style-type: none"> Begin by establishing a building program After instructor approval, begin sketching a new building on this existing lot Transfer the information to either the AutoCAD or REVIT program Find estimated quantities and costs associated with the proposal(s) <p>10. New Real Estate Options</p> <ul style="list-style-type: none"> What comparable buildings/locations are available within the city? Why should they consider selling & relocating? Cost/Size comparisons Detailed building program Detailed narrative of how this new location fits the building program Architectural drawings of proposed new building
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Appendix A:

This final project assignment provides choices for the students on content topics, in alignment with UDL Principle III: Provide Multiple Means of Action and Expression (the “how” of learning).

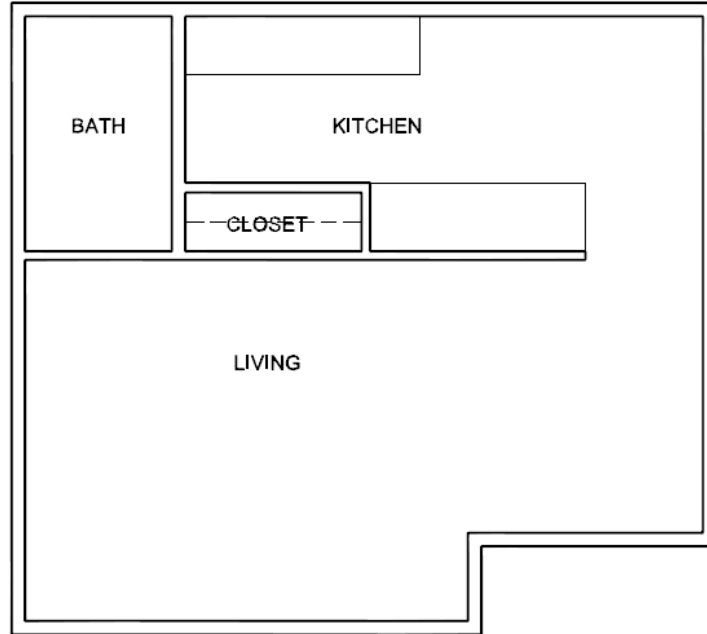
GIVEN: Floor Plan, to be printed: $\frac{1}{4}''=1'-0''$

DIRECTIONS:

1. Download and save file to your folder as "A1-AutoCAD"
2. Open the file and in Model space, adjust the plan to include the following:
 - doors- min: closet, bathroom, entry
 - windows- min: 3
 - bathroom- min: sink, toilet
 - kitchen- min: sink, ref, range
 - furniture- min: 1 sofa
 - exterior dimensions
3. In Paper Space- format the sheet to print on ANSI B, label all titleblock information per architectural standard.
4. Drop box the file by the established deadline.

Note:

- Make sure to use appropriate layers
- Ask questions as you go and take detailed notes for future reference
- Remember there is always more than one way to do things, but we have industry standards to follow.



1 FLOOR PLAN 2
A1.0 SCALE: $\frac{1}{4}'' = 1'-0''$

SCHEMATIC AUTOCAD EXERCISE
DIMENSIONING, USING DESIGN CENTER,
VIEWPORTS & SCALES

AEC-237-00X
ARCHITECTURAL TECHNOLOGY

DATE: XX-XX-XX
REVISED:
DRAWN BY:
YOUR NAME

SHEET NO.
A1.0

Appendix B:

This sample AutoCAD exercise is used to assess computer drafting skills of the AEC-237 Architectural Technology students within the first week of the term. This exercise is replicated in the introductory REVIT exercise.

Building Exercise

Recreate your AutoCAD floor plan A1.0 using REVIT. Make sure to provide the following:

Part 1: Due

Exterior Walls:	Home, Build, Wall, Wood 2x6 (Need to create this)
Interior Walls:	Home, Build, Wall, Wood 2x4 (Need to create this)
Windows:	Home, Build, Window, You choose type
Exterior Doors:	Home, Build, Door, You choose type
Dims:	Annotate, Dimension, Aligned Dimension Style: 1/8" (Need to create this)
North Arrow:	Annotate, Symbol, Load, Annotations, North Arrow 1
Section Marker:	View: Section: Building Section

We will be printing Sheet A1 on 11x17 with accurate title block information:

- Project Issue Date: Today
- Client Name: ARCH TECH
- Project Number: AEC-237-00X
- Project Name: REVIT INTRO
- Author: YOUR NAME
- Checker: GR

Note: Within print settings: select printer, select the A1 sheet to print, click on setup and change paper size to 11x17 paper and zoom to 100%

Additional Notes:

Appendix C:

For each introductory BIM assignment, a written description is provided with directions for completion and posted on the course CMS, in alignment with UDL Principles I: Provide Multiple Means of Representation (the “what” of learning).

My Home > Architectural Techn...

Glendali Rodriguez

Print Settings

Changing the location of components

Edit Topic Bookmark More Actions

Previous Next Exit

2. Computer Resources

- 1. AutoCAD
 - 1. AutoCAD 2010 Setup
 - 2. Setting up a viewport
- 2. REVIT handouts
 - 1. REVIT shortcut keys
 - 2. REVIT setup
- 3. REVIT Videos
 - 1. REVIT Startup
 - 1. Working with Components
 - 2. Changing the location of components
 - 3. Setting up a sheet for printing
 - 4. Fitting crop region and item title on a sheet

3. Week 1

4. Week 2

5. Week 3

6. Week 4/5

- 1. Assignments
 - 1. REVIT A1
 - 2. REVIT A6
- 2. Resources
 - 1. A1 REVIT Handout
 - 2. A6 REVIT Handout
 - 3. Drawing the Grid

Appendix D:

For each BIM introductory assignment, an on-screen video tutorial is created and posted on the course CMS, in alignment with UDL Principle I: Provide Multiple Means of Representation (the “what” of learning). The content tool bar, along the left of the CMS screen, shows the weekly organization of postings.

Grading Rubric

Architectural Technology

Name:

Section:

Date:

Assignment: REVIT Intro

Sheet A1 Drop box and Printed Copy- Recreation of A1.0 AutoCAD exercise

<u>Pts.</u> <u>Possible</u>	<u>Categories</u>				<u>Pts. Total</u>
7.5	Composition:	Printed to scale (3) No overlapping text (symbols, titles, dimensions, etc.) (2.5)	Content Arrangement & Grammar (2)		
	<u>Floor Plan:</u>				
6	Dimensioning:	Overall	Change In Shape	Openings	Walls
10	At a min: (To recreate A1.0)	Furnishings- sofa Bathroom- toilet & sink Kitchen- ref, sink, range, countertop		Doors (3) Windows (3)	
1	Notes:	Dimensions to Stud or Finish Framing, 2x6 walls (if not dimensioned)			
2	Markers:	North Arrow	Section (with item number and page number)		
3.5	Title Info (.5 each):	Name Course Sheet Number	Section Drawing Title	Original Date Item Title	
30					

Appendix E:

For each course assignment, a detailed grading rubric is provided on the CMS explaining how the points will be earned. Once graded, the rubric comments and score demonstrate areas for improvement. Providing clarity of expectations is fundamental to UDL.

Commercial Building Exercise Continued (Part 2)

Reference the attached drawings of a commercial building and posted REVIT videos. Using REVIT, replicate the exercise and make sure to provide the following.

Part 2: Due

Foundation:

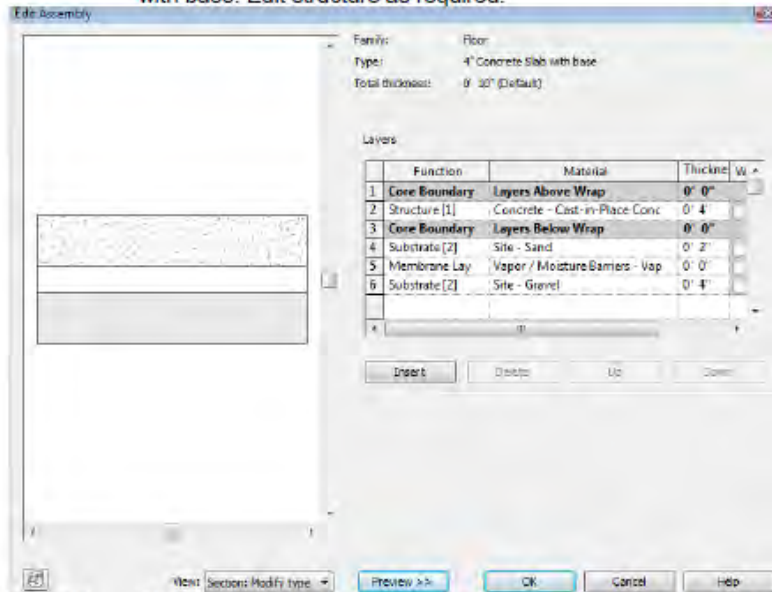
T.O. Slab view: Home Toolbar-Wall: Foundation 18" concrete (has to be created). Depth: T.O. Footing; Use the finish face exterior option to draw the foundation below the wall. Check your section view to verify accuracy. Make sure detail is set to "fine" in order to see assembly materials

Footings:

Foundation View: Structure Toolbar- Foundation-Wall
Select 36" x 12" from drop-down choices; Click on the foundation wall and footings will be placed centered and span full length below the walls.

Floor Slab:

Home, Build, Toolbar- Floor. The screen should go "grey" in sketch mode. Select "Pick Walls" and pick the inside outline to the walls
Click on floor properties- edit/new- duplicate- rename as 4" Concrete Slab with base. Edit structure as required:



Floor Slab Cont'd:

Click Apply and OK. Click Finish floor along the top of the toolbar.

Answer No to: Would you like the walls that go up to this floor level to attach to its bottom? **Answer No to:** Would you like to join geometry and cut overlapping volume out of walls? Check your final work in the 3D and section views

Roof:

T.O. Beam view: Home, Build- Roof- Roof by footprint-Pick Walls- Extend to wall core should be selected- Click on roof properties- select Insulation and Metal Deck- edit/new- duplicate- rename as 8" Insulation on Metal Deck. Edit structure as required:

Appendix F:

For each BIM assignment, a written description accompanies video tutorials and the grading rubric posted on the course CMS. This supplements in-class presentation and discussion.

Project Coordination Using Cloud-Based BIM Computing in Education

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ABSTRACT

Autodesk BIM 360 Glue cloud-based clash detection software was incorporated in the curriculum for a graduate level course on Building Information Modeling (BIM) in construction management at the University of Florida's M.E. Rinker Sr., School of Building Construction. Students were given access to the cloud-based management system for their group projects so that they could use it to conduct coordination on their project models. They used the service to upload their individual models and have them assembled in one federated model in the cloud. The students then ran the BIM 360 Glue clash detection functions on their merged models to determine conflicts, tracked those conflicts using markups and notified the appropriate group members in charge of those disciplines. This study discusses the benefits and challenges of using cloud-based coordination by graduate level Construction Management (CM) students at UF learning the fundamentals of BIM. Metrics were also collected throughout the process to determine the impact of using BIM 360 Glue on student performance and learning outcomes.

Keywords: BIM, Construction Education, Curriculum, Coordination, Cloud Computing

1. INTRODUCTION

Building information modeling (BIM) has become a necessary process in this new era of construction. From the change to electronic file transfers all the way down to tracking the smallest details in the design, it has expanded the way the AEC industry collaborates to exchange information. Consequently, having the required technical skills to create, extract and understand the abundant amount of information in a building information model is necessary for individuals looking to advance in the construction industry, particularly construction management (CM) students entering the workforce. Acquiring and developing such skills can be achieved through various resources. However, merely having the technical computer skills does not guarantee the smooth execution of BIM on a project. Rather, the ability to collaborate with other group members using new technologies can be the main driver behind successful BIM execution.

Collaboration is essential to ensuring the efficient and successful execution of construction projects in today's industry. Many construction organizations have chosen to take a BIM approach to their new projects as the industry continues to push the BIM adoption laggards forward. In order for these organizations to succeed in their new ventures, they must set long-term goals through the creation of a BIM Execution Plan (BEP). This plan documents the responsibilities and expected deliverables of each group member on a project and serves to organize the seamless transfer of information on BIM-assisted projects. It often lists the naming convention standards for models as well as due dates for each part of the project and how the information will be transferred. Furthermore, as BIM relies heavily on information technologies, it is only logical that collaboration is beginning to move to cloud-based services. With more organizations taking that approach as well, it is necessary to expose CM students to what will be the future of BIM.

2. BACKGROUND

In 2012, 74% of U.S. contractors had adopted BIM in some form within their organizations (McGraw Hill 2012). As a result, a new breed of construction professionals is developing in the AEC industry (Uddin and Khanzode 2013). To try and adequately prepare CM students for such change, university curriculum is slowly evolving. BIM integrated coursework is replacing traditional computer aided drafting, plan-reading, construction drawing and even project management courses in many construction management programs across the country. Ahn et al. (2012) surveyed recruiters of 100 construction companies to examine industry perceptions of the key competencies required for construction graduates. Of the 14 competencies identified: leadership, collaborative skills, technical computer skills, and communication were all noted. BIM curriculum when delivered in the right context can help reinforce all of these skills and create more well-rounded construction professionals. Additionally, Uddin and Khanzode (2013) noted the impact that BIM has had on traditional construction roles and the emergence of new career roles like the Design Manager and BIM Engineer. Thus, not only are BIM skills valuable for construction grads, they are necessary in fulfilling the new career paths that the industry requires. Finally, in addition to the technical and collaborative skills required of students, it is imperative that CM students also understand the global nature of construction projects (Becerik-Gerber et al. 2012). New delivery methods allow for project teams to work virtually and collaboratively in geographically dispersed locations; thus technologies such as cloud computing, sensor networks, stateless web services and semantic web are becoming critical parts of BIM management and must consequently be introduced in the academic environment (Underwood and Isikdag 2011).

Simulation of virtual team collaboration has been attempted by a number of academic institutions thus far (McCuen et al. 2011; Becerik-Gerber et al. 2012; Poerschke et al. 2010). This is perhaps one of the most valuable ways to reinforce the collaborative problem-solving and leadership skills required of CM grads during BIM-enabled coordination. To assist with this collaboration, cloud computing is one of the many ways BIM is being delivered in the industry as well as the classroom. Cloud computing is the ability to access and store information on a remote server or computer through the Internet (Griffith 2013). With the advent of this technology, users can now process information on a high-end computer device without having the high expenses associated with it. The only drawback to this alternative is that it depends heavily on Internet connection and speed; the higher the speed of the connection, the faster the processing of the information. Moreover, users can free up more disk space on their local computers, since all the data is stored in a remote terminal.

One of the main uses for cloud computing is the ability to collaborate with different users on any type of project. The different team members can access the shared information and adjust it as needed. This service has scaled collaboration to a much faster and more efficient level. Construction project teams can view the required data instantly and changes are made on the spot. In an effort to adjust to the new approaches of projects using BIM, this powerful tool has been frequently adopted by members of the construction industry. The service aids the project to progress more efficiently leading to a higher rate of success.

Several construction software companies and providers are beginning to provide such services. However, Autodesk, one of the leading software companies in the world, released a cloud-based service that stands out. The service is called BIM 360 Glue® and is designed to work smoothly with the company's existing suite of BIM authoring products. The service allows users to export their current Revit® models to the cloud and start collaborating instantly. The only step required before that is setting up access and user privileges for the other project team members. The service is advertised as a revolutionary tool in the field of construction information systems. Although models in the cloud cannot be edited or altered, users can view and interact with the properties of all objects in the model. The models in the cloud act as a screenshot of the built model at a given point in time. Any changes in the model will have to be uploaded to the cloud again to be visible to all users.

In order to expose CM students to this new method of collaboration, access to such a service must be made readily available to them. Autodesk® has always been a strong supporter of the education

community by providing educational versions of all of their software to University students free of charge. Therefore, BIM 360 Glue® set up and access were seamlessly delivered to students through email invitations from the class instructors who were given administrative rights to the class cloud node.

3. TEACHING METHODOLOGY

3.1 Overview

A graduate level Construction Information Systems course (BCN 6785) has been offered on a yearly basis to students at the University of Florida's M.E. Rinker Sr. School of Building Construction for several years now. It has successfully provided students with a leading edge in learning construction technologies and the essential skills required to master the technical aspects of BIM in the construction context. Moreover, students are given a glimpse of the difficulties and challenges faced when coordinating BIM projects. The exposure to such challenges has produced a better understanding of BIM processes and has been proven to graduate professionals capable of taking over leading BIM roles in the construction field.

BCN 6785 first provides students with fundamental modeling and analysis skills in programs such as Autodesk Revit® and NavisWorks®. Later, they are exposed to other software like Vico Office and Synchro to further their understanding of BIM's applications. In addition, students learn to export and import from other construction project management software like P6 and Microsoft Project in order to integrate with existing construction curriculum.

At the completion of the semester, students are required to submit a group project that is worth 40% of their total course grade which presents applications of all of the learned software skills in the course. This high-grade percentage reflects the required amount of effort to produce such a project and is set to encourage the students to be more engaged in the process. The project requires students to build a model in Autodesk's Revit® based on the furnished construction documents of an existing UF campus facility. The model must follow the details in the provided construction documents in addition to following the naming convention of the different components in the model in accordance with the UF BIM standards. Project groups are also asked to submit a formal BIM Execution Plan (BEP), a 4-D animation of the estimated construction schedule, and a formal presentation of the project describing the benefits, challenges, and lessons learned throughout the semester. As part of their BEP deliverable, students are required to outline the roles and responsibilities of each group member, including the assignment of a group leader who must serve as the model manager.

In the Spring of 2013 semester, there were seven project groups created consisting of 5 to 6 students. The students were assigned to groups by course instructors based on their previous academic and professional background and experience. The group assignment was intended to balance the level of expertise in each group; students with field experiences of different disciplines were grouped with those that had previous modeling knowledge. Moreover, groups assigned larger more complex buildings were given more group members to accommodate the difference in workload. The key objective of the group project component is to expose students to the challenges of group coordination. This way, students will not only learn the technical skills required for BIM, but also the difficulties that lie in organizing and managing the different portions of the model that were created by different persons with different expertise, skills, work habits, project commitment, personal schedules, etc. The assigned buildings used for the group project were of various sizes and scopes as shown in Table 1. The size and complexity of projects were taken in account when assigned to groups in addition to grading adjustments. Students were to be graded on: quality of the model, accuracy of the model, consistency of naming conventions and presentation of their work.

3.2 Students' Coordination

Groups were expected to submit one federated model of their assigned building at the completion of the semester. The workload required to produce such a model was expected to be divided equally among group

members. This was tracked through their group BEP. Each group was required to submit an execution plan detailing the various duties of each group member in addition to a tentative schedule of completion for each task. That document was used to adjust the grades of the individual group members after grading the project as a team. The students were given an introductory lesson on BIM planning and were given a sample BEP from an actual project. Although it was left for the students to discuss and decide how the project was to be divided amongst them, it was suggested that each member handle a portion of the building that included all of the different building systems. This would ensure that each student was capable of building the architectural, structural and MEP systems of any model, which was a main learning objective of the course and an individual requirement of the hands-on software-based final exam.

Table 1. Spring 2013 semester group project facilities modeled

Building Type	Stories	Size	Scope of work	group size
Research lab building 1	6	140,000 SF	New Construction	6
Research lab building 2	6	140,000 SF	New Construction	6
Graduate business building	4	70,000 SF	New Construction	5
Campus library	3	78,000 SF	Expansion and renovation	5
Law school building	2	40,000 SF	New Construction	5
Student activity center renovation	2	48,000SF	Expansion and renovation	6
Student gym	2	41, 000 SF	Expansion and renovation	6

As coordination is crucial to the success of BIM-assisted project, students were introduced to Autodesk’s BIM 360 Glue®. A demonstration was given in class showing the detailed steps of how to use the services which covered: publishing models to the Glue, merging the different models of the same project together, generating a clash detection report in the cloud and sending and receiving coordination notes. Group members were sent an invitation by course instructors which granted them access to their specific project. To aide administrative privileges, the different group members were given access the same project in the cloud but were not granted access to other groups’ projects. An overview of the coordination workflow which was used by instructors and students of BCN6787 is described in Figure 1.

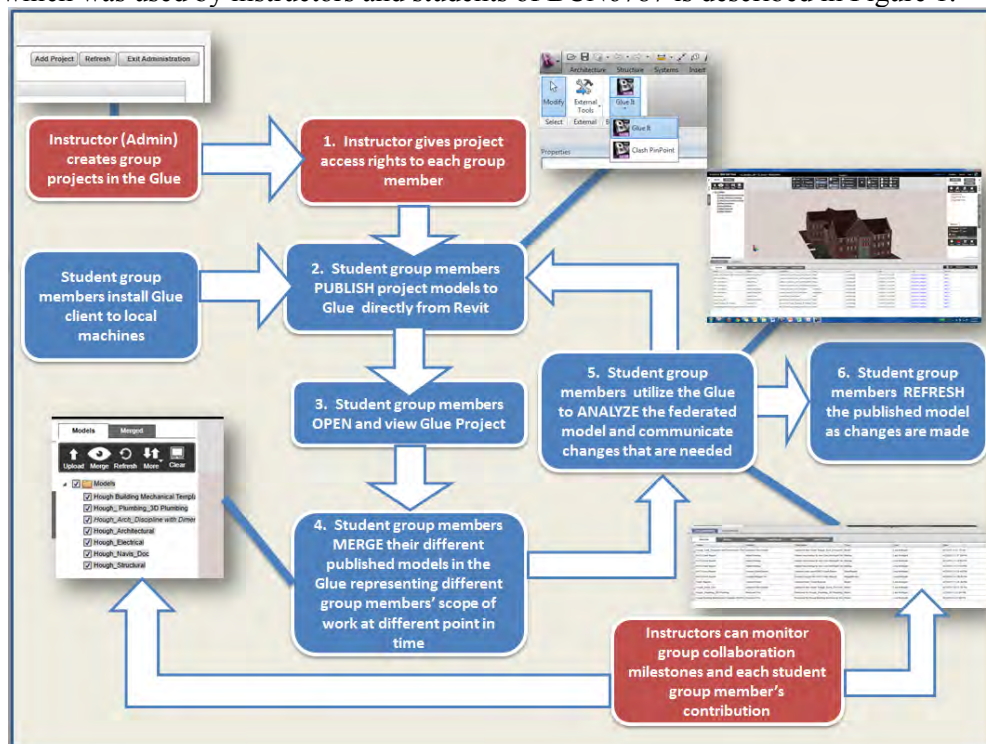


Figure 1: An overview of the BIM 360 Glue workflow

Emphasis on using the cloud-based coordination service was a large part of the project. Students were asked to describe their work to the entire class at the end of the semester in a formal presentation which had to include a description of the coordination method followed using BIM 360 Glue®. In addition, each group was asked to give their opinion of the service and how it helped them during the modeling and analysis process.

4. RESULTS

4.1 Learning Outcomes

All groups completed, submitted and presented their projects on time. The quality of the delivered models were excellent; exemplifying the skills and progress that students acquired throughout the course. However, the main objective of this study was to measure the success of cloud-based computing on BIM project coordination and to determine if it improved student learning outcomes. Figures 2 and 3 show two sample models of student projects which were coordinated using the Glue.

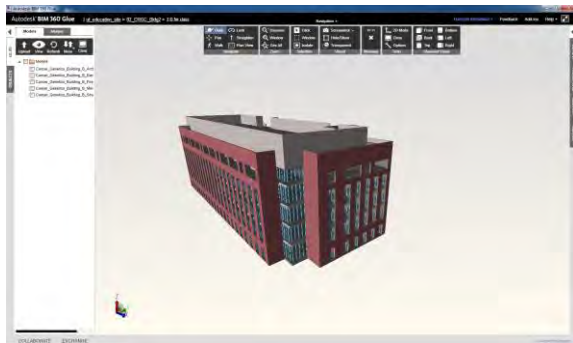


Figure 2: Student model of campus research lab

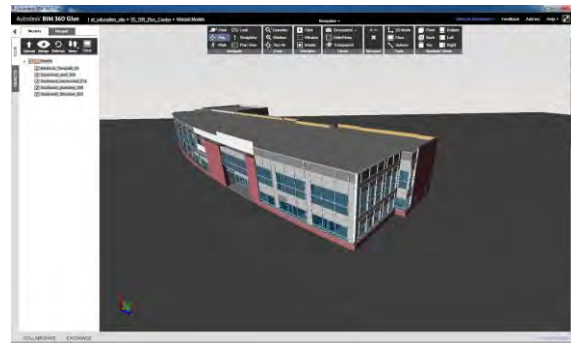


Figure 3: Student model of campus library addition

The groups used BIM 360 Glue® to coordinate their projects and the feedback about the service was very positive. The service allowed different members of the group to “glue” their portions of the model throughout the process and make adjustments accordingly. Having the latest models from each member is very important in making sure the process is efficient and positive. To assist this, BIM 360 Glue® alerts the users if a newer version of a model has been uploaded. This way, all members have access to the latest parts of the project at all times.

The main feature of the service used by the students was the ability to send coordination notifications to individual users responsible for a particular part of the model. The designated model manager of the group often used this feature by checking the accuracy of the different portions of the model and making sure that they fit together while avoiding clashes in the process. The model manager was then able to highlight or create a markup for a certain discrepancy and send a notification along with a saved marked-up viewport to the responsible user (group member) for a fix. After the adjustment of the issue by the individual, that portion is uploaded again and re-merged into the federated model in the Glue. The model manager would then check the same issue and see if it had been fixed. Otherwise, another notification was sent with further clarification. This dynamic way of coordinating on a micro level allowed the students to be more efficient, productive and engaging.

The second feature used by students in BIM 360 Glue® was the ability to access to the project, run a clash detection test and generate a report in the cloud. The other group members could then access this report, which reduced the time required to resolve the clashes of the different models. Instead of each group member having to acquire the different disciplinary models and then exporting them to Navisworks and running the clash detection test, group members could easily access the stored report in the cloud and highlight relevant clashes on the spot. Figure 4 shows an example clash highlighted in the model. This also

made it really easy for the model manager to coordinate with group members about the different clashes by highlighting them and sending notes with the attached clash to the relevant group member to fix.

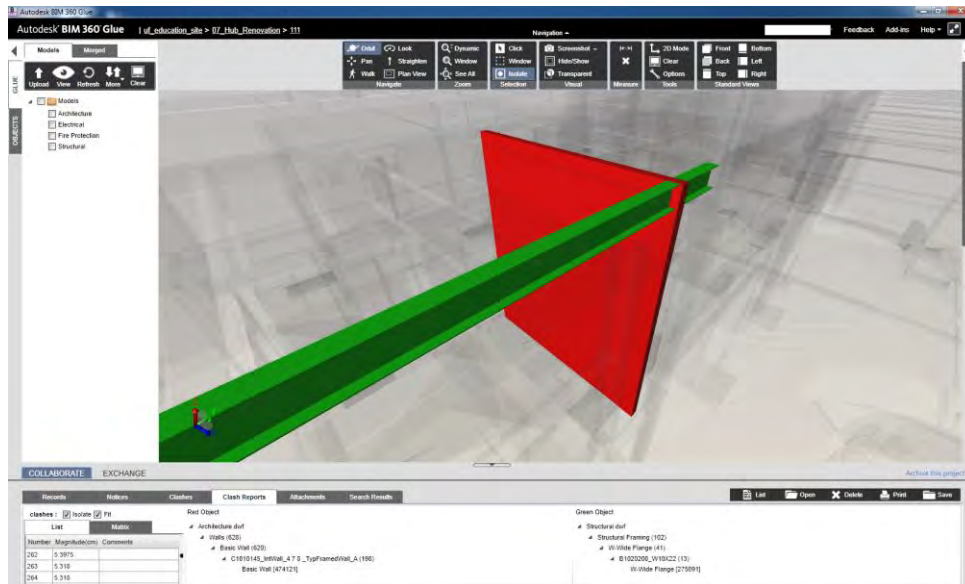


Figure 4: A highlighted clash in the cloud

One of the most useful features in the BIM 360 Glue® cloud service is the ability for group members to see a log of every activity that occurred on their project. This log indicates all members’ activities of uploads, reports and notes. Moreover, the log has a time stamp that enables users to know when each activity happened. This proved to be very helpful, especially for model managers to see all members’ activities and ensure each project participant contributed equally. It also helped course instructors to monitor the level of involvement by each student and adjust grades accordingly. In addition, the activity log cut down the time required to look for specific information. By scrolling through the log, group members could find and open previous clash detection reports. Members could also find and open created and sent notes that would take them directly to the note’s relevant viewport in the model. Figure 5 shows an example activity log shown to the user within the Glue.

Model	Subject	Description	Type	User	Date	Link	Mail To
Hough_Arch_Discipline with Dimension	Uploaded New Model	Uploaded new model 'Hough_Arch_Discipline.dwg'	Model	Lisa McKnight	5/7/2013 11:32:18 AM	Copy link to clipboard	Mail To
0423 Clash Report	Added Markup	Added new markup to view 'Lisa McKnight'	Markup	Lisa McKnight	4/23/2013 11:37:56 PM	Copy link to clipboard	Mail To
0423 Clash Report	Added Markup	Added new markup to view 'Lisa McKnight'	Markup	Lisa McKnight	4/23/2013 11:35:05 PM	Copy link to clipboard	Mail To
0423 Clash Report	Added Markup	Added new markup to view 'Lisa McKnight'	Markup	Lisa McKnight	4/23/2013 11:33:04 PM	Copy link to clipboard	Mail To
0423 Clash Report	Created Clash Report	Created clash report '0423 Clash Report'	ClashReport	Lisa McKnight	4/23/2013 11:26:46 PM	Copy link to clipboard	Mail To
0423 Clash Report	Created Merged File	Created merged file '0423 Clash Report'	MergedModel	Lisa McKnight	4/23/2013 11:26:36 PM	Copy link to clipboard	Mail To
Clash Reports	Created Folder	Created folder 'Clash Reports'	Model	Lisa McKnight	4/23/2013 11:26:36 PM	Copy link to clipboard	Mail To
Hough_Harris_Dec	Uploaded New Model	Uploaded new model 'Hough_Harris_Dec.dwg'	Model	Lisa McKnight	4/23/2013 10:32:33 PM	Copy link to clipboard	Mail To
Hough_Plumbing_3D Plumbing	Removed File	Removed file 'Hough_Plumbing_3D Plumbing.dwg'	Model	Lisa McKnight	4/23/2013 5:22:09 PM	Copy link to clipboard	Mail To
Hough Building Mechanical Template 41	Removed File	Removed file 'Hough Building Mechanical Template 41.dwg'	Model	Lisa McKnight	4/23/2013 5:21:56 PM	Copy link to clipboard	Mail To

Figure 5: A record showing the time-stamped log of all project’s activities

4.2 Challenges

As it is always the case with any new software or service, students had a slight difficulty adjusting to the new interface of the BIM 360 Glue®. The learning curve was not very steep but it raised a few concerns from some students in the beginning. The interface transition for students from Revit® to Navisworks® was somewhat overwhelming. However, the transition from Navisworks® to BIM 360 Glue® was much smoother. Even though the navigation of the 3D model in Glue was slightly different, the generated

viewports from the clash detection test made it much easier to navigate. In addition, when any member of a group saved a viewport and added a note to it, it became easily accessible by the other group members with hyperlinks. The hyperlink for each saved note can be accessed through the log or sent via email.

Another issue that was encountered by some students was the inability to access the service. Invites to access the service were sent to all students via their university email. The students then would click the hyperlink in the email and input their Autodesk's student login ID and password. That would enable them to download and install the client on their local machines, access the service and use it as dictated by the administrators. However, for some students, the service was inaccessible even after the invite was resent. The issue was discussed with Autodesk and was corrected with the next BIM 360 Glue® upgrade.

Since students have access to a limited educational version, they missed out on some of the additional features that could have enhanced their experience with the BIM 360 Glue®. The "Exchange" tools, which allowed users to send RFIs and respond to them in a construction management interface, was not available for educational use. This was due to the lack of a project management systems such as ConstructWare and CMiC. In addition, not all students got to experience the BIM 360 Glue® on the iPad, which further enhances the power of the service. The iPad app allows users to access the models on the go and review the designs outside the office.

5. CONCLUSIONS

The exposure to the BIM 360 Glue® service introduced the students to the latest advancement in BIM deployment technology. It also helped them in understanding how projects are coordinated in the industry. The new cloud-based collaboration eliminated, to an extent, the need for several follow-ups about the nature and location of each issue in the design. That leads to a more efficient way of coordinating the project since more time can be spent in addressing the issues rather than trying to comprehend them. Students' understanding of the collaboration efforts and challenges in projects adds another dimension to their core BIM competency skills. Moreover, understanding the process of collaboration using a cloud service gave them a cutting edge advantage in the job market place over other graduates.

The BIM 360 Glue® service has introduced students to more efficient ways of collaboration on BIM projects. It allowed for a faster communication about very specific issues in the model that can be accessed instantly by the relevant users. For example, instead of looking for the relevant sheet and grid locations associated with an issue, the user is taken directly to the issue in a saved viewport by clicking a hyperlink in their email. More importantly, group members can coordinate more effectively by seeing how each member's portion of the model fits with the entire project in the cloud. This eliminated the need to gain the latest model files from each member just to visualize how they all fit together. The service also helped students be more productive in terms of completing their own parts of the model without interrupting the others. In previous years, students used several means of collaboration to complete the project which included using one model that is saved in a shared cloud-based folder. The method was unproductive and led to many overwrite issues where two users tried to access the same model simultaneously; after the first user saved his or her work, the second users save would overwrite all the progress that was achieved. This overwrite issue was resolved with BIM 360 Glue® since no actual modifications were done in the cloud but rather on their local drives and then uploaded.

The BIM 360 Glue® was received very positively by the students. The model managers in particular found it extremely effective in coordinating with the other group members about any changes or issues. One of the students commented on the BIM 360 Glue® saying: "*Collaboration between disciplines is easy, and cloud access from anywhere is key.*" Another student added: "*BIM 360 Glue represents the next generation of BIM Coordination.*"

ACKNOWLEDGEMENTS

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REFERENCES

- Ahn Y., Pearce, A. and Kwon, H. (2012). "Key competencies for U.U. construction graduates: industry perspective." *Journal of Professional Issues in Engineering Education and Practice*, 138 (2), 123-130.
- Becerik-Gerber, B., Ku K., and Jazizadeh, F. (2012). "BIM-enabled virtual and collaborative construction engineering and management." *Journal of Professional Issues in Engineering Education & Practice*, 138 (3), 234-245.
- Griffith, E. (2013, 03 13). What is Cloud Computing? Retrieved 06 16, 2013, from PC Magazine: <http://www.pcmag.com/article2/0,2817,2372163,00.asp>
- McCuen, T., Speidel, E. and Liu, J. (2011). "BIM for virtual construction: a collaboration of three universities." *Proceedings from the 2011 BIM Academic Symposium*, Washington D.C.
- McGraw-Hill Construction (2012). "The business value of BIM in North America: multi-year trend analysis and user ratings (2007-2012)." *McGraw-Hill Construction SmartMarket Report*, McGraw-Hill, New York.
- Poerschke, U., Holland, R.J., Messner, J. and Pihlak, M. (2010). "BIM collaboration across six disciplines." *Proceedings from the International Conference on Computing in Civil and Building Engineering (ICCBE)*, Nottingham, UK.
- Uddine, M. and Khanzode, A. (2013). "Examples of how BIM can enhance career paths in construction." *Practice Periodical on Structural Design and Construction*, DOI: 10.1061/(ASCE)SC.1943-5576.0000171.
- Underwood, J. and Isikdag, U. (2011). "Emerging technologies." *Editorial in Construction Innovation*, 11 (3), 252-258.

Planning and scheduling curriculum integration of BIM with industry input

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Abstract

Architect-Engineer-Construction (AEC) employers have been expecting that construction management program graduates have working knowledge of Building Information Modeling (BIM). Project Planning and Scheduling is the key to understand scheduling processes and efficient resource allocations in successful projects. Introducing students to intermediate level of computerized scheduling techniques in Primavera P6 will train them to develop, monitor and update project schedules. BIM is introduced later in the semester through a visualization tool (Synchro software) helping students to understand even better scheduling techniques. By implementing a visualization tool, they have the chance to identify the sources and impact of changes and interruptions on the schedule and to compare and contrast the appropriateness of scheduling techniques for varying construction operations. A model along with a technique of linking 3D modeling to the Primavera schedules is presented as the last topic before the semester concludes with project case studies. Practical realities of Planning and Scheduling projects are reinforced during class support by a variety of guest lecturers including project managers from local industry. They deliver their materials, advising students on best practices, the day-to-day challenges they face, and the importance of the skills within their practice on the jobsite. The paper will present sample tutorials of the curriculum throughout the semester, how the content was developed and how industry input was vital to further develop on the real-life, practical skills. To meet evolving industry needs, a framework for creating and incorporating more BIM related content in the coursework linked with cost estimating will be discussed.

Keywords: Curriculum integration, Planning and Scheduling, BIM education, Primavera, Synchro

Introduction and background for the Planning and Scheduling class

Project Planning and Scheduling course is a study of the fundamentals and techniques of Planning and Scheduling for construction projects. Topics include bar charts, critical path method using arrow and node networks, precedence networks, cost-time trade-offs, PERT, resource leveling and management, updating schedules during construction, introduction and practice to project controls and intermediate level of computerized scheduling in Primavera (P6) version R8.2. BIM is introduced later in the semester through a visualization tool helping students to understand even better scheduling techniques.

Just before the mid semester, students are introduced to the use of computerized scheduling techniques using P6 to develop, monitor and update project schedules. This implementation focuses on hands-on learning approach through a combination of lecture and laboratory sessions. The practical realities of Planning and Scheduling construction projects are reinforced during the weekly class supported by a variety of guest lecturers including construction project managers, engineers and/or CEOs of local industry companies. During the lab session, students use structured tutorials, supplemented with videos, to implement scheduling

skills like in real-world case scenarios. Group work is always encouraged and submission of small assignments is required periodically to assess the students' software learning curve.

The customized tutorials provide a step-by-step guide to the software, allowing for self-paced learning and providing easy access for future reference. Also, industry professionals deliver their materials, advising students on best practices, the day-to-day challenges they face, and the importance of the skills within their practice on the jobsite. By implementing a visualization tool, students have the chance to identify the sources and impact of changes and interruptions on the schedule and to compare and contrast the appropriateness of scheduling techniques for varying construction operations.

To incorporate the BIM curriculum pertaining to the class topics, Synchro software is employed. A schedule from a simplified project scenario is deployed into a schedule visualization and analysis procedure and presented to the class. The paper will present sample tutorials of the curriculum throughout the semester. It will also describe how the content was developed, and how industry input was vital to further develop on the real-life, practical skills. A framework for creating and incorporating more BIM related content in the coursework to address industry needs will be discussed and recommended for further development.

Tutorials development in P6, R8.2 for project schedules – instance of software functionality in project samples

Multiple scheduling tools such as Primavera, MS Project, Suretrack, etc. are now available and used in the construction industry. Primavera was opted for the curriculum due to its advanced features in scheduling, high industry usage and its interoperability with BIM tools. In order to ease the learning of Primavera P6, version R8.2, a couple of tutorials were developed along with an instructional micro-project example directly applied into the software to exemplify its schedule manipulation and utility. The tutorials objectives are three-fold in nature:

- Develop deeper understanding of P6 software features and functionalities
- Understanding how important it is to develop a valid schedule for later 3D visualization and modeling
- Retaining knowledge for post-graduation times

Opening an Existing Layout

- You can choose from a number of layouts to present your project from different perspectives.
- This allows you to spend more time managing projects instead of repeatedly preparing the displays.
- You can create your own layouts or use global layouts provided by your company.
- Now you will open an existing layout.

From the Layout Options bar

Figure 1. Excerpt of instructions from Tutorial 1

The tutorials are created to progress the knowledge and understandings of the software as students advance on their learning curves in this class. The assignment was designed as a semester long project and the tutorials were meant to help them navigate the software and prepare their schedule in P6. A hypothetical project scope was presented to students with some logic of activities, constraints and available resources. The idea is to help students visualize what activities to create, how much time to assign for the activities, what would be a logical sequence etc., thereby combining all the concepts taught in the class. It was made clear to the students from the beginning that they were not expected to be “Primavera” experts, but they would benefit from the working knowledge of the Primavera at least to an advanced-beginner level or an intermediate level user in this class.

There are mainly four graphic tutorials with specific instructions and illustrations that students are encouraged to go through during the lab sessions in order to become familiar with the software and perform hands-on practice exercises presented in their assignments. The tutorials were created to explain the concepts and software features in a graphical manner. They are self-guided and self-explanatory:

- Tutorial 1: Navigating the Project Management module in P6 (excerpt in figure 1)
- Tutorial 2: Creating a new Project (create a brand new project, navigate the Projects window, view and modify information on the project details tabs, importing and exporting files, etc.)
- Tutorial 3: Creating a work-breakdown structure (WBS), implementations, multiple levels on WBS hierarchy, assigning responsible managers to WBS elements (figure 2)
- Tutorial 4: Adding and assigning activities to the project; manipulation of activity data

The students are encouraged to go through them in groups of two-three individuals and helping each-other in their respective teams.

In tutorial 4, students have the opportunity to delve deeper into the software, such as changing an activity calendar assignment or adding a notebook topic to an activity. Opportunities are made available to further study the schedule and activity resource loading in the software, thus providing students with a better understanding on schedule updates and the influence of activity resources on schedules.

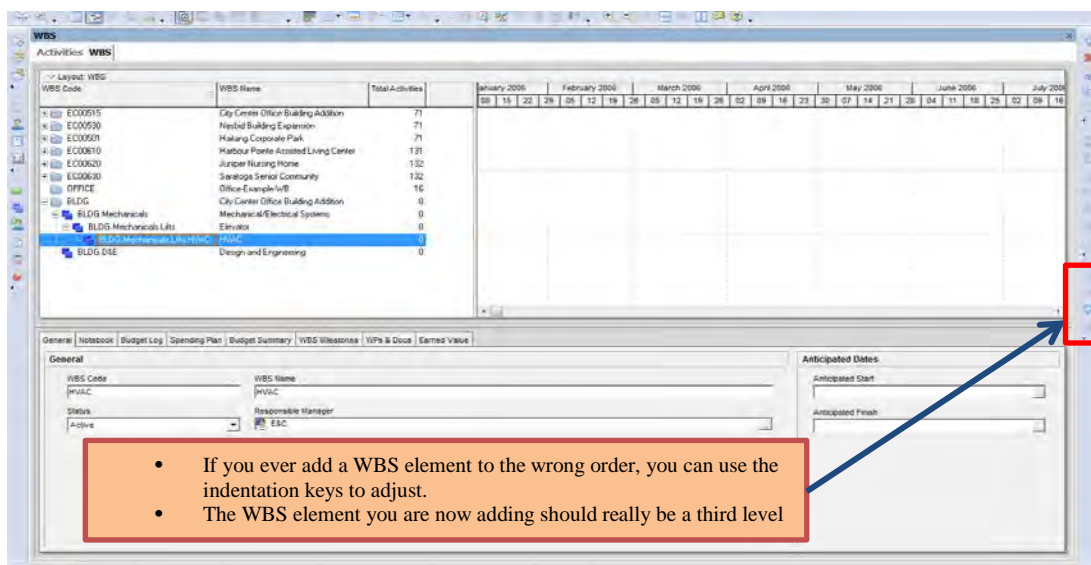


Figure 2. Excerpt of instructions from Tutorial 3

It was observed on every class via assessments that several students fail to retain the skill as they were not using the software applications constantly and were not replicating its use for other classes or assignments. This lack of continuity was complemented with theoretical knowledge and through hands-on exercises developed for in-class use.

BIM integration into Project Planning and Scheduling class – a continuous strategy

BIM has gained significant drive in a relatively short period of time in the construction industry. Therefore, the authors are assured that there will be an increased demand for individuals with BIM skills and knowledge. Young et. al. (2009) revealed that almost 50% of the industry is using BIM and its adoption will increase, expecting positive returns from the use of BIM technology. Utilizing BIM technology has major advantages for construction. It allows for an efficient construction process that saves time and money and reduces the number of RFIs and field coordination problems, compared to traditional practices. Perhaps the most important point is that the use of BIM technology improves the ability to integrate all members of project team together by communicating ideas more effectively and provides competitive advantage for innovative firms. Large companies have already realized that the BIM methodology offers the intelligent solution for the integration of the many disciplines involved in the building design process (Gallelo, 2008), one of them being project scheduling. Other academic authors are exploring areas such as integration of lean construction, sustainability, and BIM into undergraduate construction management scheduling courses (Hyatt, 2011).

Keeping up with this growing industry trend, acceptable training in BIM is needed for successful adoption. Cook states that highly skilled cross-trained staffs with both construction and IT skills are required to implement a BIM (Cook, 2004). The lack of BIM practitioners as a major bottleneck to move the industry into the BIM age is identified by Hartmann & Fischer (2008). Young et.al. (2009) also indicates that the lack of adequate training is the greatest challenge to adopting BIM in the construction industry. In parallel with industry, construction programs in higher education need to find a way to weight the BIM technology in their courses so that students can make themselves familiar with it before entering the construction field.

Many construction companies have created new BIM positions to make the transition from current practice to the one that integrates BIM technology into their organization. These individuals who are BIM “know-hows” are internally called with various titles such as BIM Construction Officer, BIM Coordinator, BIM Project Manager, Integrated Construction Engineer, and Virtual Construction Manager (Barison & Santos, 2010). Regardless of its title, they are responsible for implementing BIM on their projects while balancing traditional operations duties. Therefore, it is certain that there is a strong need for more individuals with experience and knowledge of BIM technology and Virtual Design and Construction (VDC) practices (Gallelo, 2008). However, there is still limited availability for BIM education since BIM is not formally acknowledged as the ACCE and ABET accreditation criteria. In their program curricula, students might not be interested in taking more courses for BIM education as long as they are not necessary to graduate. There is a need in Construction Management programs to quickly address the adoption of BIM in their curriculum.

BIM technology enables users to be successful in scheduling, estimating, coordination of trades, even laser scanning and many more. However, without an established workflow, the results can be inconsistent or worse than expected. There are many processes involved in BIM adoption. Fundamentally, the use of BIM requires planning and preparation to ensure successful

implementation. These plans and processes change over time based on lessons learned and developments in technology. There are a wide variety of processes and steps for each virtual construction case study. Having standards in collaboration with the industry may be essential, particularly when incorporating BIM technology into Construction Management classes. This is one of the challenges to incorporate Synchro as BIM software into the Project Planning and Scheduling class. As mentioned earlier, BIM education in Construction Management programs should mainly focus on larger industry trends and processes, not just on the software. Also, version of the software will change over time so it is required to be constantly introduced into the class with new examples. However, a basic software understanding is also important. Therefore, for an efficient integration, the program needs to instill the following:

1. BIM development, uses and interactions among various project stakeholders
2. Sort of BIM software – adoption of Synchro features and capabilities for Project Planning and Scheduling class
3. Basic software understanding of selected applications
4. Management skills to facilitate the BIM process
5. Understanding of the trades/systems that frequently contribute in the BIM process (if available time)

Currently, the construction industry expects Construction Management graduates to be aware of what BIM is and be exposed to the basic application and uses of the different BIM tools. This would be the main reason why construction firms have their own in-house training to meet their business necessities. Evidently, as time passes, BIM will become fully integrated into the undergraduate curriculum. This paper is an endeavor to incorporate a BIM curriculum into a developed Planning and Scheduling class with help of industry input. As the industry continues to realize more and more benefits from using the BIM technology, it is imperative that it should be required in Construction Management curriculum. Similar to other industries, BIM will eventually become a standard for all construction businesses.

Synchro integration as a BIM tool for Planning and Scheduling class

From instructor’s experience of the past semesters, surveys, assessments and conversations with the industry, it is apparent that integrating VDC activities as a central idea in construction education requires some necessary changes in existing teaching methods and philosophies.

Table 1. Course offerings to integrate BIM in the Construction Management program

Course name offered in the Construction program		Topics covered	Future application of these topics for understanding BIM
<u>Year I</u>	<i>Computer Concepts; Computer Applications</i>	- Geometric modeling to represent operations of construction equipment (i.e. a crane, etc.) - some form of 3D visualizations	Requirements for productivity, efficiency and safety
<u>Year II</u>	<i>BIM for Construction Management</i>	- Software applications taught in the program: Revit Architecture, Revit Structure, Navisworks, etc.	Learning BIM as a tool for future use
<u>Year III-IV</u>	<i>Project Planning & Scheduling</i>	- Project Scheduling methods such as Bar Charts, CPM and PERT, AOA, AON and CPM techniques; resource allocation and time/cost trade-off and analysis - Software used: Primavera P6 R8.2, Synchro for linking schedule to a model and simulations	Creating schedules, and simulating activities in a project examples

This is illustrated in Table 1 as course offerings (i.e. Project Planning and Scheduling) that should offer the inclusion of BIM and/or BIM applications and practices in the topic. The construction schedule developed in P6 can be integrated into a 3D building model with Synchro software. Students should be capable of linking P6 schedule with a Synchro 3D model to visualize a project schedule. This way a 4D planning and scheduling is generated by adding schedule and resource data to a 3D building model. In this process, students also learn the use of BIM for scheduling and work sequencing.

Example of project schedule modeled with Synchro

Towards the end of the semester, an example is presented to the class on how a schedule is applied to a model in Synchro. The basic-intermediate level training tutorial is presented to the class and a dedicated time is allocated for a stand-alone lab session. After the skills are mastered, small groups of students are encouraged to investigate on their own more advanced capabilities of Synchro modeling. The training tutorial is self-paced and students are conducted and assisted to experience the exchange of model information in their small teams.

Importing Data is one of the most important skills explained in this session, like: Importing Schedules, Data Date, Gantt Display, Importing 3D Models, Importing DWF Model Files, 3D Resources Creation, Import the Equipment Models (figure 3). 3D views, window navigation and axis indicator (view cube) is also taught for 3D visualization and manipulation of the model.

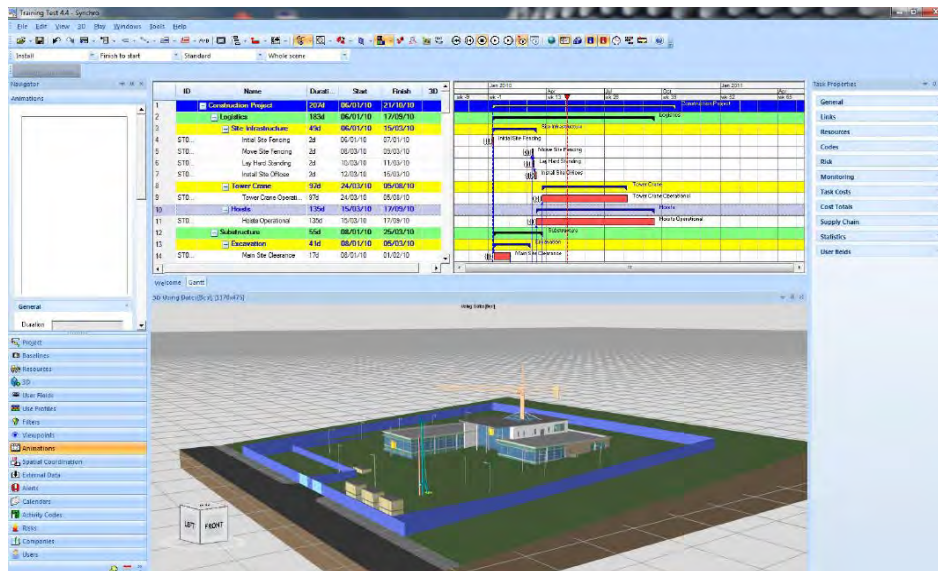


Figure 3. Importing equipment model in the 3D model

After linking 3D to the project schedule and synchronizing 3D files, another important concept presented is synchronizing the schedule and baselining. This is performed in a couple of steps:

- Explaining baselining in Synchro
- Synchronizing schedules (and the rules for synchronization)
- Basic rules for scheduling software
- Compare Baseline (using 3D views, see figure 4)
- Creating an AVI of the comparison

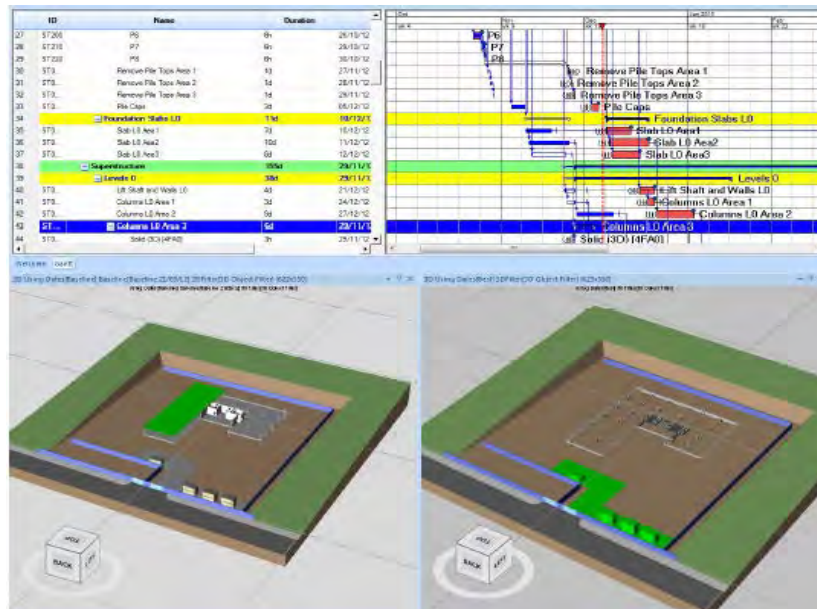


Figure 4. Comparison of baseline with updated schedule through 3D views
 Figure 4 illustrates the focused time for the baseline being moved through the project in order to review how the new schedule falls behind the baseline schedule. The focused time for the baseline schedule is behind that of the new schedule as the excavation has yet to be completed compared with the updated schedule which is part way through this construction phase. The students now have the opportunity to grasp the capability of the Synchro program as project management tool equipped with great visualization features that can help Project Managers to take and adopt their daily decisions. Also, work of trades and/or subcontractors and their implications in the overall schedule can be discussed and analyzed between team members.

Conclusions and discussion

The link between academia and industry is a critical component in bringing industry guest speakers to providing students with an understanding of quintessential topics in Planning and Scheduling and to leading them into BIM exercises and applications. The importance of the industry lecturers is relevant when the next generations of construction professionals are not actually the BIM experts but they are capable of applying their BIM knowledge to their daily job tasks. The case scenarios in Planning and Scheduling through assignments, schedule creation and model visualization example help accentuate the initiative to use technology and BIM as a way of making the building process more enjoyable and learning-effective in the same time. One of the major areas that have yet to be employed into the program's curriculum is to develop even more on the BIM applications through Synchro tool in this class and other BIM software in other critical classes, like Cost Estimating, etc. A much more dedicated time to Synchro may allow for more emphasis and a better illustration of the 4D components and simulations of construction activities in the industry projects. Learning outcomes are assessed through individual Lab sessions reports in P6 and group work submitted in P6 and Synchro.

Nevertheless, the 15 week-semester limitation is a great impediment to extend the class content to allow for extra applications given the fact that understanding projects scheduling required a blended and slow-progressing learning of theoretical, practical, applied topics and a visualization of knowledge gained throughout this process only at the end. In the near future, the industry input and participation in the classroom environment will be of critical significance in

continuing to move the curriculum forward to reflect thoroughly or even to exceed the current state of construction and help incorporate areas that have yet to benefit from the possibilities of the new BIM applications.

The constructed model along with a technique of linking 3D modeling to the Primavera schedules is presented as the last topic before the semester concludes with few project case studies. The practical realities of Planning and Scheduling construction projects are also reinforced during class support by guest lecturers including construction project managers from local industry. They deliver their materials and advise students on best practices, the day-to-day challenges they face, and the importance of the skills within their practice on the jobsite. The presented customized tutorials allow for self-paced learning, as well as knowledge to access for future reference, enhancing students' scheduling software and BIM learning curve. To meet evolving industry needs, a framework for creating and incorporating BIM related content in the coursework linked with cost estimating is further approached. The cost estimating and quantity take-off instructor is also interested to participate in a cross-curriculum experiential class in order to link better inter-related topics of estimating, scheduling and project management. This combined class attempt is envisioned by author to be supervised by industry experts that have been involved with BIM capabilities for cost estimating for a while. Some local contractors may have used the BIMs for establishing gross estimating figures early on. If that is the case, students may get an initial understanding of linkages between a scheduling technique through a project management procedure and a rough cost estimate for a building in design phase and their multiple implications. They may be exposed under this cross-curriculum exposure to the relevance of when a contractor begins to effectively leverage the BIM to the benefit of the stakeholders' team. In the same time they may better understand the real benefits that may results from the contractor's approach to an integrated project delivery method.

REFERENCES

- Barison, M. B. & Santos, E. T. (2010). An Overview of BIM Specialists. Proceedings of the International Conference on Computing in Civil and Building Engineering, ICCCBE, Nottingham University Press. Tizani, W. (Editor).
- Cook, C. (2004). Scaling the Building Information Mountain. CAD User AEC Magazine, Vol. 17(3) - March/April 2004
- Gallelo, D. (2008) "The New 'Must Have' - The BIM Manager", AECbytes Viewpoint #34, 17/01/08. Available online: http://www.aecbytes.com/viewpoint/2008/issue_34.html [last accessed: 09/24/13]
- Hartmann, T. & Fischer, M. (2008). Applications of BIM and Hurdles for Widespread Adoption of BIM. The 2007 AISC-ACCL eConstruction Roundtable Event Report, April, 2007, New Orleans, LA
- Hyatt, B. (2011). A Case Study in Integrating Lean, Green, BIM into an Undergraduate Construction Management Scheduling Course. 47th Associated Schools of Construction Annual International Conference Proceedings
- Young, N. W., Jones, S. A., Bernstein, H. M., & Gudgel, J. E. (2009). The Business Value of BIM: Getting Building Information Modeling to the Bottom Line. McGraw-Hill Construction SmartMarket Report, New York.

ENCOURAGING STUDENTS INVOLVEMENT THROUGH STRUCTURED DISCOVERY LEARNING STRATEGY IN TEACHING BIM COURSES

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ABSTRACT

This paper discusses whether educators can encourage students' involvement through structured discovery learning strategy in teaching Building Information Modeling (BIM) courses. The research results will help instructors in the areas of the teaching and research of construction graphics, design and simulation, especially BIM, to engage and encourage potentially talented students to be BIM experts. Little is known about how to configure or increase effective research engagement among the US students through students' involvement and structured discovery learning strategy. In the paper, the authors built a conceptual model of structured discovery learning strategy (SDLS) in teaching BIM courses based on previous successes from literatures. Then the authors implemented the SDLS conceptual model in the into 2 BIM courses, collected student evaluations, and analyzed the evaluation results. The authors explored how architecture/engineering/construction programs can engage and develop students through the learning of BIM courses and improve their interests in modeling and design. In this paper, the authors also investigated how the proposed method helped students to build up knowledge and sustain interest. Particularly, the proposed method will allow participants to contribute to the projects at levels that are appropriate for their developmental stages and to begin to explore the areas of BIM study.

Keywords: Students Involvement, Structured Discovery, Learning Strategy, BIM

1. INTRODUCTION

Structured discovery learning (SDL) emphasizes on grasping the basic structure of a subject. When using SDL method in teaching, educators put the basic concepts, principles and specific research methods of a subject into teaching. When preparing teaching materials, educators need to pay attention to question conditions and assumptions. In class teaching, educators help students to verify those conditions and assumptions of the problems the students need to solve in class or of the projects they need to work on by themselves. Educators raise or design the problems and projects for students. Educators guide students to learn and collect relevant information. Students can find and solve problems through their own independent learning and thinking. Using SDL method, educators can help students to develop their abilities of learning and creativities.

SDL is a method for acquiring a set of cognitive problem-solving and perceptual skills by means of actively participating in the learning process (Nyman, 2001; Ryles, 2008). There may be many situations in which people use SDL. For example, a middle-school teacher may spend half of the class-time letting students read some novels which are different from the textbooks. When students meet some new words or difficult questions, they need to use dictionaries or ask each other to find answers. Different from

traditional teaching methods, the teacher may never answer questions directly. Instead, the teacher would give the students some tips. Then the students follow the tips to find the answers for their questions.

In this paper, the authors proposed to implement SDL in teaching Building Information Modeling (BIM) courses. BIM technology helps planning, organizing, motivating, and controlling resources to achieve specific goals, typically to bring beneficial changes or added values to projects. In the current form of undergraduate and graduate education, educators face the challenges of how to balance the contents of theories and practice and how to effectively teach practical details of modern information technology. In this paper, the authors described the student evaluations to the implementation of SDL in BIM courses. The survey results showed that through the implementation, students were able to experience a simulated process of using BIM in project management and understand BIM technology better.

2. PROBLEM STATEMENT

In the current education of BIM topics, one complaint about the exam-oriented teaching model is that students have no time to reflect on their favor issues. Using structured discovery learning (SDL) educators are able to improve teaching results by letting students dedicate themselves in learning through guiding the students to find the results.

The advantages of using SDL in teaching BIM topics include the following items: (1) It provides students chances to find the answers to their questions by themselves. The seeking process helps students to retain knowledge in their memory. (2) Different students together contribute to the processes of knowledge discoveries, which improves the flexibility of classes. The disadvantages of SDL include the following items: (1) It may not provide students with precise answers to their questions, which may even reduce the students' abilities to distinguish the right answers from the wrong ones. (2) If spending too much time on discussing and searching for answers to questions during class time, an educator is not able to complete class efficiently and students cannot enjoy quiet study time (Hannafin, Land, & Oliver, 1999).

3. LITERATURE REVIEW

Jerome S. Bruner, an American psychologist, advocated the concept of discovery learning in early 1960s. Discovery learning is a learning method that students acquire knowledge and develop thinking through rediscovering the way the knowledge formed. It is an initiative learning process (Clark, 1979). Mettler (1990) applied discovery learning to help visually-impaired people to make optimal use of remaining vision for travel in unmodified environments. Through some structured discovery learning (SDL) exercises, the visually-impaired people can improve their abilities of pattern recognition, depth perception, central acuity, and central field vision with peripheral field loss. Ryan and Robert (2009) implemented SDL to athletic training education. With minimal guidance, they helped new trainers to develop injury assessment skills and appropriate rehabilitation plans. The students needed to know how to make judgment about an injury situation and how to protect themselves from emergencies without guidance on assessment and rehabilitation from the instructor.

Discovery learning in higher education helps learners to understand difficult concepts and retain long-term information (McDonald, 2011). Learners of higher education may explore in countless environments including virtual ones (Ormrod, 1995). Saab (2005) found that there existed significant relationships between communicative and discovery activities. Communicative activities occur with discovery activities most of the time. To make good use of discovery learning, people should concentrate on means to augment communicative and discovery activities that are related to positive learning outcomes. In a discovery learning process, students draw on their own past experiences and existing knowledge to discover facts, relationships, and new truths. Students interact with the world by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments. As a result, students may be much more likely to remember concepts and knowledge discovered on their own.

Examples of discovery learning include: guided discovery, problem-based learning, simulation-based learning, case-based learning, incidental learning, among others (Bruner, 1961).

In SDL, students acquire a set of cognitive problem-solving and perceptual skills through actively participating in the learning process. Students discover a satisfactory solution to structured problem situations. The cognitive techniques employed in the solving process must be reinforced and generalized with the assistance of the instructor. Then students transfer the skills to novel situations and the duration of knowledge retention is extended (Dean & Kuhn, 2006; Adelson, 2004). However, studies indicated that SDL model was not always effective or efficient. In a case study by Clark and his colleagues (Clark, Kirschner, & Sweller, 2012), it clearly demonstrated that when teaching new information or skills, step-by-step instruction with full explanations worked best. Alfieri (Alfieri, 2011) discussed that unassisted discovery learning did not benefit learners, but assisted discovery learning actually did help learners, which had same advantages as feedback, worked examples, scaffolding, and elicited explanations.

4. CONCEPTUAL MODEL OF STRUCTURED DISCOVERY LEARNING (SDL) STRATEGY IN TEACHING BIM COURSES

SDL is not limited to seek unknown things. It can be used to assist and guide people, with their own minds personally all the way, to acquire knowledge. In this pedagogical study, the authors designed the BIM class to allow students to learn and think independently, to seek self-discovered knowledge, and to master principles of BIM technology. The results showed that students obtained a sense of achievement because of the discovery process. Students learned to make their own knowledge systematic and structured. They were able to understand and consolidate learning contents.

In the following model of the SDL strategy, the model is mainly composed of the following process: master learning topics, develop vision, formulate hypotheses, test hypotheses, and develop summary. The aim is to develop learners' intelligence accompanying the cultivation of learners' emotion and learning attitude, using the main learning method of discovery learning. The structure of the SDL strategy teaching model is shown in the following diagram (Figure 1).

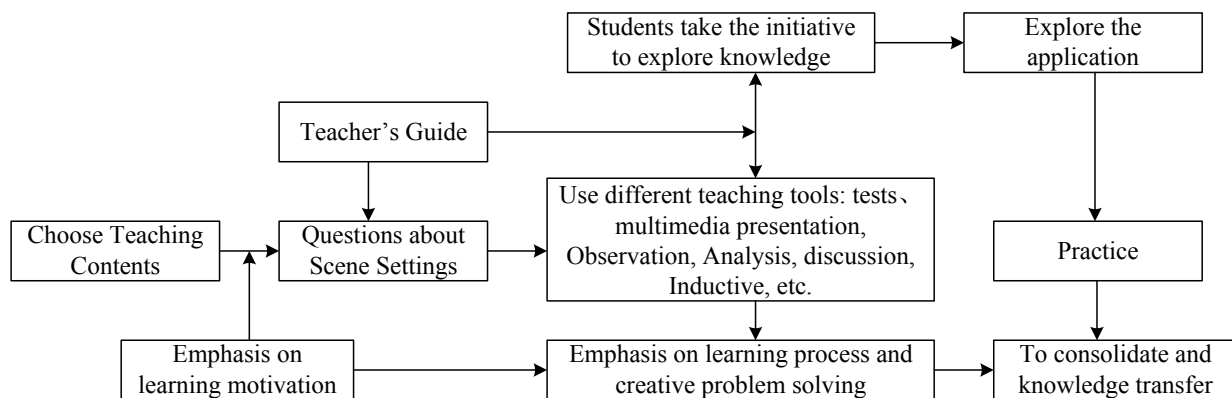


Figure 1: Structure of the SDLS teaching model

As Figure 1 shows, the first step is to choose teaching contents. Instructors collect the BIM project data and communicate with students. Instructors also design the steps of the BIM projects for students to follow and observe. The second step is about inquiry learning. BIM has important tasks in cultivating students' literacy in using 3D modeling skills to convey design ideas and maintain communication in project management team. Therefore, in BIM course design, educators implement the concept of "advocacy exploratory study" and encourage students to actively participate in the learning process. Once learning on the basic skills of BIM is over, instructors let students acquire knowledge in the activities of exploring new BIM models and help students understand the BIM working process in project

management. Students would gain knowledge through experiments, discussions, exchanges of experiences, and other activities. The third step is to use structured discovery learning (SDL) style in BIM project design. Instructors ask students to design a BIM project of their own. Students could use Internet to search for existing models and design three-dimensional building models. The purpose of this step is to establish a situation which is favorable essentials framework. Students collect materials around their mission. After students generally complete the previous three tasks, the fourth step starts. Instructors organize the BIM class to communicate and discuss the advantages and disadvantages of the BIM projects. Through discussion and collaborative learning, students are able to build conceptual design framework. Step three and four include open-end projects or homework assignments which will cultivate innovative ideas. For example, when an instructor discusses with students about how to build a house in an eco-efficiency or environmental-friendly way, the instructor can use an example of a successful BIM project with Leadership in Energy and Environmental Design (LEED) recognition. After the instructor analyzed the case study, students have two days to reflect the discussion and collect information about other implementations of combining BIM and LEED technologies. In the next class, the instructor discusses a homework assignment with the students. After the discussion, the students get better understanding of what they need to do on the assignment. Then the students can start working on the homework assignment.

5. IMPLEMENTATIONS OF THE SDL MODEL

When implementing the SDL model in a BIM class, the authors designed the BIM class according to the characteristic of BIM. BIM is a new tool used in the architecture/engineering/construction industries. It can create a virtual building before the actual project starts. BIM technology can also help to obtain an optimal solution from simulation, improve work efficiency, and detect interferences. The features of BIM technology include: visualization, coordination, simulation, and optimization. One author worked as the instructor for BIM classes. In the first step of implementing the SDL model in teaching BIM topics, the instructor educated students of the teaching framework, e.g. gave an overview of the BIM process and raised some questions according to the framework. Students answered the questions by team collaboration. The instructor discussed basic BIM functions and details with students. The instructor also designed the steps of the BIM projects for students to follow and observe. Figure 2 shows an example of the class activities the authors did for the first step.

In the second step of SDL model, the instructor listed all kinds of possibilities to the students. The possibilities created some degrees of uncertainties, which inspired the students to explore for the answers. The students needed to collect data and information, including examples of existing BIM models, to prove their conclusions. The students realized that BIM technology by its nature required teamwork. So in the teaching process, students could work in teams on a project. The students made groups, allocated job responsibilities, cooperated on the modeling and simulation process together, had discussion, and sought guides from the instructors. Students were encouraged to use analytical thinking to confirm their conclusions. They could also use deductive thinking and inductive way of thinking to solve problems. Figure 3 shows an example of the class activities the authors did for the second step. In the second step, the students learned all different formats of wall variations. They mastered the skills of creating walls from classroom learning, watching videos, and learning from each other.

In the third step of SDL model, the instructor asked the students to design BIM projects of their own. The project design was group work. The students used Internet to search for existing models and designed different three-dimensional building models. Figure 4 shows some examples of the student design. When implementing SDL model, the instructor paid attention to offer feedback information in a timely manner. To help students search for correct answers and increase their enthusiasm to the BIM topics, the instructor provided guidance to the learning process. The instructor gave the students appropriate time to reflect and think about the solutions to questions and guided the students to learn. With the instructor's help, the students were able to develop critical thinking skills and explore for knowledge with confidence. In the end of the third step, the instructor started asking the students to discuss the experiences they learned

through the entire SDL process. The students compared advantages and disadvantages of their own BIM projects. Through discussion and collaborative learning, students built the conceptual design framework.

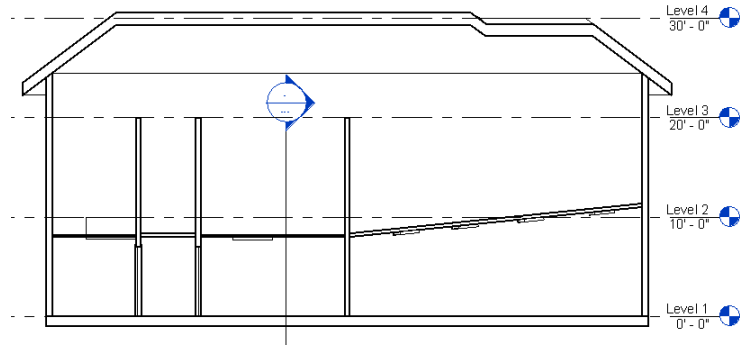


Figure 2: Example of the class activities in the first step of SDL: choosing teaching contents

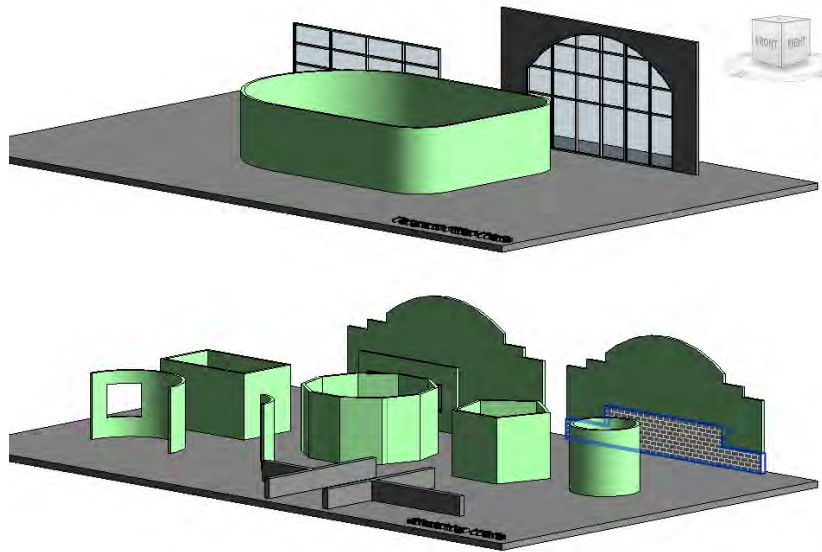
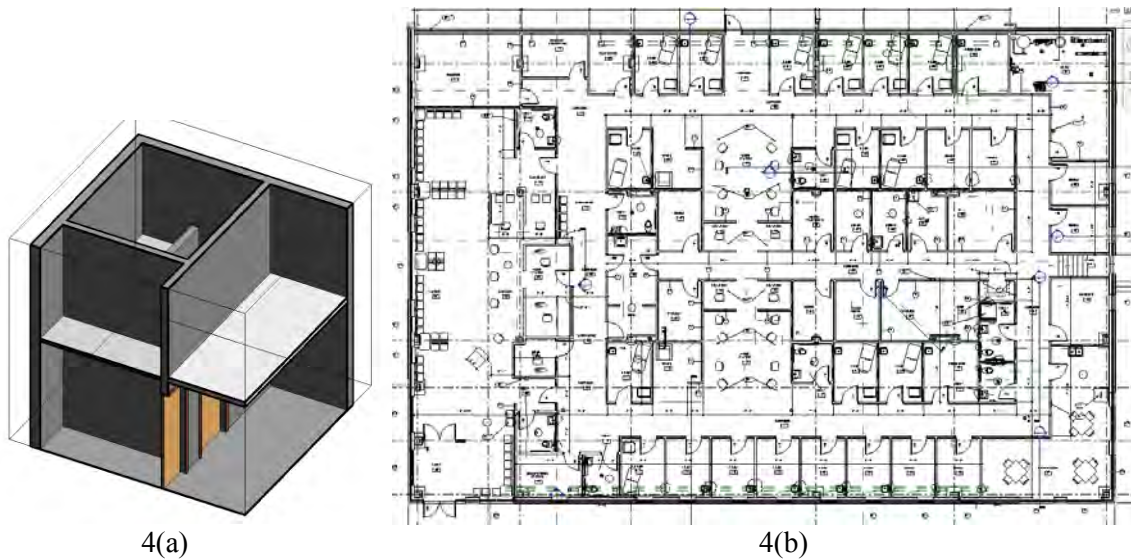
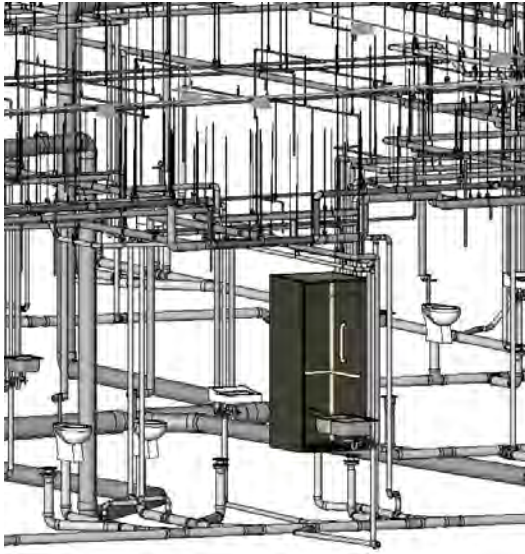


Figure 3: Example of the class activities in the second step of SDL: exploring for answers

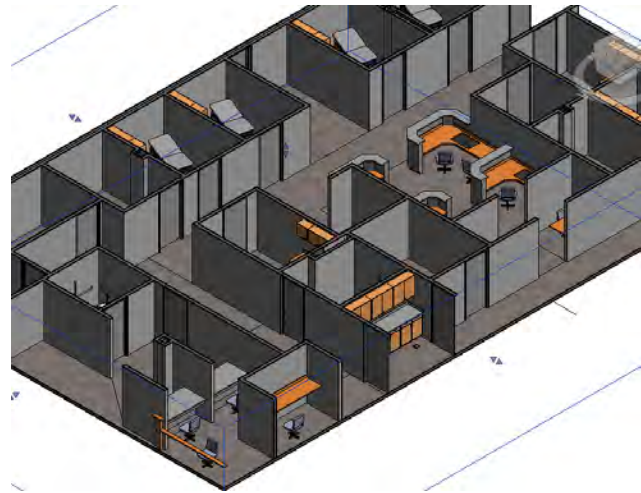


4(a)

4(b)



4(c)



4(d)

Figure 4: Example of the class activities in the third step of SDL: designing BIM projects

6. ANALYSIS OF RESULTS

The authors designed and implemented the SDL model in two BIM classes with 83 students. In order to assess the learning result, the authors designed and surveyed students' opinions with questionnaires. There were 9 questions in the survey questionnaire. Topics included BIM class teaching methods, teaching contents, improvements and suggestions. The students took participation in the survey voluntarily and anonymously. There were a total of 53 questionnaires filled out and sent back for analysis. The results of the survey were analyzed and listed below:

- Before taking the BIM class, 35.85% of the students had never heard of the technology; 50.94% of the students had heard the term; and the rest 13.21% of the students had very limited knowledge of the topic, including watching other people using the BIM technology.
- Out of the 53 students, 81.13% of them agreed that the objectives of BIM class were clear; but 18.87% of the students didn't agree with that.
- 64.15% of the students preferred to include case studies in the learning process of BIM topics.
- When asked about the most difficult aspect of learning BIM topics, 56.60% of the students ranked the software operation as the most difficult task. Other students considered lacking professional knowledge or not enough class time as the obstacles of learning BIM.
- Through the BIM study, 88.68% of the students agreed that they understood the operation of the software. The rest 11.32% of the students claimed that they mastered the BIM technology.
- After the BIM course, 56.60% of students were very interested in using BIM in their daily work in the architecture/engineering/construction industries, 34% of the students felt somewhat interested, 9.40% of the students were not very interested.
- For the question of "What do you want to learn most via the BIM class?", 62.26% of the students chose the practical application of BIM, 24.53% of the students wanted to learn the thinking process and technology of BIM, 13.21% of the students wanted to focus on the software related to BIM and no student showed interest to the software development of BIM system.

7. CONCLUSIONS AND FUTURE WORK

In this research, the authors found out that in discussing new BIM topics, training or teaching objectives were important to the achievement of understanding. The curriculum design of BIM teaching must highlight the professional features. Using SDL can help students to learn new knowledge actively.

One limitation of this research is the duration of the study. The authors only used the SDL model in two BIM classes and surveyed the teaching results from the students. Given enough time, the authors plan to study the influences of using the particular pedagogical model and in the experimental or practical teaching, such as internships, capstone projects, and graduate designs.

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REFERENCES

- Alfieri, L. (2012). Does Discovery-Based Instruction Enhance Learning? *Journal of Educational Psychology*, v103 n1 p1-18 Feb 2011. 18 pp.
-]Bruner, J. S. (1961). "The act of discovery". *Harvard Educational Review* 31 (1): 21–32
- Clark, C. (1979). Ausubel on discovery and verbal learning. *Educational Philosophy and Theory*, 11(1), 1-15. doi:10.1111/j.1469-5812.1979.tb00028.x
- Clark, R. E. Kirschner, P. A. & Sweller, J. (2012). Putting Students on the Path to Learning: The Case for Fully Guided Instruction, *American Educator*, v36 n1 p6-11 Spr 2012. 6
- Dean, D. J. & Kuhn, D. (2006). "Direct instruction vs. discovery: The long view". *Science Education* 91 (3): 384–397
- Hannafin, M., Land, S., Oliver, K. (1999). Open learning environments: Foundation, methods, and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models. A new paradigm of instructional theory Volume II* (pp. 115-140). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- McDonald, B. (2011). Self Assessment and Discovery Learning.
<http://www.eric.ed.gov/ERICWebPortal/detail?accno=ED521532>
- Mettler, R. (1990). An Integrated, Problem-Solving Approach to Low Vision Training, *Journal of Visual Impairment and Blindness*, v84 n4 p171-77 Apr 1990
- Nyman, J. S. (2001). What is Structured Discovery Learning?
<http://www.ncbvi.ne.gov/board/minutes/2006-minutes/2006-2-4/structured-discovery.html>
- Rachel Adelson (2004) Instruction vs. Exploration in Science Learning Monitor on Psychology APA Online, Vol 35, No 6
- Ryan, R. E. and Murray, S. R. (2009). The Use of Discovery Learning in Athletic Training Education. *Athletic Therapy Today*. July 2009, Vol. 14 Issue 4, p32-35. 4p
- Ryles, R. (2008). Structured-Discovery Learning: What It Is and Why It Works.
<https://nfb.org/images/nfb/publications/bm/bm08/bm0807/bm080708.htm>
- Saab, N. (2005). Communication in Collaborative Discovery Learning, *British Journal of Educational Psychology*, v75 n4 p603-621 Dec 2005. 19 pp

APPENDIX

Questionnaire for BIM class evaluation

Q1: Before you took the BIM class, your level of understanding of the BIM topics can be described as which of the following option?

- A. Thorough understanding B. Understanding C. A little understanding D. Know nothing about the topic

Q2: Whether the teaching aim of BIM is clear?

- A. Yes B. No C. Don't know

Q3: In your opinion, what kind of teaching method is better?

- A. Regular classroom teaching B. Structured discovery learning C. Don't know

Q4: What do you think is the biggest problem encountered in learning BIM?

- A. Not enough class time
B. Lacking Architecture/Engineering/Construction professional knowledge
C. BIM software operation
D. Other _____

Q5: Do you think that the length of each BIM class is reasonably arranged?

- A. Unreasonable B. In general, need improvement C. Reasonable

Q6: What's your degree of proficiency in mastering the BIM software, according to the teacher's explanation?

- A. I know what the software is and can use software to view a BIM model, such as Revit
B. I can use at least one software system to create a BIM model.
C. I am proficient with using BIM software.
D. I am very proficient with BIM software and can teach or train others.

Q7: After taking the BIM class, are you interested to do research in this area?

- A. I just want to know what BIM is.
B. I am a little interested.
C. I am interested in developing a research topic in BIM.
D. I am very interested and will consider becoming a BIM developer or modeler.

Q8: What do you want to learn most via the BIM course?

- A. The technology of BIM
B. The software related to BIM
C. The application of BIM in practice
D. The development direction of BIM

Q9: What courses do you want to learn besides the BIM class as auxiliary courses?

- A、 Engineering project management information technology and BIM
B、 Application cases of BIM
C、 Special application technology of BIM
D、 Tools and methods of BIM

TEACHING MODULES DOCUMENTING THE DEVELOPMENT OF A CENTER FOR VIRTUAL DESIGN AND CONSTRUCTION

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ABSTRACT

Virtual Design and Construction (VDC) is a process poised to play a vital and transformative role in construction education. Today, academic institutions face the challenge of physically and pedagogically integrating VDC into evolving curricula. This research explores the documentation process of a new VDC center at Colorado State University's Department of Construction Management. In particular, this paper provides a case study highlighting the educational opportunity provided by student participation in the transformation of an existing classroom into the Mortenson's Center for Virtual Design and Construction (MCVDC). This new Center provides an interactive and collaborative learning environment where students focus on modeling processes. In addition, students learned about the capabilities of specific modeling programs, and gained first-hand knowledge of and experience with the power of such tools and methods during design and construction. On a small scale, the physical design and construction of the Center itself serves powerful model of a BIM-enabled construction process. The Center is designed as a dynamic space, one planned to evolve with emergent technologies. As such, the project team carefully documented the construction process and developed two cross-curricula teaching modules for future use: laser-scanning and energy modeling using the Center as an illustrative case study of the current state of such processes. Student participation in the transformation of the small-scale physical facility promotes independent and peer-learning. This research highlights how the role of the students has evolved to become active participants and leaders in a new educational model. Collectively, implementation of such strategies can result in interactive, flexible, team-based, collaborative learning environments.

Keywords: Curriculum, Educational Integration, Collaborative Learning, VDC, BIM, Laser Scanning, Energy Modeling

1. INTRODUCTION

Research is expanding regarding the opportunity to leverage Building Information Modeling (BIM) in construction education. Several recent university studies, however, demonstrate dissatisfaction among students and educators with the advancement of technology-based curriculum and with the use of BIM in the classroom (Sylvester and Dietrich 2010; Sabongi and Arch 2009). Yet, BIM is poised to play a critical role in construction education. BIM experts agree that construction programs should include and prioritize "general introduction and knowledge of BIM" (Ahn et al. 2013). Research suggests that benefits of using BIM in undergraduate education include proliferation of integrated design, an accelerated design process,

added initial concept complexity, a more robust exploration of concepts, and an increase in collaborative and coordinated teamwork (Denzer and Hedges 2008; Hedges and Denzer 2008).

Significant obstacles exist to expanding the role of BIM in undergraduate construction education including numerous existing requirements, already full sets of elective courses, and lack of reference materials and established curricula (Sabongi and Arch 2009). To overcome some of these obstacles, integrating BIM across existing courses allows related concepts to be discussed in a way that reinforces its applicability. Such integration can help students to consider how these models serve as effective decision making tools and the importance of engaging in collaborative groups. To accomplish this goal, this paper presents the documentation process and curricula development for use in future courses based on the construction a new VDC center at Colorado State University's Department of Construction Management. In particular, this paper highlights an educational evolution based on student participation in and observation of the transformation of an existing classroom into the Mortenson's Center for Virtual Design and Construction (MCVDC). Thus, student participation in the transformation of a small-scale physical facility can be used to promote independent and peer-learning.

2. CENTER FOR VIRTUAL DESIGN AND CONSTRUCTION

The MCVDC is being built to foster collaboration among students and simulate on-site construction conditions of BIM enabled design and construction. This new Center provides an interactive and collaborative learning environment where students focus on modeling processes. In addition, students will have the opportunity to learn about the capabilities of specific modeling programs, and gain first-hand knowledge and experience of the power of such tools and methods in design and construction. The Center is designed as a dynamic space, one planned to evolve with emergent technologies.

The scope of project is the renovation of an approximately 28ft x 28ft classroom into a flexible computer-based learning laboratory for classes of approximately 20 construction management students. The remodel includes: demolishing existing drop ceiling, extensive MEP upgrades, refurbishing to include state-of-the-art equipment as well as plan tables and other construction-onsite-trailer related facilities. From a BIM perspective, the project provides a simple and effective case study since it is a basic, square room of sufficient complexity to be informative. As a result, to further the educational mission of the Center, the project team elected to use the process of redesigning and remodeling the room itself as an illustrative example of how BIM capabilities can be used on a project. While such a variety of BIM capabilities would not typically be used by industry on a project of this scale because it would lack sufficient return-on-investment, by engaging students the following BIM processes were implemented and documented: geometric modeling (using both manual take-offs and laser scanning) and energy modeling. Figure 1 shows a flow chart of the processes implemented and/or documented by students on the project.

The flowchart in Figure 1 describes the workflow of various activities and outputs related to the construction of MCVDC. These activities can be grouped into four main categories: 2D documentation; Laser Scanning; Revit and Energy Modeling; and Output documentation and comparison. In the diagram, work flows from top to bottom, and depicts how multiple, and, occasionally, redundant sources of information were documented during design and construction in the development of the teaching modules.

As noted, in industry, for a project of this scale and complexity (a remodel of a square room), the processes implemented are excessive. However, such processes were designed and implemented for the specific purpose of creating and testing the education module by mimicking the process of BIM-enhanced construction typically performed on significantly larger-scale, or more complex projects. In this way, the design and construction of this new Center provided a valuable test-bed. On a small scale, the physical design and construction of the Center serves as a powerful model of BIM-enabled construction. The project team carefully documented the construction process and developed two cross-curricula teaching modules based on the construction of the Center itself: laser-scanning and energy modeling.

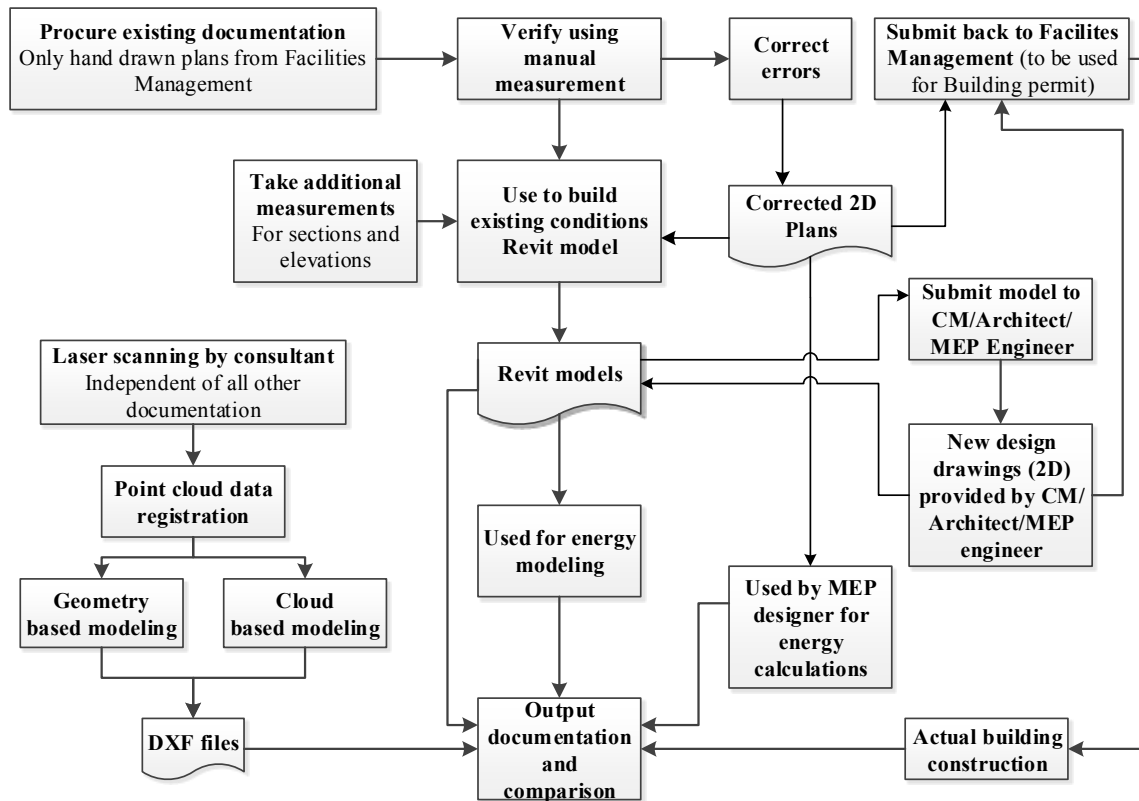


Figure 1: Process Model of VDC Center Documentation for Use as Teaching Modules

3. TEACHING MODULES DEVELOPED

Using the Center as an illustrative case study of the current BIM applications, the following teaching modules were developed during the design and construction of the Center for use in future coursework. Specifically, this paper aims to highlight how the role of the students has evolved to become active participants and leaders in the new educational model. Three students were involved directly in the 3D modeling, laser-scanning and energy modeling of the space. The teaching products developed were primarily annotated guides on how to use the computer models developed in teaching case studies. Collectively, implementation of such strategies can result in interactive, flexible, team-based, collaborative learning environments.

3.1 Laser Scanning - Teaching Module Development

The first phase in developing this teaching module consisted in creating a Revit model. This model was created using the following components.

- Basic architecture (generic walls, ceilings, floor and roof, elevation levels and annotations)
- Façade (finish materials, shape of exterior wall, roof details including parapet walls)
- Windows, doors and furniture (all custom components) – involves knowledge of building or modifying Revit Families to specifications. Involves specific measurement of windowsills, thickness of frame members etc.

- MEP components (mix of standard and custom fixtures) – Involves knowledge of MEP modeling and advanced spatial sense for correct placement of fixtures. Electrical system includes tying together fixtures and switchboard for load calculations

Given the relative simplicity of the project, the modeling process can be scoped to suit a full range student’s skill and comfort level with Revit. The model includes the existing and new design. Figure 2 and Figure 3 shows how the exterior and interior of the Revit models created, respectively.

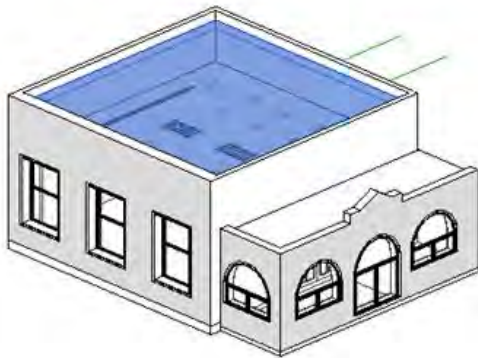


Figure 2: Exterior view of Revit Model generated of the space

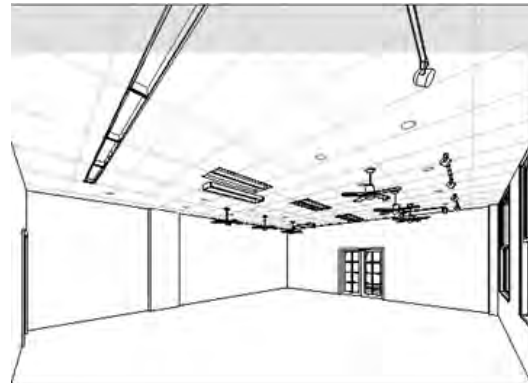


Figure 3: Interior view of Revit Model generated of the space

After a manual Revit model was created, a redundant yet illustrative process of laser scanning was performed. Several students observed and documented the laser scan of the classroom space, which was performed by an associate from Trimble. The following steps were implemented during the laser scanning: a) preparing the space; b) scanner setting and calibration; and c) capturing the data.

The space was prepared by removing the ceiling tiles so that the scanner could capture above-finished-ceiling MEP details. Furniture was not removed because scan data generated from furniture could later be deleted if necessary. Then, scanners were set around the room and calibrated. Setting up the scanner requires mounting it onto the tripod and adjusting the tripod’s height and level. The tripod’s height must be selected so that the scanner’s range of vision is not obstructed by furniture. In this project, five spherical targets were set up at various heights, somewhat equally spaced across the room. The location does not have to be exact as long as the targets are stationary throughout the process. For BIM coordination and integration into existing models, targets could be placed at survey points or grid intersections. Targets can either be mounted on magnetic surfaces using a strong magnet or placed on surfaces using a stand (as seen in Figure 4).



Figure 4. Targets set for laser scanning in the classroom to be retrofitted into a BIM lab.

Once the scanner and targets were set up, the scanner was calibrated. Parameters include: resolution, scan quality, and many others that determine the level of detail to be captured and the point cloud output quality. After the calibration of the scanner, the data was captured. The scanner shoots lasers at the rate of a million points per second in its entire angular range, while rotating slowly on a vertical axis in a “hands-off process”. The speed of rotation depends on the quality of the scan needed. In this case, the scan used took 9 minutes. The process was repeated five times by relocating the scanner with the tripod to 5 different locations across the room.

The laser scanning process produced “point-cloud” data for the area that has been scanned, one file each for each time the area was scanned. Next, these files need to be combined in a process known as Registration. In this case, five files were generated by the scanner. Trimble RealWorks software was used to perform the registration. Due to the project’s small size, auto registration was the best option for data processing. In Auto registration, the software looks for targets in all the point-cloud files and matches them automatically. The other option for registration is manually. If this latter option was used, the user would have to pick each target and assign it a consistent number throughout the point-cloud files. After targets are matched through the files, the software then blends the various point cloud files into a single project file. This process is known as registration. For this project, it took 10 minutes for the software to perform the registration process automatically. Figure 5 shows the model generated.

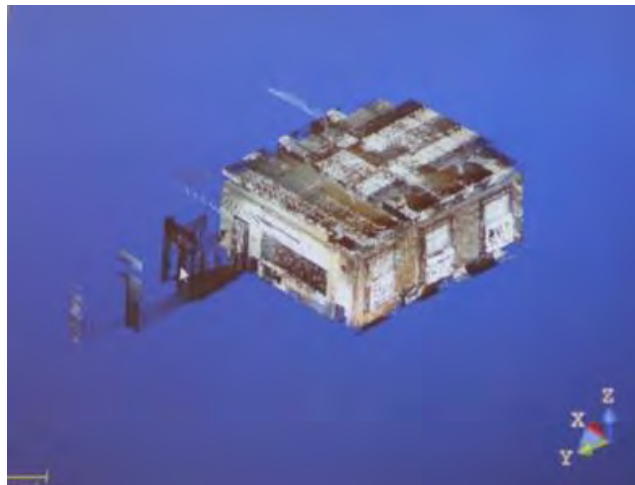


Figure 5. A registered point cloud of the classroom model.

The final phase was comparing the outputs. The comparison of outputs: three outputs, two DXFs closely related to each other and produced by laser scanning and one from Revit were spatially compared. To do this, The laser scan data was converted into DWG format, brought into Revit and visually compared.

In the teaching module, such comparison provides students a simple illustration of levels of accuracy, source of errors and allowable assumptions for each method. Such knowledge advances students understanding of how to choose a method and how/why to perform quality assurance / quality control (QA/QC) when implementing BIM on a project. Furthermore, comparison of files from different sources give students the knowledge of various file types and interoperability issues known to the industry.

3.2 Energy Modeling - Teaching Module Development

Following the generation and validation of the 3D geometric models, student also executed an energy model for the space. Using the manually created Revit model a Revit energy model was created using the following steps: defining/creating a space (volume for the space automatically updated); calculate volume; customize parameter values; calculate to automatically generate results.

The first step in energy modeling was to create or define a space. In order to successfully create a space, the space must be fully enclosed by room bounding elements (such as walls, ceilings, roofs, or floors). The “Room bounding” property constraint must also be selected for each room-bounding element used to define a space. Once the space is created Revit is capable of automatically calculating the spaces volume, however Revit defaults to automatically calculating area only but this can be changed to “ Area and Volume.”

Once the space for the energy model is defined parameters for the building are entered. For the MCVDC the building type was entered as a “school or university.” The location was entered as the exact coordinates of the building that this room is in by using the Internet mapping service within the Revit software. The ground plane was picked as an average approximation for the level that the floor of the BIM lab sits above the ground. The project phase was set to the “project completion” stage because the energy model was meant to measure how the old, completed space used energy before the exact parameters were known for the newly designed space.

It is frequently necessary to use assumptions when entering parameters that are not completely known at the time of the energy modeling. These assumptions should be as accurate a representation as possible. Multiple assumptions had to be made for the MCVDC just for the practicality of the exercise. For example, it was assumed that 28 students could occupy this space at any given time and that this space would be occupied from 8am-9pm. Since the student was unable to observe the exact materials used in the actual construction of the room, they made assumptions regarding the types of materials used.

It was not practical or possible to enter every single parameter with one hundred percent accuracy. Although the energy modeling results can be reasonably accurate, model results are generally more useful for providing comparative analysis. Such analysis is performed by keeping most of the parameters the same between two models and observing how changes of individual parameters impact the overall energy usage of a space. This can provide a powerful decision making tool when comparing alternatives.

4. DISCUSSION AND LESSONS LEARNED

The remodel of the MCVDC will be complete in a month or two, and is still on-going. However, the lessons learned after the execution of the laser scanning and development of the energy model are presented below.

Laser scanning in industry is a highly specialized and cost-intensive process performed by consultants or subcontracted out. However, the process is becoming more cost effective and some general contractors are opting to self-perform laser scanning work. The actual scanning for this particular project took only an hour (including the set up time) and served as a valuable teaching module related to BIM. Documentation this process can easily be integrated into a slideshow to become part of a lesson plan, even if the instructor has little direct knowledge of the project. Because laser scanning is closely tied to measuring existing conditions, such activities could also be a part of surveying classes.

Prior knowledge of CAD/basic spatial ability is necessary to understand how a point cloud is registered. For a beginner, the actual 3D modeling might pose a significant challenge even for a simple project of this scale. Compared to learning Revit, for example, learning how to model in 3D using point cloud registration data is difficult and time consuming. In the case of modeling MCVDC, industry gave students one hour of training and a 30-day trial license of Trimble Realworks. However, even with informal industry training and over 10 hours of self-directed work along with accessing on-line training resources, students struggled to create planes and solids in the software to match the point clouds. Specifically, students reported the program relied heavily on spatial and geometric skill, and used an unfamiliar interface, much different from the interfaces they were familiar with in other BIM tools. In the context of architectural modeling, both cloud-based modeling and geometric modeling yield DXF files, meaning purely spatial/geometric models with no embedded information. It is important to consider that Realworks has separate software flavors for MEP and steel which pull from and yield models with embedded information. Since BIM by definition involves models with information associated with them, the effort versus output for learning 3D modeling using laser scanning may not give students a significant edge in learning BIM concepts. While awareness of the process will be valuable as laser scanning becomes more prevalent in the industry, the development

of this teaching model demonstrate that laser scanning should be a supplemental rather than a core feature of construction teaching curriculum surrounding BIM.

Creating the Autodesk Revit Energy Modeling teaching module provided a valuable learning experience for the student modeler as well as future students. There is little standardization or student-focused literature on how to best approach the energy modeling process. Information to support the teaching module was, therefore, gathered from various sources, including but not limited to: Online tutorials, Revit forums, colleagues, Autodesk's website, Journal Articles, books, etc.

Although Revit is considered to be somewhat intuitive, it still has a large number of commands, some of which are more complex than others. Students with little or no background using Revit software or AutoCAD software cannot be expected to be proficient with this software after one or two classes of instruction. This teaching module, therefore, is merely intended to introduce students to the energy modeling function of Revit, guide them through the of energy modeling process for an existing model and show them how these energy modeling results can be useful as a decision making tool in construction.

Finally, it is critical to place energy modeling results in context. The process of energy modeling is not useful if the results cannot be interpreted. For instance, many students are unlikely to know if a Peak Heating Load of 54,722.3 BTU/hr is reasonable or not. Translating these values into something that is easier to conceptualize such as a BTU, which is the amount of energy it takes to heat one pound of water from 39°F to 40°F, makes these output values easier to understand. Finally, students need to understand the implications of how changing input values impacts output values.

5. CONCLUSIONS

This paper focuses on highlighting the construction process and development of two cross-curricula teaching modules for use in future coursework: laser-scanning and energy modeling. The Mortenson's Center for Virtual Design and Construction was used as an illustrative case study of the current state of such processes. During the documentation and development of these teaching modules, the project team engaged students in understanding the project delivery and the transformation of the physical facility. While laser scanning and energy modeling might not be typical on a project of this scale, using such a simple space proved informative and valuable in stimulating the learning of BIM tools. The role of the students evolved to become active participants and leaders in the new educational model by engaging not only with the instructors but also with industry professionals, and using BIM tools themselves on a real project. This approach allowed the students to analyze some of the benefits as well as limitations of implementing BIM tools. This new approach to developing teaching material may provide an opportunity for other construction programs that have indicated disadvantages with the use of BIM in the classroom.

The MCVDC still in the final stages of construction. Future work will include to identify, categorize and validate the prominent features of the teaching modules that further enhance student learning. To date, the documentation of the MCVDC has resulted in an interactive, flexible, team-based, collaborative learning environment for students and the instructors. Furthermore, the teaching modules can be shared with other programs and institutions, which will help to collect data comparing results that could be generalized. All of these efforts support the overarching goal to assist building industry professionals learn about BIM tools and their capabilities, and the importance of team collaboration among different professions. Futures studies will work to assess the best way to integrate laser scanning and energy modeling teaching modules into existing courses such as sustainable construction and infrastructure.

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REFERENCES

- Ahn, Y., Lee, N., & Cho, C. (2013). "Building Information Modeling: Systematic Course Development for Undergraduate Construction Students." *Journal of Professional Issues in Engineering Education and Practice*. doi: 10.1061/(ASCE)EI.1943-5541.0000164.
- Azhar, S., & Brown, J. . (2009). "BIM for Sustainability Analyses." *International Journal of Construction Education and Research*, 5(4), 276-292. doi: <http://dx.doi.org/10.1080/15578770903355657>
- Bank, L. C., McCarthy, M., Thompson, B. P., & Menassa, C. C. (2010). "Integrating BM with system dynamics as a decision-making framework for sustainable building design and operation." *Proceedings of the First International Conference of Sustainable Urbanization (ICSU)*.
- Denzer A. S. & Hedges, K. E. (2008). "From CAD to BIM: Educational strategies for the coming paradigm shift." In M. M. Ettouney (Ed.) *AEI 2008: Building integrated solutions*. Reston, VA: ASCE
- Hedges, K. E., & Denzer, A. S. (2008). "How A Collaborative Architecture Influences Structural Engineering Education." *ASCE Conf. Proc. Vancouver, BC, Canada*. doi:10.1061/41016(314)147
- Sabongi, F. J., & Arch, M. (2009). "The Integration of BIM in the Undergraduate Curriculum: an analysis of undergraduate courses." Retrieved from ascweb.org July 17, 2010, <http://ascpro0.ascweb.org/archives/cd/2009/paper/CEUE90002009.pdf>
- Sylvester, K. E., & Dietrich, C. (2010). "Evaluation of Building Information Modeling (BIM) Estimating Methods in Construction Education." Retrieved from ascweb.org July 17, 2010, <http://ascpro.ascweb.org/chair/paper/CEUE221002010.pdf>

A BIM-ENABLED INTEGRATED DESIGN APPROACH FOR AN ATHLETIC FIELD/PARKING GARAGE FACILITY AT THE WPI CAMPUS.

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ABSTRACT

This work describes a case study made on the design process of an Athletic Field / Parking Garage project, where the actual project design and construction was observed and mapped and contrasted with a BIM-Enabled Integrated Design approach. The study addresses the advantages of using a BIM for an integrated design process as an enhancement of the actual approach used by the designer of the project, regarding design time reduction as well as enhancing communication and coordination during the design and construction stages of the project. A BIM-Enabled approach was proposed for the design stage, which includes the creation and utilization of a BIM model for the design coordination, information and feedback, between the owner, designer and consultants. For the BIM model development a Virtual Construction technique was proposed, utilizing the actual bidding information, construction documents and shop drawings used by the actual contractor of the project. The results of the study had identified the potential enhancements and challenges in the use of BIM in the design for this specific project and their extensions in the development of a Virtual Design and Construction course

Keywords: BIM, Integrated Design and Construction, Virtual Construction, Parking Facilities

1. INTRODUCTION

The educational program at Worcester Polytechnic Institute (WPI) is based on the concept Lehr und Kuntz (Theory and Practice). For several years now, faculty and students in the Civil and Environmental Engineering Department and in particular those involved in the construction project management program, have been working together with the college administration through WPI's project-oriented educational system to identify efficient uses and implementation of Information Technology as a two-way avenue that enhances the academic experiences of the students and at the same time improve the institution's procurement construction practices for new and renovation of facilities as well as their management information systems.. This activity is now focusing on the use of Building Information Modeling (BIM) as an enabler for information integration and more collaborative design, construction and operational processes.

In late October 2011, WPI made a decision to build a \$ 20 M dollar, 536 cars one-story Parking Garage project with a rooftop Athletic Field on artificial turf for soccer, field hockey, lacrosse, rugby, and softball uses. The project includes a small section for restrooms, locker rooms for visiting teams, field storage, and concession stands. The perimeter of the field has a brick façade, fencing and netting to contain stray balls. Portable bleachers will accommodate up to 300 spectators, and field lighting will

allow for evening competitions. Although parking garages are no longer eligible for LEED certification, this new facility will be a sustainable building with features such as storm water management, energy efficiency and an electric vehicle charging station.

The project was delivered under a contractor-led design build system. The parking area was completed and occupied in January 2013 whereas the playing fields are to be substantially completed in the summer of 2013. The use of BIM modeling was not part of the contractual requirements for the project. However, this project provided a research opportunity to contrast the observations made from tracking in detail the execution of the project with a hypothetical setting in which the development of the BIM model would have facilitated the development of a more integrated design.

2. INTEGRATED DESIGN AND BIM

The American Institute of Architects (AIA) defines Integrated Design as “an approach that integrates people, systems, business structure and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction”. Integrated projects are distinguished by effective collaboration among members of an integrated team that meets the goals of the project in the early stages where everyone involved in the planning, design, use, construction, operation and maintenance of the facility must fully understand the issues and concerns of all the other parties and interact closely throughout all phases of the project (NIBS 2012).

AIA states that Integrated Project Delivery (IPD) is the most available contractual guideline for integrated design establishing the basis for collaboration among all parties focusing on project outcomes rather than their individual goals. AIA defines IPD as “A project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication, and construction” (AIA 2007)

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility in which shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from earliest conception to demolition. A BIM model encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components that allow detailed analysis and performance simulation (NIBS 2007).

The use of BIM enhances the Integrated Design practices because many design professionals can share information and concurrently apply their discipline specific knowledge to the development of a single model. BIM tools and their capabilities provide the platform to facilitate the move to an integrated practice in a practical and efficient way for architects and everyone else involved in the creation of a building. Although this technology has been used in isolation it benefits the most through integrated practices (Eastman 2011). The BIM process works better in a collaborative environment that could be implemented under any contract type. Contracts specific to integrated design typically incorporate the use of multi-party contracts, risk/reward opportunities, no-sue or limited liability clauses, and defined decision making structures. However the IPD contract, which is a relatively new procurement process, is gaining popularity as the use of BIM expands and the AEC facility management (AEC/FM) industry learns how to use this technology to support integrated teams

There is a wide variation in the level of integrated design and collaborative uses of BIM in the industry today. The use of IPD is gradually increasing in the industry but for the most part current projects are delivered under well established approaches such as Design-Bid-Build, Construction Management and Design-Build. The use of BIM by the industry is also increasing but its use is implemented at different levels of collaboration from providing a tool to produce a coordinated set of 2D drawings to the ultimate integrated level in which the BIM model becomes the contractual document.

METHODOLOGY

The guiding principle for conducting this study was based on the creation of a BIM Execution Plan (Penn State University 2010) which defines the appropriate uses for BIM on a project along with a detailed design and documentation process for executing BIM throughout a project lifecycle. It includes the following steps (Alvarez & Gomez 2012):

1. Identify the key deliverables and constrains of the selected project.
2. Map the actual design development process of the selected project.
3. Define a BIM-enabled Integrated Design approach suitable for the selected project.
4. Simulate the actual process as an alternative BIM-enabled Integrated Design Process while creating a BIM model with Level of Development (LOD) 300 based on the key deliverables and constrains mapping (AIA 2007), (BIMForum 2013).

The design deliverables and its constrains were identified to gain an understanding of the benefits and limitations of the use of BIM in an Integrated Design approach and to capture the essential team interactions commensurate with the project complexity. Table 1 summarizes deliverables and constraints categorized in terms of :

- **Owner constrains.** Restrictions imposed by the owner through the architectural program.
- **Code constrains.** Constrains prescribed in the applicable official construction code that clearly restrict the design of the deliverable.
- **Design constrains.** Constrains not regarding any official code but the by the ethics and practices in the design.

Athletic Field/Parking Garage Project Deliverables and Constrains

Deliverables	Owner Constrains	Code Constrains	Design Constrains
Schematic Design			
Design Development			
Parking Layout	+ Minimum of 500 parking spaces + Church space sharing arrangement	+ Setback of 50 ft to Park Av	+ Allocate the space occupied by the concrete structure and not affecting number of parking spaces
Field layout	+ Allocate space for soccer, softball, lacrosse, field hockey, rugby		
Concessions/Storage/Lockers Layout			
Field Pad		+ Drainage stormwater flow rate	+ Weight of the grading for drainage
Spectator Services	+ Allocate temporary bleachers, sound systems, and scoreboards. + Allocate rest rooms and food court		
Entrances	+ Provide access to the field of the maintenance vehicles. + Enable readiness for the future construction of the bridge to Harrington building.	+ Avoid disturbance of traffic on Park Ave and Salisbury St. + Provide access to firefighter vehicles	+ Access provided on Park Ave should be according to Park Ave Image. + Provide safety on all access, specially in the stairs towers.
MEP			+ Allocate temporary rainwater storage
Framing			+ Weight of the grading for drainage + Aesthetics + MEP intrusions
Foundations	+ Restriction on number of testing borings at early stage on the current field zone		
Landscaping			+ Park Av. Landscape disturbance + Salisbury St landscape disturbance + Church landscape disturbance + WPI landscape disturbance + Old trees conservation + Future bridge to Harrington Building
Lighting		+ Luminic Pollution to Park Av.	
Safety and Security	+ Stairs Control + Surveillance system	+ Surrounding Protection Net + Fire protection	
Cost Estimating			
Scheduling			
Construction Documents			
Shop Drawings			

Table 1 Design Constraints and Deliverables

One of the most complex aspects of the design in this project was the design of the entrances for both, the vehicles and the people including access to the parking garage and access to the fields at the top level.

The constraints that were imposed by the owner, codes and design practices; it also involved several joint decisions by the designers and owner.

The project team interactions were mapped through time in terms of project team interactions, significant issues to be resolved and decisions made. The process was captured by the research team by attending weekly project meetings throughout the duration of the design and construction process and by observing in detail the construction progress through direct access to the construction site as needed and analyzing digital webcam photography. It also created a similar mapping process as decisions would have been made if BIM modeling was used in the process.

One of the key elements of the construction of the BIM model was to define the Level of Development (LOD) of the BIM model, The LOD describes the level of completeness to which a Model Element is developed. A model element, or building object, is a portion of the BIM Model representing a component, system or assembly within a building or building site. The model developed in this study corresponds to a LOD 300 in which model elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location and orientation. This LOD is similar to Design Development. At this level, cost estimating is based on specific data provided and conceptual estimating techniques, and the schedule shows ordered, time - scaled appearance of detailed elements and systems.

The model was created using: 1) the precast structural subcontractor BIM model, 2) 2D construction and shop drawings and sketches, 3) information and documentation provided by the project participants during the weekly project meetings, 4) periodic visits to the site. It included objects for the majority of the bid packages of this project. The time schedule was provided by the contractor in PDF format and it served as a guide to create a new time schedule using critical path method software. Some gaps were filled in since the PDF document was an updated look-ahead version and did not show early project activities. BIM modeling integration software imported the 3D BIM model, construction schedule and cost information. There are 2621 objects in the model. In the original schedule there were 238 activities. Many of these activities are not directly related to any model element (bidding, awarding, fabricating, among others). Some of them were split into more detailed activities. For example Precast sequence 1-4 was split in 16 activities (4 for each quadrant: columns, girders, double T and spandrels). In summary there are 2621 objects grouped and related to 78 activities. Figure 2 displays the BIM model.



Figure 1: Parking Garage-Rooftop Fields BIM model

3. RESULTS

Using a color code, the major issues observed between the two design processes were categorized as: A) issues detected due the use of BIM Models [Red], B) Issues caused by lack of systematic checks of the program assumption [Blue] and, C) Issues that could be solved during reviews [Green]. These are summarized on Tables 2 to 4 respectively:

Issues Detected due the use of BIM Models (Red)

Date	Issue	Assumptions
10/13/11	An alternative ramp adjacent to the southeast end of the garage was discussed (Aesthetic and functionality of the bridge)	With the 3D BIM model of the Parking Garage and Existing Conditions, would be easy to visualize the aesthetics and functionality of the future bridge related with the REC Center and the Harrington Gym
3/8/12	Construction issues on the precast joints of the corner spandrels panels and pilasters to support the roof of the access stairs. (2D drawing vs 3D structure model)	3D model would be helpful to analyze the different solution for the precast joints and pilasters of the access stair. At the same time, with the architectural and structural model (generated with the architectural model as reference) inconsistencies between 2D drawings would be avoided
03/15/12	Still to define pilaster and posts support on the corners stairs (roof)	
3/22/12	Differences were found on the levels between the structural BIM model and Design Drawings. Design drawings do not reflect the lowering of the gravel grade height decided weeks ago	With the architectural and structural model (generated with the architectural model as a reference) inconsistencies between the models and the 2D drawings would be avoided
3/29/12	Discussion about the retaining wall needed on some parts of the perimeter to contain foundation backfill	With the 3D BIM model of the Parking Garage and Existing Conditions, would be easy to visualize the aesthetics and site requirements of the Parking Garage
4/12/12	Concerns about the aesthetics of the real view of the service door (for gator) at the Park Ave (2D drawing not reflecting this issue)	With the 3D BIM model of the Parking Garage would be easy to visualize and communicate the aesthetics and functionality of the Parking Garage

Table 2 Issues Detected due to the Use of BIM Model (RED)

To identify issues of this type, it was assumed that the enhanced visualization capabilities and clash detection functionality provided by the BIM model during its virtual construction could be sufficient to immediately detect both design and constructability problems. For example, according to the 2D drawings, the design of stairs showed 45 degree joints at wall corners. The 2D elevations for the spandrel wall showed a brick finish fully covering the wall with a perfect joint at the corners. However, this solution is very hard to achieve if not impossible with precast elements where the joint in the corner clearly shows a 3 inches gap as clearly visualized in the structural BIM model from the fabricator. Eventually, this discrepancy between design intent and fabrication was solved by changing the joint to a butt joint which affected the aesthetics desires of the architect but had practical implications.

The next category (BLUE, Table 3), is related to the issues caused by the lack of systematic check of the architectural program assumptions. These issues could have been avoided by the following the procedural steps of a BIM Execution Plan that considers a quality control implementation assuring the systematic checking of codes, design ethics and program assumptions.

Issues Caused by Lack of Systematic Check of the Programm Assumption (Blue)

Date	Issue	Assumptions
10/6/11	Bridge height is an issue as relates to the potential turnaround area for buses. Height required will be 13-2 to 13-6	All Bridge issues are considered as a part of a lack on the follow up on the program assumptions. Is imprtant that the project and design team always note the program assumptions of the project during the reviews and if any change is made on the model. Because of that, is considered that BIM team would decided to take into account the future bridge for the Parking Garage design, since the beginning and would work in tight collaboration and communication as the Integrated Design definition says.
11/3/11	WPI requested the access for the firefighter vehicle	
11/17/11	WPI requested to add the development of the bridge design on the 2 level layout	
12/16/11	Trustees ask to prepare the parking garage design for future bridge construction	
03/29/12	Discussion about the preparation of the main stair to receive in the future the bridge to connect Harrington building. (levels do not allow firefighter truck passing under the bridge)	

Table 3 Issues Caused by Lack of Systematic Checking of Program Assumptions (BLUE)

The last category (GREEN, Table 4) deals with circumstances in which changes effected in the BIM model as it was built could have been anticipated during the design. As the project and model were gradually completed some design issues could have been better resolved by using the design extensions of a BIM model. The enhanced ability for visualization and communication provided by the BIM model could have greatly be used in many design related decisions. Such was the case of the lighting of the parking garage in which the perception of lighting by users was different from the strict numerical numbers generated by mathematical models. This situation required several iterations of mathematical modeling and field observations leading to some modifications of the lighting system.

Issues that Could be Preliminary Solved During Reviews (Green)

Date	Issue	Assumptions
09/15/11	VHB ...to consolidate 2 WPI curb cuts to one	It would be easy to make a "simple" changes using the schematic 3D model during the review, so the team can visualize, in a schematic way, the functions and operations of the Parking Garage related with the spacial requirements
	WPI requested a storage room for snow blowers that would have a garage door on it to allow vehicular access	
09/22/11	The ingress and egress schemes at Park Av entrance at The church were discussed	With the 3D model of the Parking Garage, the reiew and comunication of these schemes would be lighter, specially for WPI representantives, whom would have a better and faster understandig of the design proposals for the ingress and egress of the Park Av.
11/3/11	WPI requested a second parking level option	It would be easy to make a 2nd level of the Parking Garage or any other "simple" change using the schematic 3D model during the review, so the team could visualize how the Parking garage is going to look, specially for the high related with Park Avenue and Higgins side. Is important to mention that this changes are
11/10/11	WPI preferred the option with internal ramps and requested to modify the selected option to provide 2 way ramps	considered to be done in a schematic way (only for visualization purposes) during the reviews and then in more detail
3/2/12	Some issues were detected to access the field with a turf vehicle.	The Functionality of the Parking Garage related with the transit of the turf vehicle, would be easy to visualize, understand and simulate using the 3D model.
03/15/12	New proposal of the main entrance, is moved one bay to south, and completely outside the parking garage	In addition, the aesthehic would be easy to visualize with the 3D BIM model
4/12/12	Discussion on the proposed access the field with a turf vehicle. Turning ratio restrictions	The Functionality of the Parking Garage related with the transit of the turf vehicle, would be easy to visualize, understand and simulate using the 3D model

Table 4 Issues that could have been solved during design review (GREEN)

4. CONCLUSIONS AND FUTURE WORK

This study identifies advantages that could be derived from the incorporation of a BIM-based design approach into the project following the systematic implementation of a BIM Execution Plan. It also highlights the benefits of building a BIM model in detecting design related issues before and during construction.

The work presented in this study is based on a graduate study which was developed simultaneously with the actual project. In addition to the learning benefits of this exercise, this work allowed the researchers to explore the practical and educational implications of using BIM models in different aspects of the design and construction process at WPI. Originally, it was intended that the use of the BIM model could be incorporated with the actual execution of the project knowing ahead of time that the use of BIM model was not a contractual requirement. Because of the level of involvement and educational nature of the students' projects this was not possible. However, the end product may prove to be valuable for the future operation and maintenance of the facility. WPI as an institution may also feel more comfortable in developing a more aggressive BIM-based approach for new construction and renovation of the existing plant.

The resulting model is also valuable for educational purposes since using the LOD 300 model and incorporating the site and underground conditions of this facility opens the possibility of creating a specific course in which teaching of structural and geotechnical design can be combined with construction methods, project management and the creation of construction documentation. As it is now, the BIM model can be used in complementing theoretical material in different courses and it also could be used by the administration for marketing purposes. The BIM model will also be used to further investigate current issues related to the use of this technology. Immediate extensions include the research the implications of the industry updated LOD definitions as well as the use of different BIM software tools and their interoperability.

At the departmental level, the understanding and sophistication and depth shown by those students and faculty who use BIM tools development work is increasing. Over the last five years, there has been a sustained effort to establish the use of BIM as a well understood and productive tool to support the development of MQP students' work. The students taking the junior level BIM course have expressed their intentions to use BIM tools in that way and beyond. They also considered the learning of these tools as a very important factor for future employment and career development. The encouragement and gradual adoption of BIM by the industry expecting students to acquire BIM skills and knowledge is also considered to be a strong motivator.

At a more general level, the approach herein described can be used with other projects but the amount of work involved will vary with the complexity of the project and the LOD desired.

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REFERENCES

Alvarez, S. & Gómez, M. 2012, "Integrated Design: WPI Parking Garage/Athletic Field", Independent Study Report, Worcester Polytechnic Institute, Spring Term.

Alvarez, S. & Gómez, M. 2012. BIM During the Construction Phase, Independent Study Report, Worcester Polytechnic Institute, Fall Term.

Alvarez, S., Gomez, M., Salazar, G., 2013, “Building Information Modeling (BIM) A Technological And Collaborative Platform For Improving Building Long-Term Sustainability”, Conference Proceedings Encuentro Latinoamericano de Gestión y Economía de la Construcción, Cancun Mx, June

American Institute of Architects, 2007, “Integrated Project Delivery: A guide” Version 1

American Institute of Architects 2008, Document E-202 - Building Information Modeling Exhibit

BIMForum AGC of America, “2013 Model Development Specifications – Draft” [Online Document](#), June 2013.

Eastman C., Teicholz, P., Sacks, R., Liston, K., 2011, “ BIM Handbook”, Second Edition, John Wiley

National Institute of Building Sciences 2012, “Engage the Integrated Design Process”, Website of Whole Building Design Guide, retrieved on 1/23/2012, url: http://www.wbdg.org/design/engage_process.php

National Institute of Building Sciences, 2007, “National Building Information Standard” Website of BuildingSMART Alliance. Online article at http://www.wbdg.org/pdfs/NBIMSv1_p1.pdf

Pennsylvania State University, 2010. BIM Project Execution Planning Guide, Version 2.0

THE SOFT SIDE OF BIM: CURRENT PRACTICE OF BIM TALENT ACQUISITION IN THE AEC INDUSTRY

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ABSTRACT

As building information modeling (BIM) is rapidly reshaping the architecture, engineering and construction (AEC) industry, profound transformations have taken place in companies' organizational structures as well as their business operations. In addition to the technological revolution, a "soft" issue faced by all AEC companies amid this transformation is how to align intellectual preparation with the challenges and opportunities associated with the emerging BIM business. There is a strong impetus for AEC companies to retain competitiveness in the market through efficient talent acquisition. Use of dedicated BIM job titles and the emergence of the "BIM department" as an explicit functional unit in AEC companies justify the need for a closer scrutiny of current strategies of talent acquisition in the construction industry. This research investigates the impacts of BIM on the key aspects of a talent acquisition strategy, including: identifying (gap analysis of talent shortage and needs), profiling (job description), qualifying (job requirements), sourcing (intellectual pool), recruiting (candidate screening and interviews) and managing. The study is supplemented by a survey that collects opinions of industry experts in talent acquisition and management. Results of this research suggest that the industry is still at the beginning stage of formulating holistic strategies catering to acquiring "BIM talent", in contrast to a relatively developed market of BIM adoption and implementation. The findings of this research expose some fundamental issues that AEC companies are facing or will face in BIM talent acquisition for almost all possible project types. The research also outlines a generic roadmap that may help companies initiate critical thinking and formulate preliminary strategies for BIM talent acquisition. Lastly, the research suggests that enhanced collaboration between the industry and academia may significantly improve the cultivation and acquisition of BIM talent.

Keywords: BIM, Market Transformation, Talent Acquisition, Strategy, AEC Industry

1. INTRODUCTION

Wide adoption and implementation of building information modeling (BIM) is reinvigorating the Architecture, Engineering and Construction (AEC) industry. BIM generates new business opportunities but at the same time it raises the bar for competition. As more facility owners are embracing BIM, the project procurement process has started to incorporate BIM competency as desired qualifications in selecting project teams. To stay competitive, companies have to be mentally and intellectually prepared for the upcoming transformation. Unlike challenges associated with the technological aspects of BIM, the obstacles in cultivating and acquiring the competent BIM talent seem to be soft issues that companies unconsciously overlook at the early stage of their BIM journey. Many industry professionals and research scholars have observed that BIM-savvy people will be in high demand and the lack of adequately trained personnel is hindering the further BIM uptake in the industry. Thus, it becomes a critical mission for companies to align human resources with organizational development challenges and understand the need for BIM talent, finding it and then placing employees properly within the existing system (Joseph 2011). This research aims to investigate: 1) how BIM is reshaping the skillset requirements for

construction professionals; 2) what the current practices of acquiring BIM talent in construction companies are; and 3) what other transformation, such as enhanced industry-academia partnership in college-level BIM education, is needed to satisfy the growing market demand for competent BIM talent in the construction industry.

2. BACKGROUND

2.1 The Human Factors in Challenges in BIM Uptake

BIM advocates find workforce shortage and organizational resistance to change in the AEC industry among the major challenges in which the human factors play an important role. Smith and Tardif (2009) projected that the demand for highly skilled construction professionals was expected to outpace the supply over the next twenty years, based on statistics from the U.S. Department of Labor. The supply/demand equation for the global construction industry workforce has been imbalanced, with countries including the US, UK and Canada claiming a "crisis of skilled workforce shortages". In contrast, BIM uptake is accelerating. In North America, industry-wide adoption has surged from 28% in 2007, 49% in 2009 to 71% in 2012 (McGraw-Hill Construction 2012a). In the UK, National Building Specification (NBS) (2012) reported that from year 2010 to 2011, construction professionals using BIM were more than doubled (from 13% to 31%). Owners who are BIM-educated and -sophisticated are usually more engaged with its implementation and able to reap the highest business value (McGraw-Hill Construction 2012a). They are more likely to seek out to award projects to BIM-capable companies who rely on the professionals they hire to deliver the projects to meet outcome expectations. BIM's biggest opportunity in the future will be the direction that new personnel take BIM technology (Hardin 2009). BIM-savvy people will be in high demand, and the projected supply/demand equation will place acute pressure on the industry to acquire or cultivate competent BIM talent to increase knowledge-worker productivity across the industry to meet the rising demand (Smith and Tardif 2009).

In the short term, institutions of higher learning will be unable to satisfy the workforce demand of BIM, which means employers will have to rapidly develop BIM and integrated project delivery (IPD) skills internally. Organizations that choose to repeat the conventional wisdom of the CAD era that employees will simply "pick up the skills on the job", will find themselves at a significant disadvantage (Smith and Tardif 2009). From a business innovation perspective, BIM is "transformative", meaning that there is impetus for dramatic changes in the business practices (Jordani 2008, Mihindu and Arayici 2008). Companies are urged to manage change (operational and cultural, according to Smith and Tardif 2009) and transition (Deutsch 2011) to carry BIM implementation strategy through and foster its development. The impacts of BIM on organizational structure and construction companies' day-to-day business operations are extensive as well as intensive. The resistance to change in organizations is most challenging when top management and senior personnel refuse to adopt new practices but would rather stay in their "comfort zone", which typically occurs in the course of new technology insertion and intellectual transition (Eastman et al 2008). As LeFevre (2011) pointed out that "changing mindsets is the biggest challenge" in BIM transformation. Yet the cultivation or acquisition of BIM talent is expected to attenuate this resistance and facilitate the transformation process.

2.2 Impacts of BIM on Fundamental Skillset Requirements and Education

Transformative industry trends like BIM and BIM-related greater collaboration and integrated project delivery require workers to draw upon different skills than traditional positions do. The increasing need in construction for greater productivity is likely to drive more rapid adoption of these trends, which will require a different way of looking at the skills a worker has to offer (McGraw-Hill Construction 2012b). New job titles prefixed with "BIM", e.g. "BIM Manager" and "BIM Coordinator", and the advent of new organizational function units such as "BIM/VDC department" reflect the impetus to rethink the profiling and planning of workforce oriented to BIM tasks. This is important to understand, because BIM is revolutionary shift away from drawing production in the CAD era (Eastman et al 2008). The set of skills needed is usually beyond the scope that is traditionally defined for

CAD professionals. Barison and Santos (2010) conducted an overview of BIM specialists, which provided a preliminary outline of the areas of responsibilities, and contributed to better defining the professional skills required to performing BIM related functions in construction companies.

For many, BIM training begins in academia. Education, particularly in universities, is where the ability to create new mindsets and exposure to new media is most effective (Hardin 2009). BIM education is considered as a solution to quicken the BIM learning curve thus companies can recruit ready-made BIM talent when the students graduate (McGraw-Hill Construction 2008). Therefore, the effective inclusion of BIM into college curricula has become both a pedagogic and practical aspiration needed in preparing future BIM talent for the construction industry (Crumpton and Miller 2008, McGraw-Hill Construction 2009). The classic gap between academia and industry does exist in college BIM education. Despite the pervasive presence of BIM in college curricula, academic programs are struggling to meet industry and student expectations on knowledge coverage and problem-solving skills learned from the curricula (Clevenger and Rush 2011, Wu and Issa 2013). BIM is most productive when implemented in a multidisciplinary, collaborative environment. However, in academia, the segregation of departmental units makes it very difficult to imitate this working environment. Students are typically trained with focus on technical skills. The lack of exposure to the essential BIM workflow and managerial aspects of delivering BIM projects is a major drawback of existing college BIM curricula and undermines students' learning outcomes.

3. BIM TALENT ACQUISITION: CURRENT PRACTICE

The literature review confirmed the impacts of BIM on skillset requirements for future construction professionals and the needs for companies to adapt their strategies in talent acquisition to prepare for the transforming market. Yet there is very little published research that has evaluated existing practice in BIM talent acquisition in the construction industry. Without an established baseline case, it is difficult to assess the strengths and weakness of the current system, or to identify possible opportunities and solutions for improvement.

3.1 Methodology

In order to address the three research objectives (ROs), an online survey was designed to gather information on the following aspects of BIM talent acquisition: demand, job profile and qualification, talent source, recruiting, talent retention and management, and future outlook. A total of 840 email invitations were sent through the recruiters' listserv from Rinker School of Building Construction at University of Florida and the buildingSMART alliance member listserv. Ninety-nine (99) completed questionnaires were collected, with a response rate of 11.8%. The low response rate is commonly seen in online surveys (Nulty 2008) and one of major limitations of this research. This yields a +/- 6.4% margin of error at 95% confidence level. The survey used various types of question design, including Multiple Choice, Matrix Table and Likert Scale. Skip logic was employed when certain questions were looking for participants with specific background. As a result, some questions might have fewer than 99 responses.

3.2 Survey Results

Architectural firms (24.2%), contractors (23.3%, including construction managers, general contractors and specialty contractors) and consulting firms (15.2%) are the top 3 groups of participants in this survey. Various engineering firms (civil, MEP and environmental) responded (14.2%) except for structural engineers. Other respondents include owners (8.1%), product manufacturers/distributors (2.0%), software vendors (1%) and others (12.1%). Most respondents are either directly involved (as final decision-makers, leading or supporting recruiters) with talent acquisition (41.4%), or have medium or high influence on it (39.4%).

3.1.1 Identifying BIM talent demand

To determine the demand for BIM talent, the survey focuses on: 1) how often do companies participate in projects that mandate use of BIM, which constitutes as a challenge; and 2) how much BIM contributes to the annual

revenue, which is an incentive. As shown in Figure 1, between the years 2008 and 2012, companies' business portfolio has been drastically transformed from BIM-marginal (low frequency of projects that mandated BIM, see the dashed trendline) to BIM-essential (high frequency of projects that mandated BIM, see the solid trendline). Notice that only exponential trendlines for "less than 10%" and "more than 75%" were illustrated in Figure 1. The purpose is to make the greatest contrast and show the rapid shift from low frequency to high frequency of mandated use of BIM in projects. Similar methodologies were used in subsequent Figures 2-4. During the same period of time, as shown in Figure 2, contribution by BIM to companies' annual revenue was increasing steadily, following an upward trend similar to that in Figure 1.

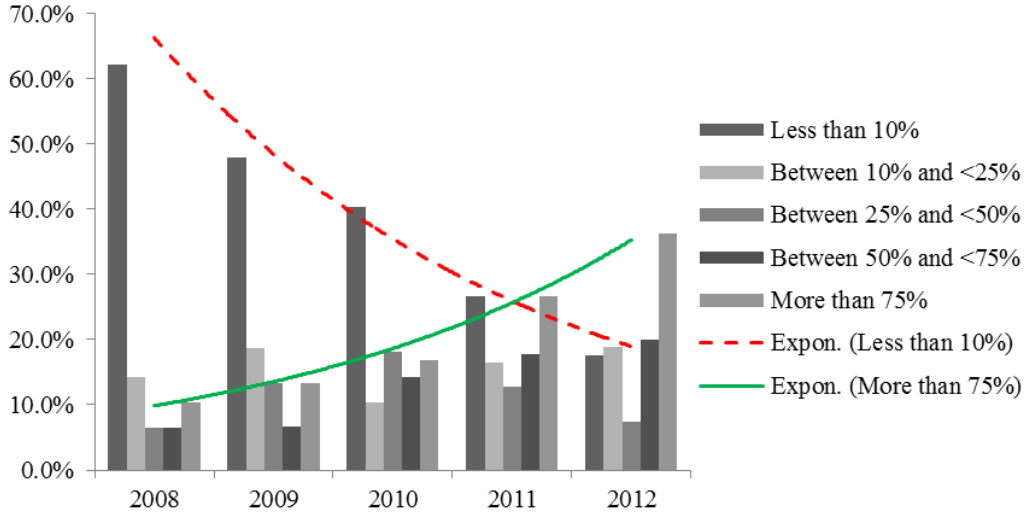


Figure 1. How often did your company participate in projects that mandated use of BIM?

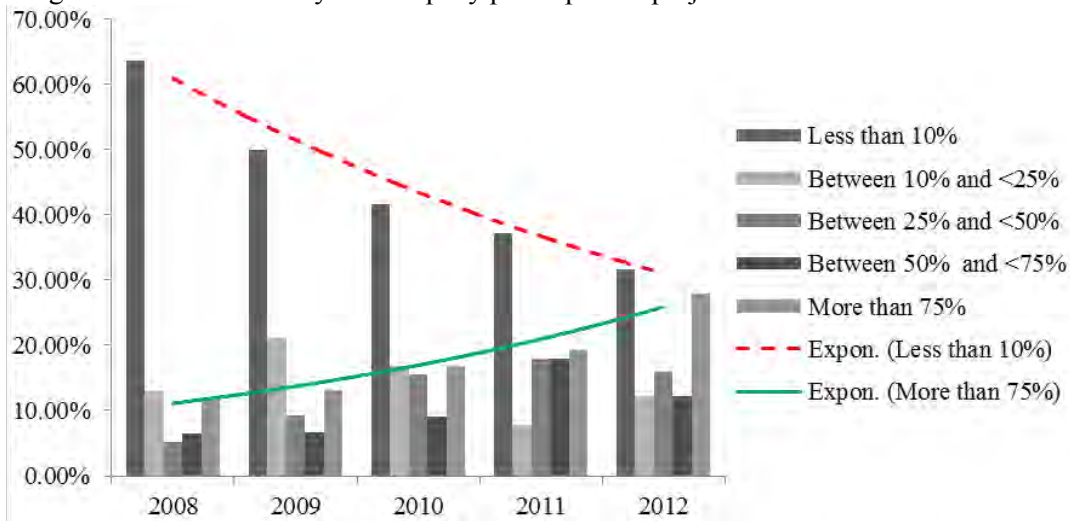


Figure 2. How much did BIM contribute to your company's annual revenue?

The demand for BIM talent has also been influenced by companies' workforce planning and the incentives that companies have perceived to adopt BIM. Most companies (53.6%) considered themselves "proactive" in workforce planning, driven by projected BIM business growth to acquire BIM talent. In contrast, about a third (28.6%) of the companies admitted to being "reactive", and only hiring when there is an immediate need for BIM talent (e.g. a project they were bidding on specified BIM as a desired qualification). In terms of incentives, companies felt most motivated by the perceived internal business benefits from BIM adoption (34.1%). They also felt encouraged to acquire BIM talent to more competently explore new business opportunities (20.9%). The third highest ranked incentive (16.5%) came from the owners' demand, as companies felt that owners might mandate BIM sooner or later.

Companies' historical hiring statistics offer reliable evidence for the rising BIM talent demand. Figure 3 provides a comprehensive summary of the participating companies' recruiting data over 2008 to 2012 in two major types: Type 1 - hiring that listed BIM as a qualification; and Type 2 - hiring that was dedicated to BIM. These exponential trendlines suggest that both types of hiring for BIM talent are increasing in terms of its percentage in total hiring, although at slightly different paces. The composition of employee structure is shifting from BIM-marginal to highly BIM-relevant.

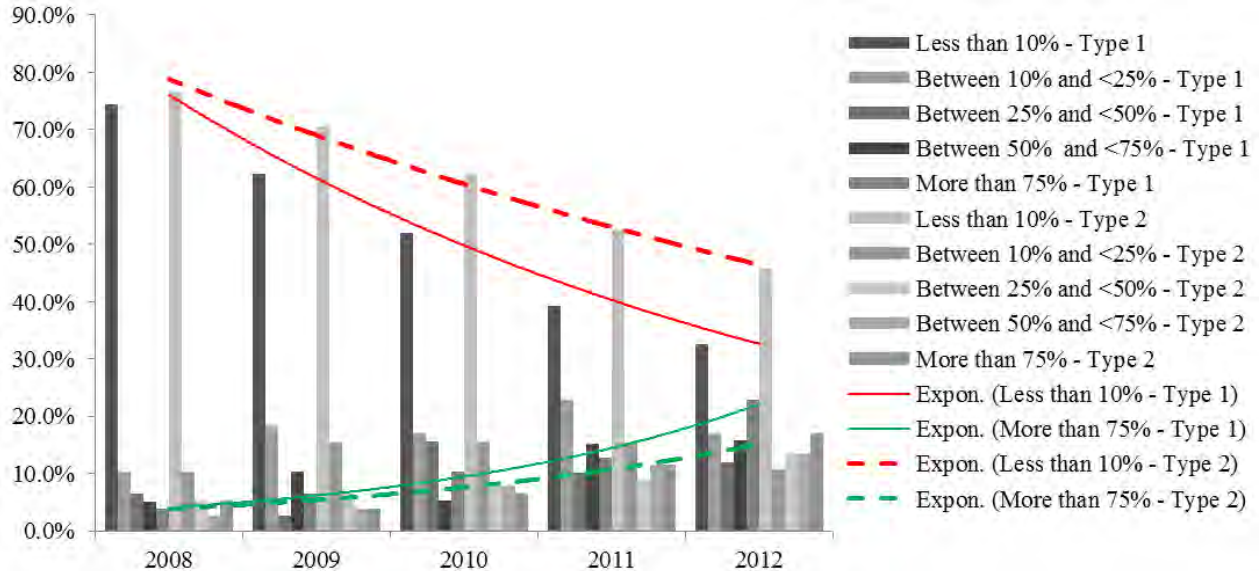


Figure 3. How many newly hired employees in your company were 1) listing BIM as a qualification or 2) dedicated to BIM?

3.1.2 BIM job profile and qualification description

Aligned with Research Objective 1 (RO1), the impacts of BIM on skillset requirements for future construction professionals were directly reflected in the description of BIM job profile and qualification. The emergence of BIM-prefixed job titles provides some insights. As found out in this survey, BIM Coordinator (47.1%), CAD/BIM/VDC Manager (42.4%), BIM modeler (31.8%) and BIM Director (29.4%) are the most popular BIM job titles among participants. But there were also a considerable number of people (28.2%) who chose not to use BIM in job titles. Very diverse opinions were observed on whether or not the company should define Job descriptions and qualifications when advertising BIM positions, with almost equivalent proponents (54.1%, 52.4%) and opponents (45.9%, 47.6%). To go in more depth, more than half of the participants in this survey found Technical/Functional Skills (74.1%), BIM Workflow/Strategic Plan and Execution Knowledge (61.2%), Multidisciplinary Model Management Knowledge (55.3%) and BIM Communication and Collaboration Skills (54.1%) most desirable qualifications. Companies relied predominantly (58.8%) on previous experience and reference checks to assess candidates' BIM competencies in recruiting. Some companies also used Internal Metrics and Standards (27.1%), instead of Industry Certification/Credentials (e.g. AGC Certificate of Management - BIM or Autodesk Certified Professionals) (5.9%). It was revealed that there was a lack of common metrics and industry-wide accepted standards for BIM competency evaluation in talent acquisition. This may be attributed to the fact that the National BIM Standard is still a working product, and the overall BIM market still lacks a consensus on the job characteristics and skillset portfolio for BIM positions.

3.1.3 Identify the source of BIM talent

Sources of BIM talent are also important to RO1 since it reflects the overall quality expectation of the talent acquired by the company. Training and educating employees was the top option (chosen by 17.9% of the respondents in recruiting 80% or more of their BIM talent, as shown in Table 1) for companies at this moment,

followed by free-agent BIM professionals in the job market. College students (non-doctoral students) were receiving more attention from companies, even though not yet a priority. This is probably attributed to the perceived strength of college students in BIM technical/functional skills, which was identified as one of the most preferred qualifications of BIM talent. CAD managers were in an awkward situation. They received second lowest votes, only better than college doctoral students who typically would not choose a career in the industry. This may suggest that more companies have realized the substantial differences between CAD and BIM competency in talent acquisition. Quite a few companies implied that they had been counting on CAD managers to take on new challenges to lead the BIM expedition, and had been successful. Despite the few commonalities, the two job titles are actually fundamentally different in terms of the desired qualification, responsibilities and expectations (Kiker 2009).

Table 1. Sources where companies typically acquire BIM talent

Sources	% of BIM talent in total acquired talent						
	Less than 5%	5% to <10%	10% to <20%	20% to <40%	40% to <60%	60% to 80%	More than 80%
College Students - Undergraduate	43.3%	13.4%	14.9%	7.5%	9.0%	3.0%	9.0%
College Students - Graduate	39.4%	18.2%	10.6%	7.6%	10.6%	6.1%	7.6%
College Students - Doctoral	81.4%	11.9%	3.4%	1.7%	0.0%	0.0%	1.7%
Professionals - Beginning BIM Competency	34.4%	32.8%	13.1%	1.6%	6.6%	1.6%	9.8%
Professionals - Intermediate BIM Competency	27.9%	18.0%	19.7%	16.4%	4.9%	3.3%	9.8%
Professionals - Advanced BIM Competency	36.1%	19.7%	8.2%	11.5%	6.6%	9.8%	8.2%
Professionals - Expert BIM Competency	41.7%	15.0%	11.7%	5.0%	8.3%	5.0%	13.3%
Transfer Internal CAD Managers	52.5%	16.9%	8.5%	5.1%	8.5%	3.4%	5.1%
Train and Educate Internal Employees	19.4%	14.9%	10.4%	14.9%	16.4%	6.0%	17.9%

3.1.4 Recruiting BIM talent

As directly pertaining to RO2, BIM recruiting is an important investment for companies. More than half (52.4%) of the companies had set aside budget and personnel for BIM recruiting, and 9.5% of them even made this a routine. Most companies (59.5%) still rely on conventional web-based job posting for recruiting, followed by conventional job fairs (32.1%). New generation social media (e.g. LinkedIn and Facebook) are also gaining recognition (27.4%). Special attention was given to college BIM recruiting. About a third of companies either hired students to fill permanent BIM positions (34.9%) or BIM internships (31.3%). Yet, there were still more than a third of companies (38.6%) that had never recruited college students at all. It seems that more incentives have to be in place in both academia and the industry.

3.1.5 Retaining and managing BIM talent

Recruiting is not the end of BIM talent acquisition, but a starting-point. To further address RO2, it is extremely important to investigate what talent retention and management strategies have been taken by companies to sustain the success of their transformation to BIM. The survey found out that most companies (76.2%) did not have an established BIM career path, like the way the traditional project managers and estimators were. Major efforts made to retain BIM talent include encouraging organizational learning and knowledge management (55.4%), cultivating BIM culture and celebrating BIM champions and success (42.2%), encouraging BIM career development (39.8%) and creating a clear vision and goals for BIM business (38.6%). In terms of managing BIM talent, most companies (59.0%) made them blending with the conventional workforce, and performing both conventional and BIM-specific tasks. About a quarter of companies (22.9%) would put their BIM talent in existing departments and assemble them for project-based BIM tasks. But with the emergence of new functional

units such as BIM department, there were 13.3% of the companies that had created BIM/VDC departments to accommodate the acquired BIM talent and let them handle only BIM business.

3.1.6 Outlook of market demand for BIM talent

To address RO3, the survey also identified some deficiencies in current BIM talent acquisition. Companies attributed such deficiencies majorly to lack of competent talent pool (46.7%). Other challenges they found in acquiring BIM talent include tight budget versus increased recruiting costs (37.0%), lack of opportunities to conduct BIM business and gain project experience (30.4%). Lack of top management commitment (28.3%) was still significant but no longer a dominant obstacle. To facilitate acquisition of BIM talent, more than half (55.6%) of the participants believed the key would be the continued growth of BIM business market, Enhanced College BIM Education and Professional BIM Training (53.3%), Enhanced Partnership and Collaboration between Industry and Academia (50%) and Development and Implementation of BIM Standards (50%). In forecasting the hiring of dedicated BIM positions over the subsequent 5 years, Figure 4 shows that respondents anticipated significant increase in both frequency (notice that the "0" hiring trendline drops while the "20+" hiring trendline rises) and magnitude (notice the increasing percentage of "20+" hiring), where "0" and "20+" denote numbers of dedicated BIM positions budgeted.

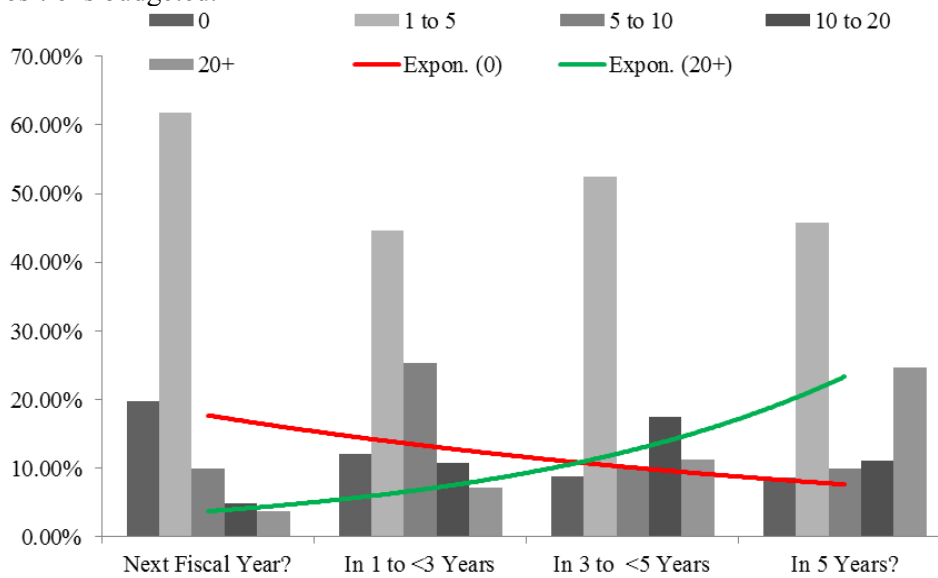


Figure 4. How many dedicated BIM positions do you company plan to recruit?

4. CONCLUSIONS AND FUTURE WORK

BIM is drastically reshaping the construction industry at large, and acquisition of the desired BIM talent becomes critical for companies to address the dual technology and process challenge in the BIM transformation. After reviewing the challenges and impacts of BIM on workforce planning, an online survey was designed and conducted to identify the key features that characterized current practice of BIM talent acquisition in the industry. The results of the survey suggest that BIM as a trend is strengthening, with further expanded business opportunities. The impacts of BIM on talent acquisition were confirmed yet very few companies had established holistic strategies to address such impacts. More sophisticated strategic planning and financial investment are desirable to improve the status quo. Among the various efforts in meeting the rising demand for BIM talent, organizational learning, knowledge management and industry-academia partnership in BIM education are facilitators that deserve stronger commitment and further development.

REFERENCES

- Barison, M. B., and Santos, E. T. (2010). An overview of BIM specialists. In: Tizani, W (Ed), *Proceedings of the 13th International Conference on Computing in Civil and Building Engineering*, June 30 - July 2, University of Nottingham.
- Clevenger, C., and Rush, M. (2011). Collaborating with Industry and Facilities Management to teach BIM, *Proceedings of EcoBuild America 2011: BIM Academic Forum*, December 6-8, Washington D.C.
- Crumpton, A., and Miller, B. (2008). Building Information Modeling: State of the A&D Industry and BIM integration into Design Education, *Proceedings of Interior Design Educator's 2008 Annual Conference*, March 5-8, Montreal, Quebec, Canada.
- Deutsch, R. (2011). "BIM and Integrated Design: Strategies for Architectural Practice". Hoboken, New Jersey: John Wiley & Sons, Inc.
- Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2008). "BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors". Hoboken, New Jersey: John Wiley & Sons, Inc.
- Hardin, B. (2009). "BIM and Construction Management: Proven Tools, Methods, and Workflows". Indianapolis, Indiana: Wiley Publishing, Inc.
- Jordani, D. (2008). BIM: A healthy disruption to a fragmented and broken process, *Journal of Building Information Modeling*, Fall 2008, 24-26.
- Joseph, J. (2011). "BIM Titles and Job Descriptions: How Do They Fit in Your Organizational Structure?" *Autodesk University 2011*, November 29 – December 01, Autodesk, Inc.
- Kiker, M. W. (2009). BIM Manager - The Newest Position, *Autodesk University 2009*, December 1-3, Autodesk, Inc.
- LeFevre, M. (2011). No BIM for You: The Case for Not Doing BIM - Leverage Points, Reframing and Key Decision Factors in BIM Transformation, *Journal of Building Information Modeling*, Spring 2011, 14-17.
- McGraw-Hill Construction. (2008). "BIM: Transforming Design and Construction to Achieve Greater Industry Productivity". Bedford, MA: McGraw-Hill Construction.
- McGraw-Hill Construction. (2009). "The Business Value of BIM: Getting BIM to the Bottom Line". Bedford, MA: McGraw-Hill Construction.
- McGraw-Hill Construction. (2012a). "Business Value of BIM in North America Multi-Year Trend Analysis and User Ratings (2007-2012)". Bedford, MA: McGraw-Hill Construction.
- McGraw-Hill Construction. (2012b). "Construction Industry Workforce Shortages: Role of Certification, Training and Green Jobs in Filling the Gaps". Bedford, MA: McGraw-Hill Construction.
- Mihindu, S., and Arayici, Y. (2008) Digital Construction through BIM Systems will drive Re-engineering of Construction Business Practices. In: Ceballos, S (Ed), *Proceedings of VIS 2008*, July 9-11, IEEE.
- National Building Specification (NBS). (2012). "National BIM Report 2012". London: RIBA Enterprises, Ltd.
- Nulty, D. D. (2008). The adequacy of response rates to online and paper surveys: what can be done? *Assessment & Evaluation in Higher Education*, 33(3), 301-314.
- Sacks, R., and Barak, R. (2010). Teaching Building Information Modeling as an Integral Part of Freshman Year Civil Engineering Education, *Journal of Professional Issues in Engineering Education and Practice*, 136(1), 30-38.
- Smith, D., and Tardif, M. (2009). "Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers". Hoboken, New Jersey: John Wiley & Sons, Inc.
- Wu, W., and Issa, R. (2013). BIM Education for New Career Options: An Initial Investigation, *Proceedings of Building Innovation 2013: BIM Academic Education Symposium*, January 7-11, Washington, D.C.

THE APPLICATION OF BIM FOR INTERIOR DESIGN AND THE IMPLICATIONS FOR FACILITY MANAGEMENT

ABSTRACT

Prior to designing the interior of a building there should be a comprehensive understanding of the occupants' activities and owner's needs. Analysis of the activities and needs is the first step in design, and it is the responsibility of a professional interior designer. Interior design problems are qualitative and quantitative. The problems require solutions associated with space planning, specifications for fixture, equipment and materials, lighting, indoor air quality, and health, safety and welfare. Building Information Modeling (BIM) provides interior designers the means to simulate, analyze and solve design problems as active members of a collaborative design team. Interior designers also use BIM to organize, document, and ultimately disseminate all of the detailed information about the solutions they develop. This information is essential for the owner's operation and maintenance of the building. For example, paint must be touched up, damaged carpet tiles replaced, and light fixtures will need new bulbs.

With the adoption of the Construction to Operations Building information exchange (COBie) in the National BIM Standard (NBIMS) version 2, information about the finished building interior is now required prior to the BIM handover. Utilizing COBie, Interior Designers can provide owners and facility managers with the complete, detailed, and organized information they need to ensure their building continues to perform and look like the original design solution developed. It is important that interior design students learn to analyze and solve built environment problems. BIM education for interior design students is also essential for fulfilling their responsibilities on a collaborative BIM team. This paper will outline: 1) the applications of BIM for interior design, 2) education for interior design students to fulfill their role on collaborative BIM teams, and 3) the numerous benefits and implications for building owners and facility managers.

Keywords: BIM, Education, Interior Design, Facility Management

1. INTRODUCTION

Interior designers are responsible for designing functional and aesthetic interior built environments. Their design solutions are required to meet the needs of building's occupants and owners and must be coordinated with the building site, shell and systems. The problems interior designers solve are both qualitative and quantitative. The solutions to these problems are associated with space planning, specifications for fixtures, equipment and materials, lighting, indoor air quality, and health, safety and welfare. Building Information Modeling (BIM) applications provide interior designers the tools to simulate, analyze and solve design problems as members of a collaborative design team.

BIM applications also facilitate the organization, documentation and ultimately dissemination of all the detailed information about the solutions interior designers develop. The

management of this information is necessary throughout the entire lifecycle of a building from the onset of its development in the design process, into construction and even facilities management. The information is essential for the owner's operation and maintenance of the building. The National BIM Standard (NBIMS) version 2, implements the Construction to Operations Building information exchange (COBie). Interior designers can utilize COBie to provide owners and their facility managers with the complete, detailed and organized information they need to ensure their building continues to perform and look like the original design solution that was developed.

Current industry practices revolve around integrated and collaborative processes. Building Information Modeling software provides a platform to facilitate collaboration among built environment professionals. This paper will outline the applications of Building Information Modeling (BIM) for interior design and will discuss strategies for educating interior design students to fulfill their roles on collaborative BIM teams. The resulting benefits and implications of the utilization of Building Information Modeling (BIM) by interior designer for building owners and facility managers will also be detailed.

2. THE APPLICATIONS OF BIM FOR INTERIOR DESIGN

Interior design practice requires a careful balance between creative and technical solutions for the overall built interior environment. This balance requires the decisions made by interior designers to be both qualitative and quantitative. At the onset of the design process, during the programming phase, it is the responsibility of the interior designer to analyze all of the owner's and occupant's needs. This phase establishes the detailed project requirements and overall project plan. The interior designer must work as a collaborative team member to communicate the results of this analysis to the rest of the project team. Interior building designs must be developed in direct coordination with the design of the building shell and in relation to site conditions. Some interior design projects are within new buildings, some are within old buildings being renovated. Ultimately, interior designers are responsible for protecting and enhancing the health, safety and welfare of the public in all the decisions that they make.

2.1 Programming and Schematic Design Development

Before the first wall is modeled, the programming phase helps to determine how much space is needed to achieve all of the required activities of the occupants. Interior designers develop space programs that list all of the required rooms, along with all of their square footage requirements. The entire process for building information modeling relies upon virtual models and databases that are interrelated and interconnected. Space programs are utilized in the development of a BIM to initially list all of the space elements that have not yet been modeled. The space elements are then assigned to the rooms spaces that are created within the model. Space programs also help to make sure support spaces are not forgotten, such as mechanical rooms and janitor's closets, and provide comparisons between the programmed spatial requirements and the actual modeled spatial requirements within the plans of the design solution.

Once the sizes and quantities of all of the interior spaces have been determined, the bubble and block diagramming phases are utilized to study the locations and relationships between the spaces. The overall plan and shell of the building design then begins to develop. Coordination between members of the design team is necessary at this stage for establishing locations for exterior penetrations including doors and windows to meet the required needs for egress,

daylight, and views. Interior designers are responsible for creating the interior floor plans of buildings to provide the necessary space planning to meet the needs of the design program while following code and regulatory requirements. With BIM, floor plans are developed by modeling interior walls and partitions with interior fenestrations such as windows and doors.

2.2 Interior Building Components

Each parametric object within a model has a defined set of properties that provide specification data such as the type, size, construction, materials and finishes. Interior designers are responsible for not only placing interior walls, doors and windows objects within the model to fulfill the spatial program requirements, but must also assign the information to specify the type, size, construction, materials, finishes, performance, manufacturer and even cost data with each component. They also must coordinate the vertical circulation components such as stairs and elevators. The information part of BIM allows interior designers to easily specify such things as a wall to be fire rated, to provide acoustic separation or to include additional framing components to support the weight of millwork attached to it, in addition to what the outside finishes will be. When modeling doors, BIM provides interior designers the opportunity to simulate what the door will look like and define how it will perform by specifying its type, size, finish properties and fire rating.

2.3 Furniture, Millwork, Fixtures, and Equipment

In addition to developing interior floor plans with walls, doors and windows, interior designers also develop furniture, fixture and equipment, plans that show placement of all of the moveable and fixed furniture, millwork, fixtures and equipment within the interior of a building. Many manufacturers now provide online BIM catalogues of their products to be used by interior designers. These models include manufacture specific specifications such as size, finish, model number, quality, and cost, as well as accurate model components to replicate the actual piece for use within a project's building information model. BIM software applications also provide generic models that can be manipulated and tools to create new models, both detailed with additional specification information to fully communicate what was chosen by the interior designer.

Interior design solutions typically include custom millwork and signage to creatively and completely solve specific design problems within interior spaces. For example, one of the most common custom millwork pieces developed by interior designers is the reception counter. This type of millwork is typical in hospitality, retail, institutional, and corporate interiors. Within a building information model, interior designers model the individual components needed build the millwork piece, they specify what materials will be used on each individual part, and their complete model provides the construction documents to explain how to build it and what to build it with. Interior designers can also test their ideas by using BIM as a simulation tool. They can further explain their design solutions to their clients by using BIM as a photorealistic rendering tool to explain what the proposed interior environment would look like.

2.4 Ceilings and Lighting Design

Ceiling designs are one of the most complicated design challenges for interior designers within a project. They require the full coordination between mechanical, electrical and plumbing systems, something that is facilitated by the use of BIM. Interior designers specify the ceiling

systems within the interior spaces, design the overall lighting plans and specify fixtures that must integrate with the ceiling system and layout. They must ensure that the light fixtures provide the appropriate lighting quantities and types for the overall design solution, and ensure that none of the fixtures clash with any of the mechanical or plumbing systems. Since BIM creates a replica of what will actually be constructed for a building, the coordination of these systems can be tested within the model and any conflicts that present themselves can be resolved before the construction begins. When lighting designs are being developed, BIM allows the designer to simulate how the lights will perform within interior spaces and how all of the correlating conditions within the interior environment can affect the lighting being specified. Material reflectance and daylight impacts are just a couple of the factors that can be simulated and tested when developing lighting designs using BIM. Fixture types and lamp types are both defined within BIM lighting plans.

2.5 Interior Finishes

Finishes for each surface within each interior space are specified by the interior designer. Even within a small project, these specifications can become very lengthy and complicated. For example, consider the finishes that were used in a public bathroom that you recently visited. There were probably different finishes on each surface, perhaps even multiple finishes on some of the surfaces. The finishes might also have been installed with varied patterns. BIM allows interior designers to detail each surface of an interior environment and specify not only what the finishes will be, but also how they will be installed, how they will perform, how much they will cost and how to maintain them.

Building Information Modeling provides interior designers the ability to test and communicate their design ideas through the advanced simulation of the interior environment they have created with photorealistic renderings and construction drawings. It also provides interior designers the mechanism to define all of the many interior component types and material finishes they specify through the detailed information assigned for each component and summarized with schedules. All of this is completed within the context of one model that provides all the necessary information for constructing the actual interior environments.

3. EDUCATION FOR INTERIOR DESIGN STUDENTS TO FULFILL THEIR ROLE ON COLLABORATIVE BIM TEAMS

3.1 Building Information Modeling (BIM) and Integrated Practice

In 2007 the American Institute of Architects noted that “new modes of project design and delivery have created an opportunity for professionals and educators alike to reassess the dynamics of practice and education...This integrated approach, enabled by integrated design tools, is resulting in enhanced communication, more comprehensive and coordinated documents, and improved collaborative teams.” Current practices in the design and construction industries require an integrated approach for design and project delivery. It is important for interior design students to learn to analyze and solve built environment problems as members of collaborative teams. The 2014 Council for Interior Design Accreditation (CIDA) Standard 5 requires “entry-level interior designers to engage in multi-disciplinary collaboration.....students must have an awareness of: a) team work structures and dynamics, b) the nature and value of integrated

design practices. This involves an integrated team process in which the design team representing all disciplines (interior design, architecture, construction, etc.) and all affected stakeholders (clients, community participants, etc.) work together,” (CIDA, 2014). Building Information Modeling (BIM) software facilitates collaboration among the built environment professions. It is becoming an industry standard for developing and communicating design projects (Crumton & Miller, 2011). New models are being developed in design education and in Interior Design programs in order to better prepare students for future roles in integrated teams using the BIM software that is becoming an industry standard.

3.2 Anderson’s ACT-R Theory

Anderson’s ACT-R theory can be utilized to structure the primary education of BIM in interior design. ACT-R (Adaptive Control of Thought—Rational) was developed by John Robert Anderson at Carnegie Mellon University. The basic premise is that cognitive tasks humans perform consist of a series of separate actions and procedures. ACT-R’s main assumption is that knowledge can be classified as declarative and procedural. Declarative knowledge is factual knowledge, while procedural knowledge is how to perform cognitive tasks. According to Anderson, procedural knowledge is acquired in three stages of skill development: cognitive, associative, and autonomous. The cognitive stage represents the phase in which “subjects develop a declarative encoding of the skill; that is; they commit to memory a set of facts relevant to the skill,” (Anderson, 1995). The associative stage results out of repeated practice as a result of which performance becomes smoother and more rapid, thus leading to proceduralization. As the procedure becomes more automated through practice, the autonomous stage emerges.

3.3 Foundation Applications

Anderson’s ACT-R general implications for teaching procedures start with students developing an accurate and elaborate declarative representation of the desired procedure (actions) and conditions under which it should be used. Using the expository or discovery methods for teaching can allow the teaching method to be teacher-centered (expository) or via discover (Anderson, 1995). The accompany chart (Table 1) summarizes the application of ACT-R theory to teaching the Building Information Modeling philosophy and Revit. Students are taught accurate and elaborate declarative principles of Building Information Modeling and Revit in order to help them understand the interface. Learning is achieved through expository (teacher centered instruction to help students develop declarative knowledge) and discovery (students learning through discovery) methods. Constant feedback is given during the learning process to correct any disequilibrium students may have. Eventually, students achieve automaticity due to continued practice.

The following two case studies, the Law Office project and the Art Gallery project illustrate experiences from the sophomore level interior design computer applications course using Revit. Both projects required the students to develop the complete detailed interior model of both buildings with all interior walls, doors, windows, flooring and ceiling systems, lighting, furniture, equipment, millwork, signage, assign applicable materials and finishes and all applicable specification data. The law office project is utilized for expository centered instruction through multiple interactive demonstrations that are focused on helping the students develop declarative knowledge of BIM software and its application to interior design practice.

The art gallery project is utilized for the discovery method of education where students work independently to apply and expand their knowledge of BIM in the development of their own unique individual design solutions. The students design an art gallery from the “inside out” developing the overall building geometry, core and shell with a complete design of the interior. The interior elements include all interior walls, doors, windows, flooring and ceiling systems, lighting, furniture, equipment, millwork, and signage. The students also assign chosen materials and finishes and all applicable specification data. They generate the entire model with fully detailed interiors and basic exterior elements. Feedback is provided by the instructor throughout this project and with continued practice of the BIM tools and techniques utilized in the development of this model, automatization occurs.

Table 1: Anderson ACT-R General Implications for Teaching BIM Philosophy and Revit

Task	Process
Develop accurate and elaborate declarative representation of BIM	Begin with fundamental premise that “Building information modeling is about the management of information throughout the entire lifecycle of a design process, from early conceptual design through construction administration, and even into facilities management” (p. 1) (Demchak, Dzambazova, and Krygiel, 2009) Examples of concepts covered to help students develop an accurate and elaborate representation of BIM and Revit are the following: Parametric Objects and Parametric Relationships; Bidirectional Associativity; Embedded Relationships; User Defined Rules; Model Categories; Annotation Categories; Subcategories; Families in Revit–System, Standard, and in Place Families; Modeling Basics–Levels, Walls, Floors, Roofs, Ceiling, Doors, Windows; Modifying Elements; Color-Coded Drawings; Presentation Graphics; Construction documentation; and; Sharing Files.
Expository Methods (Teacher centered instruction)	Using the expository methods involves teacher centered instruction to help students develop declarative knowledge. The above listed topics are presented in PowerPoint and interactive presentation lecture format and hands on demonstration to students.
Discovery Methods	The discovery method allows students to learn through discovery. Outside of class exercises will help students practice the concepts learned.
Feedback Component	Feedback is an important component, because it fosters proceduralization. Any misconceptions and disequilibrium is fixed with feedback and constant critiques and pin ups.
Automatization	Continued practice leads to automatization and this will be evident in upper levels in the curriculum in the complexity developed in the quality of the student work.

Source: (Asojo & Pober, 2009)

3.4 Curriculum Integration

Instruction of BIM and the associated software applications are integrated with the method described above in the second semester of the sophomore level within the interior design program curriculum. Students are also introduced to the purposes and benefits of BIM including its uses within integrated project teams and the implications and benefits of its use for owners and facility managers. BIM applications are utilized as tools throughout the remainder of the design studio courses in the curriculum. This year a new interdisciplinary project has been integrated as a component to the spring capstone courses of the interior design, construction science and architecture programs. The students will utilize BIM applications and processes within an interdisciplinary team to solve the given built environment problem.

At the sophomore level students assign typical model element data for construction, materials, dimensions, identify, and other properties along with developing appropriate schedules. They learn about the uses and benefits of this data for the project team, owner, and future facility managers. Future integration of the training videos being developed by the Building Smart Alliance for

self-paced industry instruction of COBie will be integrated into the interior design capstone course in spring of 2014. Senior students will then be required to populate the COBie information by model element within their project model and will be required to provide COBie data as part of their deliverables for the course.

4. BENEFITS AND IMPLICATIONS FOR BUILDING OWNERS AND FACILITY MANAGERS

The utilization of BIM during the design and construction of a building provides many benefits. However, the use of BIM during these phases does not provide the greatest benefit to the owner in terms of the life cycle costs of the building. According to Singh, Smith and Przybyla (2009), “The total cost of ownership for planning, design, construction is 25 percent; and 75 percent is for operations and maintenance.” The greatest impact for cost savings during the operations and maintenance stage of the life cycle of a building is highest when all of the information is assembled during the planning, design and construction stages and prepared for dissemination to owners and facility managers. Significant improvements to the operation, maintenance can be made achieved by a facility manager when the quality and quantity of information about the building is maximized (Sigh, Smith, & Przybyla, 2009). Although BIM is currently being used extensively during the design and construction phases of projects, there is a significant need for the information within these models to be utilized by facilities management throughout the lifecycle of the building (Foster, 2011).

The National BIM Standard (NBIMS) version 2, implements the Construction to Operations Building information exchange (COBie). COBie is the platform that is now used to collect operations and maintenance data within the BIM. COBie secures the project data within the BIM as it is created during the design, construction and commissioning stages of a project (Sigh, Smith, & Przybyla, 2009). Interior designers can utilize COBie to provide owners and their facility managers with the detailed and organized quantitative and qualitative information from their models to help them with a multitude of maintenance and operation’s needs. COBie can summarize quantitative interior information about floors, spaces and rooms for area calculations as well as function designations for each. As interior designers specify furniture, fixtures, equipment and finishes, they can provide the specification information such as the manufacturer, model numbers, performance criteria, maintenance procedures, and warranty information. Interior designers can propagate the COBie information by model element within the model to assign detailed specification information for later use by the owner and facility manager. Typical interior scheduled information can be further detailed, organized and disseminated with COBie.

Another important benefit provided by BIM for facility managers is an improved method for visualization of the space, its systems and components. Dimensioned drawings are typically utilized by owners and facility managers, but it is often difficult for many people to visualize how the two-dimensional drawings translate into real three-dimensional space. BIM provides a complete three-dimensional representation of the building that can be used to better understand spaces and systems. Although it requires some training with the software to be able to fully view and analyze the model, there are numerous benefits to having the model to reference. It is important for owners to recognize the benefits of BIM for the whole lifecycle of their buildings. Owners should be involved in specifying the level of detail required for the BIM during design and construction to set the expectations of communication between the design and construction

team. The end results provide a well-constructed, detailed and data rich model that can be valuable in improving the effectiveness of overall building operations.

5. CONCLUSIONS

The current rising trends and demands of the design and construction industry are requiring early team formation and constant communication throughout the life cycle of a project. Building Information Modeling (BIM) provides interior designers the platform to simulate, analyze and solve design problems as active members of a design team. Educators must adapt to the demands of the profession and teach and encourage these software applications and this collaboration. ACT-R theory can effectively help interior design students gain a better understanding of Building Information Modeling software to help prepare them for integrated practice where they will be members of collaborative teams. BIM applications also facilitate the organization, documentation and ultimately dissemination of all the detailed information about the solutions interior designers develop. The management of this information is necessary throughout the entire lifecycle of a building from the onset of its development the design process, into construction and even facilities management.

REFERENCES

- American Institute of Architects (2007). *Draft White Paper, Part II-Integrated Project Delivery methods*. Retrieved June 24, 2012 from http://blog.aia.org/whitepaper/2007/09/draft_white_paper_for_the_naab_5.html
- Anderson, J.R., (1995). *Cognitive Psychology and its Implication*. New York: Freeman.
- Asojo, A., & Pober, E. (2009). "Building Information Modeling (BIM) Strategies: Pedagogical Models for Interior Design." *Design Principles and Practices: An International Journal*, 3 (2), 159-167.
- Council for Interior Design Accreditation (2014). *Council for Interior Design Accreditation: Professional Standards 2014*. Grand Rapids, MI: Author.
- Crumpton, A. & Miller, L. (2011). "The E Design Studio: Employing Multiple Technologies to Improve Interior Design Teaching and Learning." *Proceedings of the 2011 Interior Design Educators Council Annual Conference*, Denver, Colorado, p. 26-29.
- Demchak, G., Tatjana, D., & Krygiel, E. (2008). *Introducing Revit Architecture 2009 BIM for Beginners*, Indianapolis, IN: Wiley.
- Foster, B. (2011). "BIM for Facility Management: Design for Maintenance Strategy." *Journal of Building Information Modeling*, Spring 2011, 18-19.
- Hansen, A., & Stine, D. (2012). *Interior Design Using Autodesk Revit Architecture 2013*. Kansas: Schroff Development Corporation Publications.
- Johnson, Jamie. (2013). "COBie Explained." Bimtaskgroup Newsletter, Retrieved September 26, 2013 from http://www.bimtaskgroup.org/wp-content/uploads/2013/06/Digital_Library_COBie-Explained-Jaimie-Johnston.pdf
- Singh, H., Smith, D., Przybyla, J. (2009) "Reducing Facility Management Costs through Integration of COBIE and LEED – EB." *Journal of Building Information Modeling*, Spring 2009, 21-23.

BUILDING INFORMATION MODELING AND COPYRIGHT

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ABSTRACT

Building information modeling (BIM) has become a design standard in the construction industry. The historic two-dimensional construction drawings associated with a construction project have become obsolete, in favor of three-dimensional digital models. However, construction project workers may not recognize the implications of using this technology. Copyright and fair use considerations associated with three-dimensional model creation are often disregarded by those not named in a contract. Often unnoticed, BIM designs may expose trade secrets by displaying a digital model of architectural and engineering information which may result in consequences associated with improper BIM information use. This creates uncertainty for the design professional and the model recipient(s), as to the rights relinquished when a model is shared. Moreover, at what level can BIM model details be shared, while protecting the intellectual property of the designer? Lastly, what are the frequently overlooked liability concerns of licensing a project model for future use in an increasingly collaborative industry? The construction industry has yet to fully explore the potential legal issues concerning BIM technology. BIM increases productivity and streamlines costs. These benefits have left copyright, fair use and trade secrets omissions unresolved to this day, which will require future research and collaboration from educational institutions, based on the status of current law.

Keywords: building information model(ing), three-dimensional model(ing), computer aided design, copyright, trade secret, fair use

1. INTRODUCTION

In 1989, the United States Copyright Office provided several compiled reports regarding copyright and architectural design. *The Report of the Register of Copyrights on Works of Architecture* (U.S. Copyright Office, 1989) addressed the state of copyright protection for design work, with interview excerpts from the architectural design community, including the Frank Lloyd Wright Foundation (p. 319 – 343).

The report established the basis for current copyright protection of digital building information models (BIM). However, when written, the authors did not have the foresight to predict current BIM technology. BIM is a simulated building process that can reduce possible construction problems using clash detection tools, for example. Traditionally, problems on the constructability

of a project may not be promptly discovered, resulting in schedule delays and overages during construction, without BIM based tools. Delays may subject the contractor to claims and future litigation proceedings.

2. TRADITIONAL TO DIGITAL COPYRIGHT

In December 1990, § 102 of the Copyright Act (17 U.S.C.) was amended, which relates to architectural works. Subsequently, the United States Copyright Office issued *Circular 41* (updated 2010) that states a building design “created in any tangible medium of expression, including a constructed building or architectural plans, models, or drawings, is subject to copyright protection” (p.1). The circular provides legal definitions should a BIM copyright infringement claim arise. It provides detailed explanation of the relationship between client and design professional (p. 2), where the author / owner of a work is not the creator, but rather the employer or contracting agency.

3. OMISSIONS IN LEGAL PROTECTIONS

The circular also listed designs not afforded copyright protection, such as “functional elements whose design or placement is dictated by utilitarian concerns” (p. 2). For example, a three-dimensional model of mechanical/electrical/plumbing (MEP) systems may not be covered under the Copyright Act (17 U.S.C.). Consider the following example of a MEP subcontractor hired for a project utilizing a BIM model. Previously, contractors worked with MEP subcontractors to assemble drawings as a part of project submission requirements. Traditionally, a *light box* was used to determine potential conflicts between the systems. The *light box* allowed transparent layering of the drawings to determine construction issues. BIM uses clash detection to achieve similar results. If the coordination drawings are also assembled using BIM by the subcontractor, they most likely are not afforded copyright protection, as they are based on the original project design.

What about systems not detailed in the project design, such as fire protection? The fire protection sub-system, a combination of a sprinkler system and standpipes is often minimally represented in the project design. The fire protection subcontractor is expected to design systems meeting the project goal and regulatory requirements. How does this design requirement differ from information in the original project design?

Copyright protection and infringement claims for a functional sub-system, such as fire protection, designed to fit a specific project may appear to be unique. However, if an architect/engineer (A/E)’s prior work is infringed upon, may the claim extend to functional project elements? As Howard W. Ashcraft (2008), a Fellow of the American College of Construction Lawyers, opines in the End Notes to his report on *Implementing BIM: A Report From The Field On Issues And Strategies*, “enforcing the firm’s copyright would require constant vigilance and expensive legal action” (p. 20). This quote refers to the A/E, but a contractor/subcontractor will have the same concerns, when they create what may be an original design.

When copyright protection for architectural work is considered, fair use and trade secrets should also be reviewed. Referring to the light box example and coordination drawings creation, often

the subcontractor assembling the plumbing drawings requests that the A/E use CAD files as the basis for the specific system being designed. ‘Background’ drawings (typically plan views, vertical sections and elevations), expedite the plumbing drawing creation, to minimize the need to recreate original documents that captured the intention of the project. Subsequent use of CAD information is not specifically detailed within Section 107 of the Copyright Act (17 U.S.C. § 107).

Ashcraft also addresses two scenarios that can be applied to trade secrets and digital modeling. In *BIM: A Framework for Collaboration* (2008), he indicated that the model information contains the proposed final project construction, which may disclose the owner’s planned operations (p. 26 and 27). The first situation involves the project owner, and the second considers the general contractor and subcontractor. Sharing information within a three-dimensional project design may compromise the business model developed by the A/E, contractor or subcontractor, which may afford a competitive edge to their competitors. Without appropriate waivers, sharing of information negates the secrecy element of a trade secret.

The novelty associated with BIM also means that issues are still evolving, and the responsibilities amongst the principal participants are changing. In 2011, the first BIM lawsuit was settled, illustrating the need for all parties to be educated on the expectations for any BIM information used. Nadine Post (2011) from the Engineering News Record (ENR) reported that when a claim design issue was identified, and the principal medium for conveying the expectations of the project was via BIM: “(t)he contractor sued the owner, the owner sued the architect, and XL (the insurance carrier) brought in the MEP (mechanical / electrical / plumbing) engineer” (p. 1). Due to confidentiality, the settlement and the resulting damage amount(s) is unknown, but there is increased likelihood that future claims will go to trial, as the results of this trial will set a precedence for future legal action.

4. EDUCATIONAL INSTITUTIONS AND BIM

From the perspective of a construction contractor and the A/E, legal uncertainties are a problem, until a standardized set of rules for BIM can be agreed upon. A potential solution is to encourage universities to conduct research to further define BIM criteria. One way to generate research on this topic is to integrate the content into educational institution curriculums. The accreditation organization, American Council for Construction Education (2013), for example, has the means to evaluate the manner in which university curriculum criteria are decided. The core matter in construction law courses could adjust topical content for instruction hours to include such a change. Inclusion of the legal implications of BIM use would address the problem at the undergraduate level, whereas the graduate level would focus on solutions to the problem.

5. CONCLUSIONS AND FUTURE RESEARCH

How then do contractors and subcontractors avoid copyright issues in the A/E community, as contractors become more proficient with BIM? Education for principle project parties on the Copyright Act (17 U.S.C.), as well as possible infringement issues is essential. Pertinent contract language in the project documentation must be developed, included and understood. The American Institute of Architects, (2008) has available documentation for incorporation into the various contracts for construction between the owner and contractor.

Of final note, the Post (2011) ENR story regarding the first BIM lawsuit provided little information regarding the legal issues mentioned above. Post states that “construction contracts must address the allocation of the risks associated with the use of BIM so that the parties involved in design and construction of the project know their roles and responsibilities from the outset” (p. 2). Further research must examine the “what if” scenario: Is the claim based on infringement or trade secret issues? This discussion should be considered an observation, not legal advice. Interested parties should contact legal counsel for advice on questionable contract matters.

REFERENCES

- American Council for Construction Education (2013). Document 103: Standards and criteria for accreditation of postsecondary construction education degree programs. Retrieved September 16, 2013, from <http://acce-hq.org/documents/Document103053113.pdf>
- American Institute of Architects (2008). AIA document E202-2008 building information modeling protocol exhibit. § 2.2 Model Ownership and §3.6.2.1 Authorized Uses. Retrieved December 26, 2012, from <http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab083007.pdf>.
- Ashcraft, H.. (2008). Building information modeling: a framework for collaboration. *The Construction Lawyer*. 28(3), 5. Retrieved December 26, 2012, from Academic OneFile.
- Ashcraft, H.. (2008). Implementing BIM: a report from the field on issues and strategies. *Paper Presentation at the 47th Annual Meeting of Invited Attorneys*. Retrieved from <http://www.plbrokers.com/articles/ImplementingBIMUpdate-Ashcraft.pdf>.
- Copyright Act of 1976, 17 U.S.C. § 101 et. Seq.
- Post, N. (2011). BIM Lawsuit offers cautionary tale. *Architectural Record* (originally presented in Engineering News Record). Retrieved December 26, 2012, from <http://archrecord.construction.com/news/2011/05/110519-BIM-Lawsuit-1.asp>.
- United States Copyright Office (1989). The report of the register of copyrights on works of architecture. Retrieved December 26, 2012 from <http://www.copyright.gov/reports/architecture.pdf>.
- United States Copyright Office (2010). Circular 41 – Copyright claims in architectural works. Retrieved December 26, 2012 from <http://www.copyright.gov/circs/circ41.pdf>.
- United States Copyright Office (2010). Circular 92 – Copyright Law of the United States of America and Related Laws Contained in Title 17 of the United States Code §120. Retrieved June 20, 2013 from <http://www.copyright.gov/title17/92chap1.html#120>.